STAT 582 – Project 2

Optimizing Feeder Size for Egg Production Efficiency

Introduction

An egg producer is aiming to optimize production costs by studying the total feeder space provided to hens in their cages. Conducted in a single hen house with a centrally located door on the left, the experiment aimed to accommodate 15 hens per cage across 96 cages, each equipped with a feeder of varying size. The study considers six different feeder sizes. For each cage, measurements were taken for feed consumption (g/hen/day) and egg production (eggs/hen/day) initially and over a 12-month period. The producer seeks to determine the ideal feeder size to assign to all cages in future operations.

Description of the Variables used for the Analysis

CageID: Unique Cage Number
Days in Trt: The day on which the observation is recorded
Weeks of age: Age of hens in weeks
Consumption: Amount consumed by each hen in grams per day
Production: Number of eggs produced per hen per day
Cost Effectiveness: A ratio between the production and consumption of hens, justifying cost effectiveness.
Feeder Size: The feeder size for hens in inches

Data Analysis

a. Exploratory Data Analysis:

Figure 1 shows the interaction plot between the feeder size and the days. Since the lines are not parallel, we can see that there exists an interaction and correlation between the feeder sizes and days. Feeder size with 14 inches seems to interact the least with other sizes.

Figure 1. Interaction plot between Days and Feeder Size

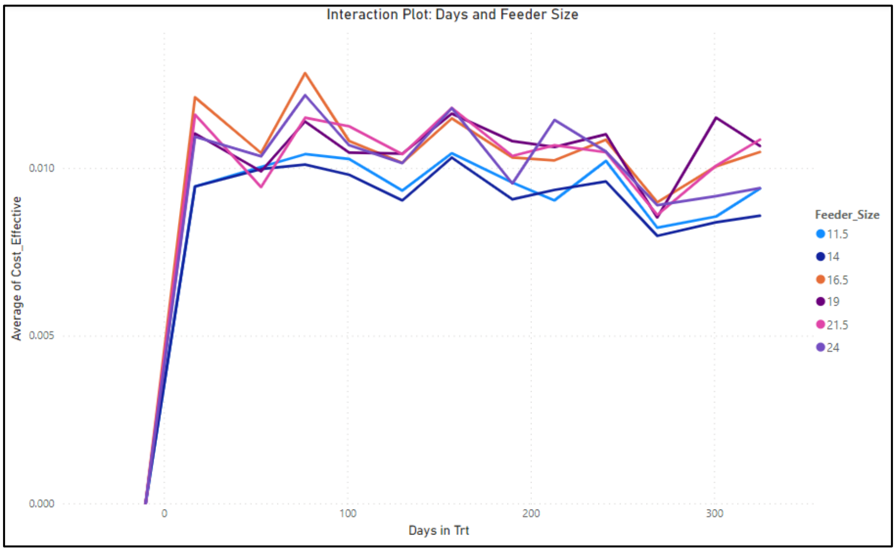
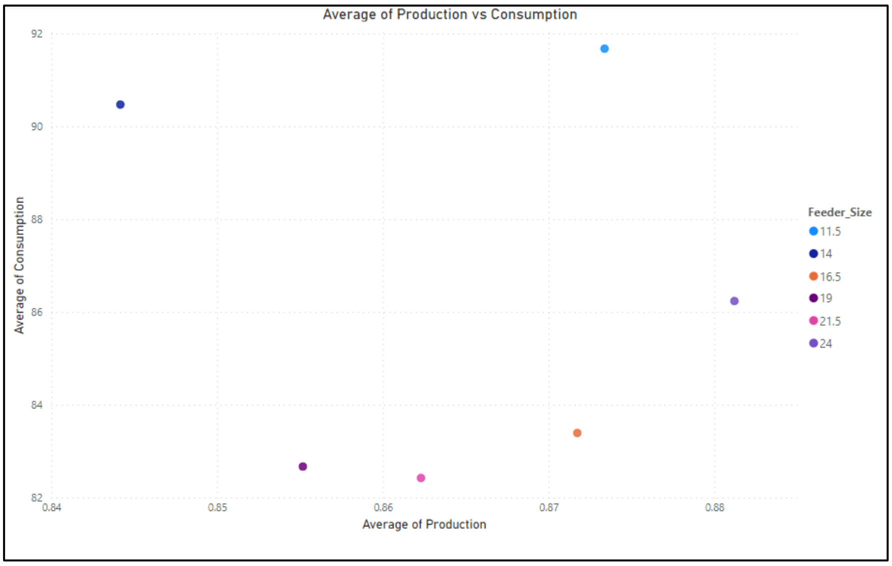


