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# Proposal for Temperature Settings of Poultry Houses, Aiming at Death Reduction

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**Abstract:** Poultry farming is an important industry in Japan. To increase profits, firms seek to increase the numbers of eggs produced by reducing the number of hen deaths during breeding periods. We hypothesize that the setting temperature of the poultry house has a large influence on the number of deaths. Therefore, we conduct a regression analysis on the number of hen deaths to reveal the influence of temperature. Thus, we correlate the fluctuating ranges of summer temperatures with hen deaths. The large fluctuating range of temperature seems to reduce the number of deaths in summer.We speculate that a rise of the temperature in a poultry house with a rise of outside temperature leads to an increase of the fluctuating range of the setting temperature and the reduction of the number of deaths.

**Key words:** management; poultry house; setting temperature; regression analysis
**JEL code:** L660

## 1. Introduction

Eggs provided by hens are classified as livestock products, and their production method is more heterogeneous than other livestock items are. There are many more breeding hens than there are cows and pigs, which are large domestic animals. Because of this difference, differences of breeding techniques can lead to differences in sales. Adil (2009) showed how climate can affect the performance of a poultry house. Thus, effective and careful breeding techniques are in demand.

There are many prior studies about the poultry industry, reflecting its importance. Rabinder et al. (2006) investigated the component of hen feed and its effect on health and egg status. There was also a book published about hen nutrition (National Research Council et al., 1994). Additionally, Newberry et al. (1986) researched light intensity effects on cocks to show the relationship between light and health. Thus, poultry management is important worldwide.

There are many evaluation indices for breeding techniques (e.g., feed and light); however, we adopt the number of hen deaths in the poultry house as the most important factor for managing egg production and profit. Several factors affect the number of deaths, but it is difficult to determine causation. However, an experiment with changing conditions can help clarify problems, such as the breeding environment. Therefore, we assume that analyzing past data is a realistic approach.

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Cooperative research partner, Company A, which manages poultry houses, collects many kinds of operational data connected to breeding. In this study, we use regression analysis to clarify the relationship between the number of hen deaths and breeding environment. Before conducting the regression analysis, we consider the temperature in a poultry house is a key variable. Hens do not sweat. Thus, temperature easily influences body temperature, which is usually more than 37.8° Maximum body temperature is 47° Nonetheless, temperature control as a management technique has not been correlated to other important factors, such as feed intake, egg-laying rate, and stress. Lucas and Marcos (2013) showed that heat stress negatively affected the welfare and productivity of hens. However, the relationship between heat stress and the number of deaths was not shown. Lucas et al. (2013) also highlighted the need for further research.

For these reasons, we conduct a regression analysis that adopts the number of hen deaths as a criterion with the data related to temperature in a poultry house as explanatory variables. We can contribute to the improvement of poultry farming and realize higher egg production if we can elucidate the effects of temperature on hens.

## 2. Material and Methods

### 2.1 Definition of Terms

Breeding hens are replaced every 2 yrs. We examine data from 28 poultry houses collected between 2013 and 2017 at Company A. Some data are from the same poultry house, but both breeding month and year may be different. These data contain Date, Day-Old, Feed Intake, Egg-Laying Rate, and Mean Room Temperature. Data is recorded every day, and all data of the same line is gathered on the same day.

First, Day-Old reflects the age of hens in days. Poultry data are recorded from 120 days old, when hens begin to lay eggs, until 700 days old, when they are replaced with new 120-day-old hens. Second, the number of deaths expresses how many hens died per Date and Day-Old. Third, Egg-Laying Rate can be calculated using a characteristic that hens lay only one egg per day.

$$\text{The Egg-Laying Rate}=\frac{\text{Total Number of Eggs Per Day}}{\text{Number of Living Hens}}\times 100 \tag{1}$$

Fourth, FeedIntakeexpresseshowmuchfeedis distributed perday. However, the measure does not reflect whether the individual hens ate. Fifth, the temperature is always set by managers at the poultry house. This variable does not affect maximum room temperature, but it helps prevent the smallest room temperature from becoming less than the set temperature. However, there are effective ways to lower the temperature in a poultry house. Jairo et al. (2011) introducedmisting cooling. It requires equipment under the ceiling of the poultry house. This type of cooling requires a major overhaul. Thus, we do not adopt this method. Last, Mean Room Temperature is calculated using thermometers installed inside the poultry house.

