Investigating the Best Feeder Size to Maximize Egg Production

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1 Summary

Based on the data and design of the experiment, we can regard this research's design as a Repeated Randomized Complete Block Design (RCBD). By applying the possibly best model, "Linear Mixed Model," on a newly created dataset under some statistical assumptions, the best "Treatment" level concludes to be 24 out of all possible 6 "Treatment" levels.

2 Introduction

This report outlines the statistical model used to analyze the impact of different feeder sizes (treatments) on egg production in a hen house experiment. Our goal is to identify which treatment maximizes egg production, ensuring that the egg producer can make informed decisions to enhance production efficiency. The experiment took place in a hen house with 96 cages holding 15 hens each. Eight feeder sizes were considered and randomly assigned to cages. Feed consumption (g/hen/day) and egg production (eggs/hen/day) were measured at baseline and over 12 months.

3 Methods

It is essential to understand how we can interpret this research to smoothly move on to the following "Analysis" part. In order to execute the statistical analysis, these columns are used:

- Days_in_Trt (13 months including base month)
- Consumption (g/hen/day)
- Production (response) (eggs/hen/day)
- Treatment (fixed effect, 6 levels)

- Block (fixed effect, 16 levels)
- CageID (Index of each cage, 96 types)

Please see the explanation and Figure 1 below. No other columns are directly used in analysis. However, three columns: "Side," "Tier," and "Distance from Door" are used to create a grouping factor which is often described as "Block" in a statistics domain. The reason for this specific grouping pattern is because by doing so, each block can have every possible treatment level within each group (= Block). This categorization into "Blocks" allows us to account for variations in the production data that might be due to location within the hen house rather than differences in the treatment (feeder space). By controlling for these variations, we can more accurately determine the impact of feeder space on egg production.

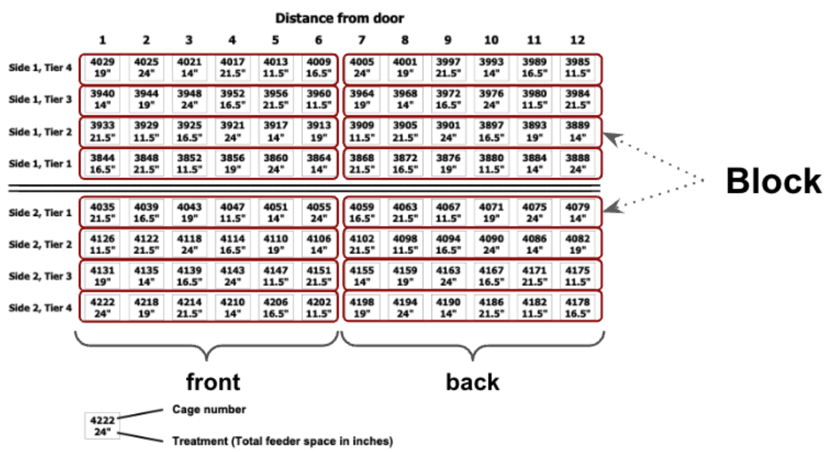

Figure 1: Overhead view of the hen house layout showing the categorization of cages into different "Blocks" based on "Side," "Tier," and "Position"

Example
As an example, consider Cage 3844:

- It is located on Side 1.
- It is part of Tier 1.
- It is in the "Front" position because its distance from the door is 4.

Therefore, Cage 3844 is categorized in Block "1.1.front." Each Block represents a unique environment within the hen house that can affect the hens' egg production.

3.1 Assumptions

Key to our analysis is the assumption of independence among treatments. This means we consider each feeder size's effect on egg production without assuming any inherent ordering or relationship between different sizes.
Additionally, we assume that variations within cages housing the hens are accounted for by including *CageID* as a random effect. This approach helps us isolate the treatment effect by controlling for potential environmental influences associated with specific cage locations.

4 Analysis

The analysis focuses on the relationship between feeder space (treatment) and egg production, while also considering the duration of treatment application (*Days_in_Trt*) and the specific location of cages within the hen house (*Block*). We have taken into account that hens were housed in different cages (*CageID*), which could influence production due to environmental factors.

4.1 Statistical Model

The statistical model employed can be described by the following equation:

$$\text{Production} = \beta_0 + \beta_1 \times \text{Days\_in\_Trt} + \beta_2 \times \text{Block} + \sum_{i=2}^{6} \beta_{3i} \times \text{Trt}_i + b_k + \epsilon_{ijk} \quad (1)$$

where:

- Production is the transformed production, which serves as the response variable.
- β_0 represents the baseline egg production when other factors are not considered.
- β_1 estimates the effect of days in treatment on egg production.
- β_2 estimates the effect of the cage block on egg production.
- β_{3i} (where $i = 1, \dots, 6$) represents the effect of the i-th treatment level on egg production, with β_{31} for Treatment 1, β_{32} for Treatment 2, and so on, until β_{36} for Treatment 6.
- ϵ is the error term, capturing random variations not explained by the model.