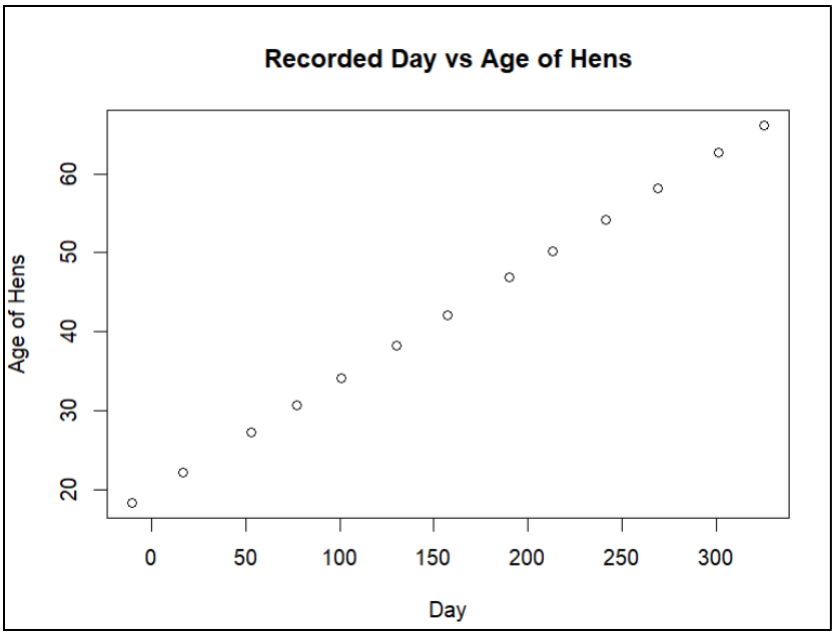
Figure 2 shows the average of Production against consumption and it can be seen that feeder size 11.5 and 14 have higher means than the rest of the feeder sizes.

Figure 2. Average of Production against average of Consumption



It was observed that factors Days in Treatment and Weeks of Age have the same effect on the response variable (Cost Effectiveness) as the correlation between them is one and the graph shows a perfect linear trend (Figure 3). Hence, we can consider either of them, and decided to consider the Days in Treatment (Days) for the analysis. Days can be considered a fixed effect in the model.

Figure 3. Days in Treatment vs Age of Hens



b. Quantitative Data Analysis:

The objective of the study is to see what feeder size should be assigned while keeping cost effectiveness in mind.

- Since the egg producer is interested in making production as cost effective as possible, we consider a ratio of production of eggs to consumption in hens and use it as a response variable for the model.
- The goal of the study is to determine which feeder size should be assigned in future; we consider feeder size as an independent variable with six levels i.e. 11.5, 14, 16.5, 19, 21.5 and 24 inches. The feeder size is a fixed factor.
- Since the cages is a sample representing a population of all the cages, it can be considered as a random factor in the model.
- Days in Treatment will be considered as a fixed factor.
- Looking at the interaction plot between days and feeder size in Figure 1, we will also include the interaction term in the model.

Since we have a mix of fixed and random variables, we will consider a linear mixed effect model, which can be expressed as:

(Cost Effectiveness) ijk = ui + (Feeder Size) ij + (Days in Treatment) ik + (Days in Treatment * Feeder Size) ij + eij

i = 1, …, 96 cages for the hens eij = residual term

j = 1, …., 6 feeder sizes

k = 1, …., 13 days

We do not consider the side, tier and distance of the cage from the door as there is no difference in the significant variable with the presence of it i.e. it has no effect on response variable. Since the main aim is to look at the feeder size while keeping cost effectiveness of production, we only focus on these variables without the distance, side and tier blocking.

On checking the assumptions, an issue of outliers is observed. There is a presence of outliers in the lower tail of the Q-Q plot and little at the upper tail (Figure 4). This is because the baseline Cost Effectiveness values are zero i.e. there is no production with the respective consumption. The ways to deal with the outlier are: a) The baseline values can be eliminated or remeasured, which is not the preferred case. b) We can take the log of the response variable. c) A lower bound and upper bound can be set of 2.5% and the values following beyond that can be eliminated. On discussing with the client, one of the methods can be selected or one go ahead with the analysis, keeping the outliers in mind for the final inferences.

Considering a 95% level of confidence, we use R to carry out the analysis with being cautious about the outliers. Using the lmer() function in R, a p-value is less than 0.05 was found for the model, indicating that the model is significant. The ANOVA for fixed effects (Table 1) indicate that Feeder Size, Days in Treatment and the interaction between the two is significant. Random effect of Cage was also found to be significant in the model.

Table 1. ANOVA for Fixed Effects

	Degrees of Freedom	P-value
Feeder Size	5	0.0016
Days in Treatment	12	< 0.0001
Feeder Size * Days in Treatment	60	0.0029

From the Fixed Effects summary, it was also observed that the Feeder size of 14 inches and Feeder size of 16.5 inches were significant. To asses this, a pairwise comparison was carried out (Table 2) using the function lsmeans() in R. All the feeder sizes show significance as zero does not lie in the confidence interval for the any of the feeder sizes (Table 3). It was inferred that Feeder Size of 14 inches was significantly different from the others. Feeder size was 16.5 also seemed to be slightly different from the other feeder sizes.

Table 2. Pairwise Comparison between the Feeder Sizes

Contrasts	P-value
Feeder Size 11.5 - Feeder Size 16.5	0.0462
Feeder Size 14 - Feeder Size 16.5	0.0084
Feeder Size 14 - Feeder Size 19	0.0253
Feeder Size 14 - Feeder Size 21.5	0.0444

Table 3. Confidence Interval for different Feeder Sizes

Feeder Size	Lower CL	Upper CL
11.5	0.00824	0.00933
14	0.00802	0.00912
16.5	0.00942	0.0105
19	0.00929	0.01035
21.5	0.00922	0.01028
24	0.00909	0.01017

Conclusion

Considering the analysis carried out to find the best Feeder size while focussing on the cost effectiveness for production, Feeder size with 14 inches seem to be the best fit. Feeder size with 14 inches seem to be cost effective i.e. producing more with the consumption and is significantly different from other feeder sizes too.

Appendix

Figure 4. Q-Q Plot for the residuals