### 2.2 Forced-molting Method and Disease

Figure 1 shows the transition of Egg-Laying Rate. The vertical axis expresses Egg-Laying Rate percentage, and the horizontal axis expresses Day-Old. This figure shows that Egg-Laying Rate gradually degrades, beginning at approximately 360 days old.Forced molting is a special technique (i.e., starvation) used to force hens to shed feathers. However, during starvation, hens do not lay eggs. After molting, the hens get fed and begin laying eggs at a fast rate. Thus, Egg-Laying Rate ascends rapidly. This method is effective, but non-recommended in terms of animal welfare (Botreau et al., 2007). Furthermore, via this method, hens die regardless of temperature. Therefore, we do not analyze the death of the hens caused by Forced-Molting.

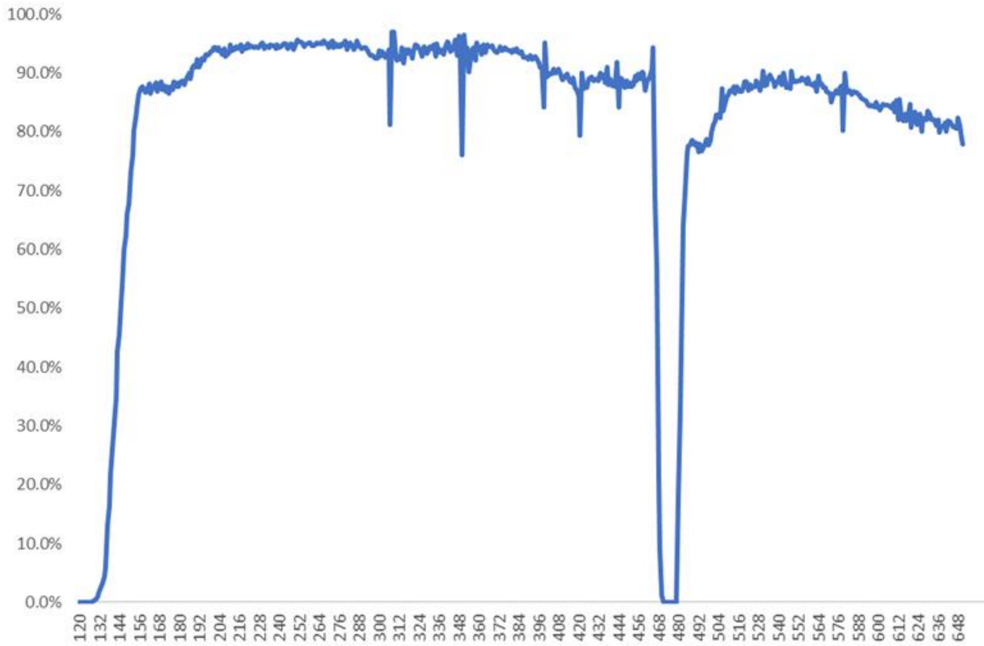

**Figure 1 Transition of Egg-laying Rate**

Disease is a major factor of death. Key diseases are Salmonella Typhimurium, Campylobacter, and Avian Influenza. Salmonella Typhimurium and Campylobacter are related to temperature and must be controlled via the hen's drinking water (Hong et al., 2001). Avian Influenza is a danger for hens and humans, because humans are known to have been infected by birds (Ron et al., 2003; Yu et al., 2013). Therefore, we do not analyze the deaths of the hens caused by disease. We analyze only deaths linked to temperature conditions.

### 2.3 Setting Temperature

Currently, Company A changes its set temperature in the poultry house between 22° and 27°. They have also adopted several new methods of setting the temperature. It is highly automated, and we assume that Company A dictates methods managers must use. We divide the changing methods into patterns A, B, and C, and provide an explanation below.

- Pattern A starts at 22.0° or 22.5° at 120 days old and gradually increases.
- Pattern B starts at approximately 25.0° at 120 days old and gradually increases.
- Pattern C does not change the set temperature.

