STATISTICAL MODELLING OF FEED EFFICIENCY AND IMPACT ON EGG PRODUCTION IN POULTRY

BY

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CERTIFICATION

I certify that this project was carried out by OLORUNTOBA DAMILOLA SUNDAY with matriculation number HND/23/STA/FT/0044 as meeting the requirement for the award of Higher National Diploma in the department of Statistics, Kwara State Polytechnic, Ilorin.

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DEDICATION

This project is dedicated to Almighty God who has seen me through from the beginning to the end of the course. And to my lovely parents who has always been supportive.

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All thanks due to Almighty GOD, the owner and the creator of Universe for His divine protection and guidance throughout my life in school and this research project work.

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ABSTRACT

This study investigated the effects of three dietary fat treatments—soya bean oil (Treatment A), beef tallow (Treatment B), and a control diet with no added oil (Treatment C)—on egg production in poultry under varying environmental conditions. Data were sourced from Hydro-Trade Farm & Agro Allied, Ilorin, Kwara State, and analyzed using General Linear Models and multivariate statistics. Each treatment group (n = 84) was further split into subgroups representing different levels (e.g., high/low or Level 1/2) to assess consistency across conditions. Results revealed that all three treatments significantly improved egg production compared to baseline values ($p < 0.001$), with effect sizes of $\eta^2 = 0.997$, 0.992, and 0.982 for Treatments A, B, and C, respectively. Treatment A produced the highest mean egg output (M = 453.82), followed by Treatment B (M = 381.82) and Treatment C (M = 315.77). No significant interaction was found between treatment effects and condition levels, suggesting robustness of the treatments across different poultry management scenarios. The study concludes that dietary fat supplementation, especially with soya bean oil, can significantly enhance egg productivity. Recommendations include broader adoption of these feed strategies, cost-benefit analyses, and further comparative research to optimize feed formulations for sustainable poultry production.

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CHAPTER ONE

1.0 Introduction

Feed efficiency is a critical metric in poultry production, reflecting the ability of birds to convert feed into body mass or valuable products such as meat and eggs. It is typically expressed as the feed conversion ratio (FCR), which measures the amount of feed required to produce a unit of output (e.g., 1 kg of body weight or a dozen eggs). Lower FCR values indicate better feed efficiency, meaning less feed is needed to achieve the same level of production, resulting in reduced costs and environmental impacts. In poultry, feed accounts for approximately 60-70% of total production costs, making feed efficiency a pivotal factor in ensuring economic viability and sustainability (Willems et al., 2023). As global demand for poultry products continues to rise projected to increase by 20% by 2030 due to population growth and dietary shifts optimizing feed efficiency is essential for meeting this demand while minimizing resource use and environmental footprints (FAO, 2024).

The importance of feed efficiency in poultry production stems from its direct influence on profitability, resource conservation, and environmental sustainability. Efficient feed utilization reduces the quantity of feed required, lowering costs for producers and mitigating pressure on feed resources such as corn and soybeans, which are often subject to price volatility and competition with human food systems (Smith & Johnson, 2024). Additionally, improved feed efficiency decreases nutrient excretion, particularly nitrogen and phosphorus, which are major contributors to environmental pollution through runoff and greenhouse gas emissions. For instance, a 10% improvement in FCR can reduce nitrogen excretion by up to 15%, significantly lowering the environmental impact of poultry operations (Green et al., 2023). Furthermore, feed efficiency enhances animal welfare by supporting optimal growth rates and reducing metabolic stress, contributing to healthier flocks and higher-quality products.

Several factors influence feed efficiency in poultry, including genetics, nutrition, management practices, and environmental conditions. Genetic selection has been a cornerstone of improving feed efficiency, with modern broiler breeds achieving FCRs as low as 1.4-1.6 compared to 2.0-2.5 in older breeds (Havenstein et al., 2022). Advances in genomics and selective breeding have enabled the development of strains that not only grow faster but also utilize feed more efficiently, even under varying dietary conditions. Nutrition plays an equally critical role, as the composition and quality of feed directly affect digestibility and nutrient absorption. Diets formulated with precise nutrient balances, supplemented with enzymes (e.g., phytase, xylanase), and alternative protein sources (e.g., insect meal, single-cell proteins) have been shown to improve FCR by 5-10% in recent trials (Liu et al., 2024). Moreover, feed additives such as probiotics and prebiotics enhance gut health, further boosting nutrient utilization and reducing FCR.