The model also includes an interaction between *Days_in_Trt* and (*Block + Treatment*), allowing us to understand how the effect of treatment on egg production may change over time and across different cage blocks.

4.2 Simulated New Data

The simulated new data is generated under statistical assumptions and it is partially shown below.

	Treatment	Block	Days_in_Trt	Predicted_Production	Predicted_Production_bc
1	16.5	1.1.front	-10	0.9545	-0.0447
2	21.5	1.1.front	-10	0.9602	-0.0391
3	11.5	1.1.front	-10	0.9487	-0.0502

Table 1: Partial view of the simulated new data

4.3 Conclusion: Best Treatment Level and Predicted Production

Based on the predictive modeling performed, the best treatment level for maximizing egg production is identified. The model predictions suggest that:

Treatment Level	Predicted Production
24	0.9708 (adjusted for baseline covariates)

Table 2: The best treatment level identified by the model

The above table displays the treatment level alongside the predicted production, adjusted for baseline covariates. This treatment level is expected to maximize egg production when applied across all cages.

A Appendices

A.1 Variance of Production Over Time

The plot below illustrates the variance in egg production over time. From the plot, we can observe that there is a trend in production and a noticeable difference in variance between months.

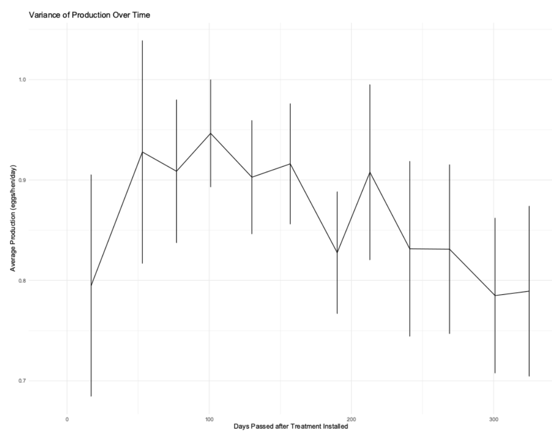

Figure 2: Variance of egg production over time

A.2 Normality Assessment of Residuals

QQ Plot Before Box-Cox Transformation

This QQ plot displays the residuals of the model before the Box-Cox transformation was applied.

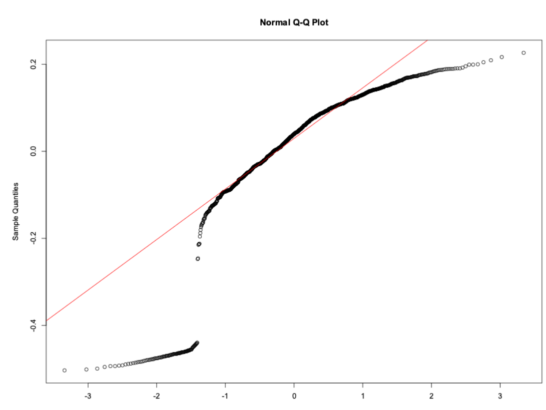

Figure 3: QQ plot of the residuals before Box-Cox transformation

QQ Plot After Box-Cox Transformation
This QQ plot shows the residuals of the model after applying the Box-Cox transformation, indicating an improvement in the normality of the residuals.

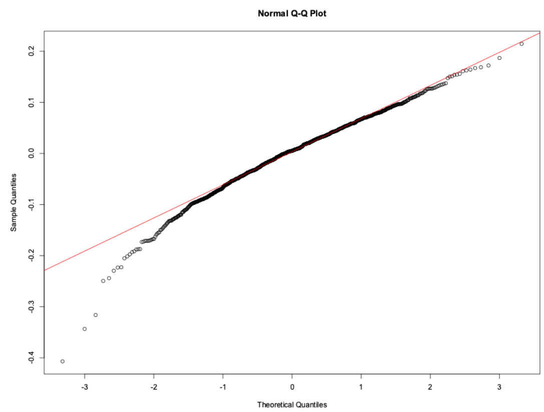

Figure 4: QQ plot of the residuals after Box-Cox transformation

Within the modeling and prediction processes, the transformed response variables (=Production) were utilized.