Figure 2 shows the difference in the temperature-setting methods of five poultry houses that started breeding hens in February. Its vertical axis expresses temperature, and the horizontal axis expresses age. In Poultry House A, see the orange line in Figure 2, temperatures started near 22° for 120 days-old hens, gradually increasing afterwards. Thus, this behavior is classified as Pattern A. Poultry House C, yellow line, is classified as Pattern B. Poultry House D, green line, is classified as Pattern C. Pattern D data break off at 460 days old, because we conducted our research at the end of January, 2018. However, we confirm that setting temperature falls suddenly to around 22° at approximately 500 days old at most poultry houses because of forced molting. Farming manuals show that temperature should be set to 22.2° for forced molting. However, forced molting can also be conducted at 25.5°, see the gray line.

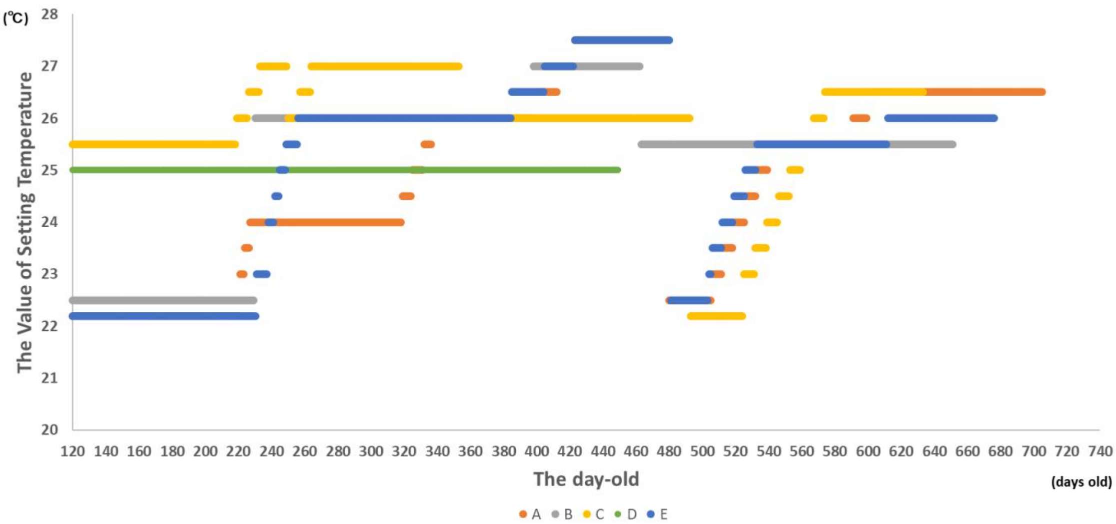


**Figure 2 Temperature Changes (Start in Feb.)**

### 2.4 Breeding Time

We conduct a regression analysis and adopt the number of the hen deaths as the criterion variable. However, we must consider which viewpoint should be adopted. Thus, we adopt either the average number of deaths over the whole breeding period or the sum of the number. We must also decide whether to pay our attention to the number of deaths only for a particular date or the entire breeding period. We adopt the sum of the number of deaths in August.

This study presents three reasons to focus on August. First, Company A has the problem where temperatures fluctuate between 25.5° and 27°. Second, if we do not use a month with great temperature unevenness when deaths are high, we will have trouble confirming the impact of temperature on the deaths. Figure 3 shows differences in the mean numbers of deaths at each poultry house (different colors) from January to December. The vertical axis expresses the mean number of deaths, and the horizontal axis expresses months. As seen in Figure 3, there is greater unevenness in the number of deaths in July and August than the other months. Furthermore, August is the third summer month. Thus, we assume that trends in temperatures and deaths will be well-set by then.