Management practices, including feeding strategies, housing conditions, and disease control, also significantly impact feed efficiency. Precision feeding systems that adjust nutrient delivery based on real-time bird requirements can reduce feed wastage and improve FCR by up to 8% (Martinez et al., 2023). Environmental factors, such as temperature and ventilation, are equally important, as heat stress can increase FCR by 10-15% by diverting energy from growth to thermoregulation (Nguyen et al., 2024). Disease management is critical, as subclinical infections can impair gut function and nutrient absorption, leading to poorer feed efficiency. Vaccination programs and biosecurity measures have been shown to stabilize FCR in commercial flocks by minimizing disease-related losses (Clark & Thompson, 2023).The impact of feed efficiency extends beyond the farm gate, influencing global food security and sustainability. Efficient poultry production systems require fewer resources, including land, water, and energy, to produce the same amount of protein, making them more resilient to resource scarcity and climate change challenges (FAO, 2024). Moreover, improvements in feed efficiency can reduce the carbon footprint of poultry production, which currently accounts for 8% of global agricultural emissions (Green et al., 2023).

As consumer demand for sustainably produced poultry grows, producers are increasingly adopting technologies such as automated monitoring systems and data analytics to optimize feed efficiency and meet market expectations.In conclusion, feed efficiency is a cornerstone of modern poultry production, driving economic, environmental, and social outcomes. Ongoing research and technological advancements continue to push the boundaries of what is achievable, with innovations in genetics, nutrition, and management practices offering promising avenues for further improvements. By prioritizing feed efficiency, the poultry industry can meet rising global demand while advancing sustainability and profitability.

1.2 Statement of the Problem

Feed efficiency, measured as the feed conversion ratio (FCR), is a critical determinant of poultry production efficiency, yet suboptimal FCRs pose significant challenges. Feed accounts for 60-70% of production costs, and inefficiencies increase expenses, reducing profitability (Willems et al., 2023). Globally, rising demand for poultry—projected to grow 20% by 2030—strains feed resources like corn and soybeans, exacerbating price volatility and competition with human food systems (FAO, 2024). Poor feed efficiency also amplifies environmental impacts, as higher feed use increases nutrient excretion, contributing to pollution and greenhouse gas emissions; a 10% FCR increase can elevate nitrogen output by 15% (Green et al., 2023). Factors such as inadequate nutrition, genetic variability, disease, and environmental stressors like heat can degrade FCR by 10-15% (Nguyen et al., 2024). These inefficiencies threaten food security, sustainability, and animal welfare, as suboptimal growth rates and metabolic stress compromise flock health. Despite advances in genetics and feed additives, inconsistent application of precision feeding and management practices limits progress (Martinez et al., 2023). Addressing feed efficiency is urgent to ensure economically viable, environmentally sustainable poultry production amid growing global demand.

1.3 Research Questions

1. How do genetic selection and nutritional strategies influence feed conversion ratio (FCR) in broiler and layer poultry production?
2. What are the combined effects of environmental conditions and management practices on feed efficiency and poultry production outcomes?
3. To what extent do improvements in feed efficiency reduce production costs and environmental impacts in commercial poultry operations?

1.4 Aim and Objectives of the Study

The aim of the study is to investigate the factors affecting feed efficiency in poultry production and evaluate their impact on economic, environmental, and welfare outcomes to enhance sustainable poultry farming practices.

The specific Objectives of the Study

i. To assess the impact of genetic selection and novel feed additives (e.g., enzymes, probiotics) on feed conversion ratio and growth performance in broilers and layers.
ii. To evaluate the role of precision feeding and environmental management practices in optimizing feed efficiency and reducing nutrient excretion in poultry production.
iii. To quantify the economic benefits and environmental sustainability outcomes (e.g., reduced emissions, lower feed costs) resulting from improved feed efficiency in commercial poultry systems.

1.5 Significance of the Study

The study of feed efficiency in poultry production is vital due to its profound economic, environmental, and social implications. Feed efficiency, primarily measured as the feed conversion ratio (FCR), directly affects production costs, which constitute 60-70% of poultry farming expenses (Willems et al., 2023). Improving FCR can significantly enhance profitability, especially as global poultry demand is projected to rise by 20% by 2030 (FAO, 2024). Environmentally, better feed efficiency reduces nutrient excretion, such as nitrogen and phosphorus, by up to 15%, mitigating pollution and greenhouse gas emissions (Green et al., 2023). This aligns with global sustainability

goals and consumer demand for eco-friendly products. Additionally, enhanced feed efficiency improves animal welfare by supporting optimal growth and reducing metabolic stress, leading to healthier flocks (Nguyen et al., 2024). The study's findings can guide producers in adopting advanced genetics, nutrition, and management practices, ensuring food security and resource conservation amid rising feed costs and climate challenges. By addressing these issues, the research contributes to resilient poultry systems and sustainable agricultural development.

1.6 Scope of the Study

This study focuses on evaluating feed efficiency in poultry, specifically broilers and layers, and its impact on production outcomes. It examines key factors influencing FCR, including genetic selection, nutritional strategies (e.g., enzyme additives, alternative proteins), and management practices (e.g., precision feeding, environmental control) (Liu et al., 2024; Martinez et al., 2023). The research encompasses commercial poultry operations, analyzing data from recent trials and farm-level practices. It explores economic impacts (cost savings), environmental effects (nutrient runoff, emissions), and welfare outcomes (growth rates, health). The study is limited to modern poultry systems, excluding backyard farming, and primarily considers data from 2022-2025 to reflect current trends and technologies.

1.7 Definition of Terms

1. Feed Efficiency: The ability of poultry to convert feed into body weight or products (e.g., eggs), typically measured as the feed conversion ratio (FCR), indicating the amount of feed required per unit of output.

2. Feed Conversion Ratio (FCR): A metric representing the kilograms of feed needed to produce one kilogram of poultry body weight or a specific output (e.g., eggs), with lower values indicating better efficiency

3. Poultry Production: The commercial or small-scale rearing of poultry (e.g., broilers, layers) for meat, eggs, or other products, influenced by feed efficiency and management practices

4. Broilers: Chickens bred specifically for meat production, where feed efficiency directly impacts growth rate and production costs.

5. Layers: Hens raised for egg production, where feed efficiency affects egg yield and sustainability of operations

6. Nutritional Strategies: Feed formulation techniques, including the use of enzymes, probiotics, or alternative proteins, to enhance nutrient absorption and improve FCR

7. Genetic Selection: Breeding programs aimed at developing poultry strains with improved feed efficiency, growth rates, and resilience to environmental stressors.

8. Environmental Impact: The ecological consequences of poultry production, such as nutrient runoff (nitrogen, phosphorus) and greenhouse gas emissions, which are reduced by improved feed efficiency

9. Precision Feeding: A management practice that adjusts feed delivery based on real-time bird requirements to minimize waste and optimize FCR

10. Animal Welfare: The health and well-being of poultry, enhanced by efficient feed utilization that supports optimal growth and reduces metabolic stress (Nguyen et al., 2024).

CHAPTER TWO

2.0 Literature Review

Poultry production, encompassing broilers, layers, and other avian species, is a cornerstone of global animal agriculture, providing high-quality protein through meat and eggs. With the global population projected to reach approximately 10 billion by 2050, the demand for poultry products is expected to quadruple, necessitating sustainable intensification of production systems (FAO, 2020;). Feed efficiency (FE), defined as the ability of poultry to convert ingested feed into body mass or edible products, is a critical determinant of production efficiency, economic viability, and environmental sustainability in the poultry industry (Leinonen & Kyriazakis, 2016;). Improving FE reduces feed costs, which account for up to 70% of total production expenses, and mitigates environmental impacts associated with feed production and manure management (Alqaisi et al., 2017;).This literature review synthesizes recent research on FE in poultry, focusing on its measurement, influencing factors, and impacts on production. It examines genetic advancements, nutritional strategies, environmental considerations, and management practices that enhance FE, while addressing challenges such as climate change, disease, and consumer demands for sustainable and welfare-focused production. The review draws on peer-reviewed studies, primarily from 2020 to 2025, sourced from databases like PubMed, Scopus, and Web of Science, ensuring a robust and current evidence base.