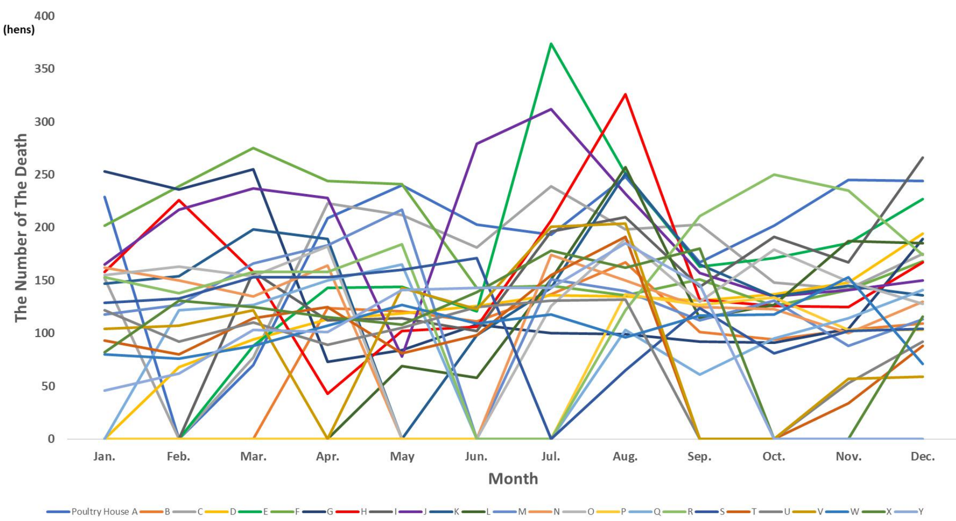


**Figure 3 Mean Numbers of Death Per Month**

Because egg productionincreasesifwecanreducedeaths, we must clarify the relationship by performing a regression analysis whose primary variable is the number of total deaths in August.

**2.5 Explanatory Variables**

Company A's data have five variables: Day-Old, Feed Intake, Egg-Laying Rate, Setting Temperature, and Mean Room Temperature. The setting temperature is chosen as an explanatory variable resulting from the argument mentioned above; however, assumptions are necessary about the other four variables.

Regarding Day-Old, we consider that age affects the likelihood of death. Regarding Feed Intake, we consider that it affects the likelihood of death. However, the change is not substantial all the time. Therefore, we do not use this variable as an explanatory variable, because will be difficult to measure standard error. Regarding Egg-Laying Rate, we consider it a dependent variable on Death. Additionally, the change is not substantial all the time. Therefore, we do use egg-laying rate. Regarding Mean Room Temperature, we need to know the real temperature separately from set temperature for analysis. The setting temperature of August is important; however, most poultry houses begin hen breeding outside of August. Therefore, we should adopt the set temperature before August as an explanatory variable. In conjunction with the August set temperature, because poultry houses either change or do not change temperatures, we choose a variable that expresses change as a dummy variable. We adopt a nominal scale indicating the month when breeding occurred. We adopt seven variables as explanation variables. Additionally, we choose August data taken prior to forced molting from all poultry houses.

Table 1 showsdatafor the regressionanalysis. "Pattern" reflects the difference change method for setting temperature. "Day-Old Before August" indicates age at July 31$^{st}$. "The number of the deaths in August" is the number of the total deaths in August, and the "Fluctuating range of setting temperature" shows changes of the setting temperature from breeding-start time to August at each poultry house. We express "Change of setting temperature in August" as 0 if the setting temperature does not change and 1 if it changes.

## 3. Results

We conducted a stepwise regression. The criterion variable reflected the number of deaths in August, and the explanatory variables were all other variables in Table 1, except for Death. We chose explanatory variables that correlate with the number of deaths via manual operation on the basis of a *p* value less than 0.05 as meaningful.

The explanatory variable that became meaningful early was Breeding-Start Month. Table 2 shows a model at this stage. From Table 2, we analyzed the value of adjusted R-square at 0.29, and the estimation value had a negative sign. Therefore, we considered that we may reduce the number of deaths when the breeding-start months are June, July, August, or November. Data from July and August had fewer deaths than other breeding months and had fewer maximums of numbers of deaths than minimums of other months.

Table 3 shows the data of the number of the deaths during August per breeding-start month. Start-month data (i.e., June, July, August, and November) had fewer numbers of deaths than the other months. The poultry houses that started breeding in June, July, or August differed from other poultry houses, because hens endured summer before stable egg-laying. Therefore, when the egg-laying rate was unstable, an increase in the number of deaths was probably suppressed. We considered that the difference in the number of deaths based on differences of breeding-start month was larger than the difference of the number of deaths based on the difference of other variables. Therefore, we could not explain the change of the number of deaths from other variables unless we adopt this variable.

**Table 1 Regression Analysis Data**

| Poultry house | Start | Pattern | Day-old before August | The number of the death in August | Setting temperature in August | Fluctuating range of setting temperature | Change of setting temperature in August | Mean room temperature |
|---|---|---|---|---|---|---|---|---|
| A | Feb. | A | 286 | 248 | 24 | 1.5 | 1 | 27.1 |
| B | Feb. | A | 290 | 167 | 26 | 3.5 | 1 | 27.3 |
| C | Feb. | B | 290 | 198 | 27 | 1.5 | 1 | 28.3 |
| D | Feb. | C | 293 | 251 | 25 | 0 | 0 | 28.3 |
| E | Feb. | A | 307 | 135 | 26 | 3.8 | 1 | 28.8 |
| F | Mar. | A | 267 | 136 | 24 | 3 | 1 | 27.4 |
| G | Mar. | A | 251 | 99 | 24.5 | 2.5 | 1 | 27.2 |
| H | Mar. | B | 272 | 326 | 26.5 | 1 | 1 | 27.9 |
| I | Mar. | C | 280 | 210 | 25 | 0 | 0 | 28 |
| J | May | A | 213 | 232 | 25 | 2.8 | 1 | 27.5 |
| K | May | B | 199 | 251 | 26 | 1 | 1 | 27.8 |
| L | May | C | 215 | 257 | 25.5 | 0 | 0 | 29.4 |
| M | Jun. | A | 160 | 140 | 22.2 | 0 | 0 | 27.7 |
| N | Jun. | B | 175 | 150 | 25.5 | 0 | 0 | 28.2 |
| O | Jun. | C | 177 | 189 | 27 | 0.5 | 1 | 28.6 |
| P | Jun. | C | 187 | 137 | 25.5 | 0 | 0 | 27.9 |
| Q | Jul. | B | 141 | 103 | 25.5 | 0 | 0 | 28.6 |
| R | Aug. | B | 131 | 122 | 26 | 0 | 0 | 27.8 |
| S | Aug. | B | 125 | 65 | 25 | 0 | 0 | 28.1 |
| T | Oct. | A | 409 | 191 | 26 | 4 | 1 | 28.6 |
| U | Oct. | A | 403 | 132 | 27 | 4 | 0 | 28.7 |
| V | Oct. | B | 405 | 204 | 27 | 1.5 | 0 | 28.5 |
| W | Nov. | A | 380 | 96 | 24.5 | 2.5 | 1 | 27.7 |
| X | Nov. | B | 388 | 162 | 26.5 | 1.5 | 1 | 27.7 |
| Y | Dec. | A | 346 | 185 | 27 | 4.8 | 1 | 28.1 |

**Table 2 Result of Stepwise (Initial Stage)**

| **Summary of Fit** | | | | |
|---|---|---|---|---|
| R-square | 0.32 | | | |
| R-square Adj | 0.29 | | | |
| RMSE | 52.55 | | | |
| Mean of response | 175.44 | | | |
| Observations (or Sum W gts) | 25 | | | |
| **Parameter estimates** | | | | |
| Term | Estimate | Std. error | t ratio | Prob. > $\|t\|$ |
| Intercept | 165.354 | 10.9475 | 15.1 | < .0001* |
| Breeding start month (Aug. & Jul. & Nov. &Jun. – Oct. &Dec. & Mar. & Feb. & May) | -36.021 | 10.9475 | -3.29 | 0.0032* |
| **Prediction expression** | | | | |
| = 165.35416667 | | | | |
| -36.02083333 × Breeding start month (Aug. & Jul. & Nov. &Jun. – Oct. &Dec. & Mar. & Feb. & May) | | | | |

**Table 3 Average Number of Deaths in August**

| Start | Average of the number of the death in August |
|---|---|
| Feb. | 199.8 |
| Mar. | 192.75 |
| May | 246.67 |
| Jun. | 154 |
| Jul. | 141 |
| Aug. | 93.5 |
| Oct. | 175.67 |
| Nov. | 129 |
| Dec. | 185 |

During the second stage, the fluctuating range of setting temperature became meaningful when we adopted Breeding-Start Month. Table 4 shows that the adjusted R-square rose to 0.47. Because the estimation value had a negative sign, if the change level of the Fluctuating Range of Setting Temperature was large, it led to a decrease in the number of deaths.