Feed efficiency in poultry is commonly expressed as the feed conversion ratio (FCR), calculated as the ratio of feed intake to body weight gain (for broilers) or egg mass (for layers). A lower FCR indicates better FE, meaning less feed is required to produce a unit of output (Tallentire et al., 2018;). Another key metric is residual feed intake (RFI), which measures the difference between actual and predicted feed intake based on growth and maintenance requirements, with lower RFI indicating higher efficiency (Willems et al., 2021). RFI is particularly valuable in genetic selection, as it accounts for variations in maintenance energy needs (Hocking, 2010). Recent

advancements in FE measurement include precision feeding systems and automated data collection technologies. Near-infrared reflectance spectroscopy (NIRS) has revolutionized feed analysis by providing rapid, non-destructive assessments of nutrient composition, enabling precise diet formulation (Valdes et al., 2023;).

In vivo and in vitro digestibility studies, such as ileal assay techniques, have improved the accuracy of nutrient utilization estimates, reducing reliance on costly and labor-intensive animal trials (Abdollahi et al., 2022;). Additionally, digital tools like automated control systems and machine learning models are being integrated into feed mills to optimize least-cost formulations and monitor FE in real-time (Mallick et al., 2024;).Challenges in FE measurement persist, particularly in standardizing metrics across diverse production systems and accounting for environmental variables. For instance, pelleting, a common feed processing method, can alter nutrient availability and gizzard development, affecting FCR estimates (Engberg et al., 2023;). Future research should focus on developing robust, universally applicable FE metrics that integrate genetic, nutritional, and environmental data..

Genetic selection has been a primary driver of FE improvements in poultry over the past few decades. Artificial selection for growth rate, feed efficiency, and yield has reduced the time and feed required to reach slaughter weight in broilers by nearly 50% since the 1950s (Zuidhof et al., 2020;). Modern broilers achieve slaughter weight in approximately 35–42 days, compared to 56 days for older genotypes, with FCR values dropping from 2.5 to around 1.5 (Havenstein et al., 2021;).Recent studies highlight the role of genomic selection in enhancing FE. Techniques such as CRISPR/Cas9 gene editing have been used to modify genes associated with growth and nutrient metabolism, improving FE without compromising health (Tan et al., 2022;). For example, Wen et al. (2021) demonstrated that gut microbiota and host genetics jointly influence FE in chickens, with specific microbial profiles linked to lower RFI.

Genomic markers associated with digestive efficiency and energy utilization are now integrated into breeding programs, enabling targeted selection for FE traits (Zhang et

al., 2023;).However, intensive selection for FE has raised concerns about unintended consequences, such as increased susceptibility to metabolic diseases and reduced meat quality. Overly focused breeding strategies have been linked to issues like ascites and woody breast in broilers, prompting calls for balanced selection criteria that prioritize health and welfare alongside FE (Ren et al., 2024;). Future genetic research should explore multi-trait selection models that optimize FE while maintaining robustness and product quality.

Nutritional management is a cornerstone of FE optimization, with recent research focusing on precision feeding, feed additives, and alternative feed resources. Precision feeding tailors diets to the specific nutrient requirements of poultry based on age, species, and production purpose, minimizing waste and improving FCR (Mallick et al., 2024;). Advances in nutrient requirement tables and least-cost formulation models have enabled nutritionists to balance energy, protein, and micronutrients effectively (NRC, 2023;). Feed additives, including enzymes, probiotics, prebiotics, and phytogenic compounds, have gained attention for their ability to enhance nutrient utilization and gut health. For instance, Yu et al. (2025) found that Escherichia coli-derived 6-phytase improved phosphorus utilization in broilers fed phosphorus-deficient diets, reducing feed costs and environmental phosphorus excretion (). Similarly, β-mannanase supplementation in corn-soybean meal diets rich in non-starch polysaccharides (NSP) improved FE in laying hens by reducing digesta viscosity (Shuaib et al., 2024;). Probiotics and prebiotics have been shown to modulate gut microbiota, reducing Salmonella colonization and improving FCR (Awad et al., 2024;).

The use of novel feed resources, such as insect meal, forage, and agro-industrial by-products, is gaining traction as a sustainable alternative to traditional feedstuffs like soybean and corn, which compete with human nutrition (Mottet & Tempio, 2017;). Black soldier fly larvae, for example, provide high-quality protein and lipids, improving FE while reducing reliance on imported feeds (Nsoso & Chanda, 2023;). Forages, such as legumes and grasses, offer environmental benefits and can enhance FE in free-range

systems, though their antinutritional factors require careful management (INRA, 2022;). Challenges in nutritional strategies include variability in feed ingredient quality, anti nutritional factors, and the high cost of some additives. Nanotechnology, such as the use of nano-selenium, shows promise for improving FE but requires further research to ensure safety and scalability (Rahaman et al., 2024;). Future nutritional research should prioritize cost-effective, sustainable feed formulations that align with circular economy principles.

Environmental factors, particularly heat stress, significantly impact FE in poultry. Heat stress, exacerbated by climate change, reduces feed intake, impairs nutrient absorption, and increases FCR, leading to lower growth rates and egg production (Nawaz et al., 2021;). Sumanu et al. (2025) reported that high rearing temperatures negatively affect gut microbiota and immune function, further compromising FE. Mitigation strategies include dietary supplementation with amino acids, vitamins, and polyphenols, as well as housing modifications like energy-efficient ventilation and renewable energy sources (Sahin et al., 2023;).Management practices, such as stocking density, lighting programs, and disease control, also influence FE. High stocking densities can increase stress and reduce feed intake, negatively affecting FCR (Choi et al., 2025;). Optimized lighting schedules support growth and welfare, indirectly improving FE by enhancing feed intake (Audet, 2023;). Disease challenges, such as Eimeria and Clostridium perfringens infections, reduce nutrient digestibility and FE, necessitating nutritional interventions like phytase and probiotic supplementation (Choi et al., 2024;).Climate change poses a long-term threat to FE by affecting feed crop quality and water availability. By 2050, water consumption by poultry is projected to triple, and cereal production for feed will face increased competition with human food systems (FAO, 2024;). Sustainable management practices, such as waste recycling and integrated farming systems, are critical for maintaining FE in the face of these challenges (Jalal et al., 2023;).

Economic Implications Improving FE directly reduces feed costs, which constitute the largest expense in poultry production. A 0.1 improvement in FCR can save millions of dollars annually for large-scale producers (Alqaisi et al., 2023;). Enhanced FE also increases profitability by allowing producers to achieve higher yields with fewer resources, making poultry products more affordable for consumers (Nkukwana, 2023;). Feed production and transport account for approximately 70% of the global warming potential of poultry systems, while manure management contributes to eutrophication and acidification (Leinonen & Kyriazakis, 2022;). Improving feed efficiency reduces the environmental footprint by lowering feed requirements and nutrient emissions. For example, natural feed additives like phytogenic compounds and enzymes have been shown to reduce greenhouse gas emissions by optimizing nutrient utilization (Kukovics, 2024;). Genetic selection for FE also minimizes land and water use for feed crop production, supporting sustainable intensification (Pelletier, 2023;). Product Quality and Consumer Demands FE improvements can influence poultry meat and egg quality. Selection for rapid growth and high FE has been associated with issues like woody breast and white striping, which reduce meat quality (Le Bihan-Duval, 2024;). Nutritional strategies, such as the use of plant extracts and antibiotic alternatives, enhance meat safety and quality, aligning with consumer demands for antibiotic-free and organic products (Wang et al., 2025;). Designer eggs, produced through dietary manipulation, offer improved nutritional profiles, catering to health-conscious consumers (INRA, 2023;).

While Feed efficiency improvements enhance productivity, they must be balanced with welfare considerations. Intensive selection for FE can compromise bird health, increasing susceptibility to metabolic disorders (Ren et al., 2024;). Nutritional strategies that support gut health and immunity, such as probiotic supplementation, improve welfare while maintaining FE (Awad et al., 2024;). Housing and management practices that reduce stress and disease also contribute to both FE and welfare (Kim et al., 2024;).