We confirmed the characteristic that hens bred in February and March had fewer numbers of deaths in the poultry house, where the change level of the Fluctuating Range of Setting Temperature until August was large. We confirmed that the difference between the minimum number of deaths of hens bred in February and March and the maximum number of deaths of hens bred in August was small. For these reasons, we concluded that it was because paths from Fluctuating Range of Setting Temperature to the number of deaths in August were shut out by Breeding-Start Month (Aug. & Jul. & Nov. & Jun. – Oct. & Dec. & Mar. & Feb. & May).

**Table 4 Result of Stepwise (Second Stage)**

| | | | | |
|---|---|---|---|---|
| **Summary of Fit** | | | | |
| R-square | 0.52 | | | |
| R-square Adj | 0.47 | | | |
| RMSE | 45.31 | | | |
| **Parameter estimates** | | | | |
| Term | Estimate | Std. error | t ratio | Prob. > $\|t\|$ |
| Intercept | 192.746 | 13.1553 | 14.56 | < .0001* |
| Breeding start month (Aug. & Jul. & Nov. &Jun. – Oct. &Dec. & Mar. & Feb. & May) | -53.197 | 11.0505 | -4.81 | < .0001* |
| The fluctuatiing range of setting temperature until August | -20.432 | 6.8349 | -2.99 | 0.0068* |
| **Prediction expression** | | | | |
| = 192.7463057 | | | | |
| -53.19678998× Breeding start month (Aug. & Jul. & Nov. &Jun. – Oct. &Dec. & Mar. & Feb. & May) | | | | |
| -20.43236478× The fluctuatiing range of setting temperature until August | | | | |

The Change of Setting Temperature in August became meaningful after we adopted the Fluctuating Range of Setting Temperature. Table 5 shows that the adjusted R-square rose to 0.56. Because theestimation value had a positive sign, we considered that not changing thesetting temperature in August led to a reduction in the number of deaths. From Table 1, using data of June, July, and August, we confirmed that data that did not change the temperature in August had less number of deaths. However, data that began in October had more deaths. Thus, it did not become a meaningful pass when we adopted the Breeding-Start Month, because a contradicting characteristic was mixed. The Temperature Change in August became meaningful after adding Fluctuating Range of Setting Temperature.

**Table 5 Result of Stepwise (Third Stage)**

| | | | | |
|---|---|---|---|---|
| **Summary of Fit** | | | | |
| R-square | 0.61 | | | |
| R-square Adj | 0.56 | | | |
| RMSE | 41.61 | | | |
| **Parameter estimates** | | | | |
| Term | Estimate | Std. error | t ratio | Prob. > $\|t\|$ |
| Intercept | 180.568 | 13.2331 | 13.65 | < .0001* |
| Breeding start month (Aug. & Jul. & Nov. &Jun. – Oct. &Dec. & Mar. & Feb. & May) | -52.416 | 10.1541 | -5.16 | < .0001* |
| The fluctuatiing range of setting temperature until August | -29.606 | 7.47945 | -3.96 | 0.0007* |
| The change of setting temperature in August | 47.9533 | 21.2629 | 2.26 | 0.0349* |
| **Prediction expression** | | | | |
| = 180.5678084 | | | | |
| -52.41622099 × Breeding start month (Aug. & Jul. & Nov. &Jun. – Oct. &Dec. & Mar. & Feb. & May) | | | | |
| -29.60549968 × The fluctuatiing range of setting temperature until August | | | | |
| +47.953329966 × The change of setting temperature in August | | | | |

Table 6 shows a model provided as a result of these variable choices. The adjusted R-square rises to 0.65, and RMSE decreases to 36.96 from 52.55 at the age of the initial stage. Because the Breeding-Start Month (Oct. & Dec. & Mar. & Feb.-May) and the Breeding-Start Month (Oct. & Dec. - Mar. & Feb.) had a positive sign, we considered that the data started in May correlated to more deaths death than in February, March, October, and December. The data started in October and December had more deaths than February and March. Thus, the data having a long period before August correlates to the reduction in the number of deaths. Additionally, from the prediction in Table 6, Pattern, Day-Old, Setting Temperature in August, and The Mean Room Temperature did not become meaningful.