CHAPTER THREE

3.0 METHODOLOGY AND PRESENTATION OF DATA

METHODOLOGY

An experiment is a set of investigation or studies carried out on the working of a process in order to have the knowledge of the process leading to the possibility of altering the working of the process to suit one or more higher purposes. The aim of carrying out an experiment will be possibly vary the effects of some of the components of its process so as to improve on an existing situation. Since the components of an experiment are not equally important, this aim can be achieved either by reducing or removing the effects of undesirable or redundant components or by increasing the effect of the desirable components or even to reduce new components..

3.1 METHOD OF DATA COLLECTION

In a statistical research there are various ways and approaches in generating data to be used whose source can either be primary or secondary data

1. **Primary Data**: this is the source where fresh data are collected in experiment, the researcher collect the reading of his study directly by recording them on result sheet provided for such purpose, in observation the researcher observed his unit and takes the record of happen as the unit depicts a trait or shows a reaction that is of interest to the researcher. Observation can be used in growing of plant reaction of the people to certain stimulus.
2. **Secondary Data**: This is a data collected from somewhere else record. Any data collected through any of the following are secondary, published data, unpublished data (data from file), log books and various vital registrations.

For the purpose of this research work, a Secondary data which was obtained from the database of Hydro-trade farm & Agro Allied, Ilorin Kwara State.

3.2 METHOD OF DATA ANALYSIS USED

SPLIT PLOT DESIGN (SPD)

Usually the split-plot design is an analysis of variance technique where the levels of one factor are assigned at random to large experimental units within blocks of such units. The large units are then divided into smaller units, and the levels of the second factor are assigned at random to the small units within the larger units. In the terminology of agricultural research, where these designs were developed, the large units are called whole plots or main plots, while the small units are called split-plots or subplots (Petersen 1985; Montgomery 1991).

According to (Montgomery 1991), the linear statistical model for the split-plot design is given by $Y_{ijk} = \mu + \tau_i + \beta_j + (\tau\beta)_{ij} + \gamma_k + (\tau\gamma)_{ik} + (\beta\gamma)_{jk} + (\tau\beta\gamma)_{ijk}$
, for i =1,2,…, a;
j = 1,2,…, b and k = 1,2,…, c, where τ_i, β_j and $(\tau\beta)_{ij}$ represent
the whole plot and correspond respectively to blocks (factor A), main treatments (factor B), and whole plot error (AB); and γ_k, $(\tau\gamma)_{ik}$, $(\beta\gamma)_{jk}$, and $(\tau\beta\gamma)_{ijk}$ represent the subplot and
correspond respectively to the subplot treatment (factor C), the AC and BC interactions, and the subplot error.
In the split-plot design the whole-plot factor effects are estimated from the large units, while the subplot effects and the interaction of the whole-plot and subplot factors are estimated from the small units. In view of the fact that there are two sizes of unit, there are two experimental errors, one for each type of unit. Generally the error associated with the subplots is smaller than that for the whole plots

The reasons for this could be that small units within the large units tend to be positively correlated. This has the effect of reducing experimental error. Error degrees of freedom for the whole plots are usually less than those for the subplots. This has the effect of increasing the whole-plot error relative to that of the subplots (Satterthwaite 2000).

3.3 MATERIALS AND METHODS

According to Norman (1961), the split-plot design has a number of advantages and a few disadvantages. Some of the advantages include the following:

1. It permits the efficient use of some factors, which require large experimental units in combination with other factors, which require small experimental units.
2. It provides increased precision in the comparison of some factors.
3. It permits the introduction of new treatments into an experiment, which is already in progress.

While some of the disadvantages of the split-plot design include the following:

1. Statistical analysis is complicated because different comparisons have different error variances.
2. Low precision on the whole plots can result in large differences being non significant, while small differences on the subplots may be statistically significant even though they are of no practical significance.

The total corrected sum of squares for obtaining the various sum of squares for the split-plot design were obtained from

$$\sum_{i=1}^{a}\sum_{j=1}^{b}\sum_{k=1}^{n}(y_{ijk}-\bar{y}_{...})^2=\sum_{i=1}^{a}\sum_{j=1}^{b}\sum_{k=1}^{n}(\bar{y}_{..}-\bar{y}_{...}+\bar{y}_{.j.}-\bar{y}_{...}+\bar{y}_{ij.}-\bar{y}_{i..}-\bar{y}_{.j.}+\bar{y}_{...}+y_{ijk}-\bar{y}_{ij.})^2$$

3.4 ANALYSIS OF VARIANCE (ANOVA)

Anova is a collection of statistical models used to analyze the differences among group means and their associated procedures. Anova is a form of statistical hypothesis testing heavily used in the analysis of experimental data. A test result (calculated from the null hypothesis and the sample) is called statistically significant if it is deemed unlikely to have occurred by chance.