Via the differences of Fluctuating Range of Setting Temperature, a difference in the number of deaths was produced using the data of poultry houses during the same month. Therefore, Day-Old has no coherent tendency. The Setting Temperature of August and the Mean Room Temperature did not have a specific tendency, such as having higher numbers of deaths at a high mean room temperature.

**Table 6 Result of Stepwise (Fourth Stage)**

| **Summary of Fit** | | | | |
|---|---|---|---|---|
| R-square | 0.72 | | | |
| R-square Adj | 0.65 | | | |
| RMSE | 36.96 | | | |
| **Parameter estimates** | | | | |
| Term | Estimate | Std. error | t ratio | Prob. > $\|t\|$ |
| Intercept | 187.869 | 12.1654 | 15.44 | < .0001* |
| Breeding start month (Aug. & Jul. & Nov. &Jun. – Oct. &Dec. & Mar. & Feb. & May) | -63.71 | 9.97151 | -6.39 | < .0001* |
| Breeding start month (Oct. & Dec. & Mar. &Feb. – May) | 3.50852 | 14.0179 | 0.25 | 0.805 |
| Breeding start month (Oct. & Dec. - Mar. &Feb.) | 39.6453 | 15.529 | 2.55 | 0.0194 |
| The fluctuatiing range of setting temperature until August | -44.069 | 9.56099 | -4.61 | 0.0002* |
| The change of setting temperature in August | 81.6246 | 23.952 | 3.41 | 0.003* |
| **Prediction expression** | | | | |
| = 187.86920912 | | | | |
| -63.70978351 × Breeding start month (Aug. & Jul. & Nov. &Jun. – Oct. &Dec. & Mar. & Feb. & May) | | | | |
| +3.5085248713 × Breeding start month (Oct. & Dec. & Mar. &Feb. – May) | | | | |
| +39.645308755 × Breeding start month (Oct. & Dec. - Mar. &Feb.) | | | | |
| -44.06856207 × The fluctuatiing range of setting temperature until August | | | | |
| +81.624566296 × The change of setting temperature in August | | | | |

## 4. Discussion

The setting temperature before reaching August was more important to reducing the number of deaths than the setting temperature of August (see Table 6). In particular, a large value of Fluctuating Range of Setting Temperature led to a reduction in the number of deaths. Therefore, we should choose a lower setting temperature to reduce the difference of room and outside temperatures as much as possible, except during summer, and we should raise the setting temperature conforming to a rise of summer temperatures to breed strong hens for heat tolerance. In the case of either changing or non-changing temperature in August, because the mark of the estimation value is positive, not changing the setting temperature in August leads to the reduction in the number of deaths. However, because there are data that correlate to fewer deaths in June, July, and August, and the Setting Temperature was not selected as a meaningful pass for the number of total deaths in August, it is difficult to conclude that changing or not changing the setting temperature in August had a large effect on death reduction in August.

By the above-mentioned argument, we focus on the summer season. We should lower the setting temperature in the poultry house when outside temperatures are not high. Managers should use their methods and gradually change setting temperature when it approaches summer. This is classified by the pattern of A in the change methods of the setting temperature of Company A. Additionally, regarding the Setting Temperature in the Summer Season; we did not determine the optimal temperature between 25.5° and 27°. We paid attention to the relations of setting temperature and the number of deaths during summer, but we only studied the first summer season for hens. We did not study the second summer. Hens experience summer once or twice, depending on breeding-start time, and data from the second summer differs according to Forced Molting. Nevertheless, we will continue collecting data for Company A so that we can perform more detailed analysis using data of the second summer.

## 5. Conclusions

Using regression analysis, we revealed that the change method of the setting temperature before entering August was more important to reducing the number of deaths in August than was the setting temperature for summer. The tendency of data with large fluctuating ranges of setting temperature until August correlated to a greater reduction in the number of deaths than months with small ranges of fluctuation. We recommend setting a lower temperature to reduce difference of room temperature and the outside temperature as much as possible during seasons when the temperature is not high. Temperature should gradually rise until August. This practice should provide hens a tolerance for high room temperatures in summer, leading to fewer deaths.

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