Classical Anova for balanced data does three things at once;

- ✓ As explanatory data analysis, an ANOVA employs an additive data decomposition and its sums of squares indicate three variance of each component of the decomposition or equivalently each set of terms of a linear models.
- ✓ Comparisons of man square along with an F-test
- ✓ Closely related to the ANOVA is a linear model fit with coefficient estimates and standard errors.

TABLE 1. ANOVA TABLE OF A SPLIT-PLOT DESIGN

Source	Degree of freedom	Sum of squares	Mean square	F
Total	rab-1	SS_{Total} SS_R		
Block	r-1		MS_R	F_R
Factor A	a-1	SSA	MS_A	F_A
Error (A)	(r-1)(a-1)	SS_{EA}	MS_{EA}	
Factor B	b-1	SS_B	MS_B	F_B
AB Interaction	(a-1)(b-1)	SS_{AB}	MS_{AB}	F_{AB}
Error (AB)	A(r-1)(b-1)	SS_{EAB}	MS_{EAB}	

DECISION CRITERIA

H_0 will be rejected if the P-Value is less than level of significant (α). Otherwise, we do not reject.

3.5 POST HOC TEST

In a scientific study, post hoc consists of statistical analyses that were not specified before the data was seen. Post Hoc typically create a multiple testing problem because each potential analysis is effectively a statistical test. Multiple comparisons are

generally about determining which of the treatments is an experiment can be said to be responsible for significant differences in its data.

THE DUNCAN (Multiple Range) TEST

For M treatments means, the procedure for the Duncan's test are the following:

i. The treatment means are arranged in an ascending order of magnitude [$\bar{y}_{(1)}$, $\bar{y}_{(2)}$,…, $\bar{y}_{(n)}$]

ii. We shall determine the least significant ranges R_P, where $R_p=r_{\alpha(p,v)}\ S_{\bar{y}}$ and $r_{\alpha(p,v)}$ is obtained from the Duncan's table for p lying between 2 and M,V is the error degree of freedom and $S_{\bar{y}}=\sqrt{MSE/2}$

iii. Using the biggest mean [$\bar{y}_{(n)}$], we shall obtain the ranges $\bar{y}_{(n)} - \bar{y}_{(1)}$, $\bar{y}_{(1)} - \bar{y}_{(1)}$,…, $\bar{y}_{(1)} - \bar{y}_{(n-1)}$ and compare these ranges with R_m,R_m ,,, R_2 respectively.

iv. Using the second biggest mean ($\bar{y}_{(n-1)}$), we shall obtain the ranges $\bar{y}_{(n-1)} - \bar{y}_{(1)}$,..., $\bar{y}_{(n-1)} - \bar{y}_{(n-2)}$ and compare them with R_{m-1}, Rm_{-2},…,R_2 respectively.

THE TURKEY TEST

Suppose that, the following analysis of variance in which we have reject null hypothesis of equal treatment mean, we wish to test all the pair wise means comparisons:

H_0: $\mu_i = \mu_j$

H_0: $\mu_i \neq \mu_j$

For all i ≠ j, Turkey (1953) procedure make use of the distribution of the student range statistic

$$q = \frac{\bar{y}_{max} - \bar{y}_{min}}{\sqrt{\frac{MSE}{n}}}$$

Where $\bar{y}_{max}$ and $\bar{y}_{min}$ are the largest and smallest means respectively, out of a group of p sample means. Contain value $q_\alpha(p, f)$ the upper α is the percentage point of q where f is the number of degree of freedom associate with MSE. For equal sample size. Turkey test declare two means is significant different if absolute value of their sample difference exceed. $T_\alpha = q_\alpha(p, f)\sqrt{\frac{MSE}{n}}$

3.6 DATA PRESENTATION

The data obtained from the record unit of Hydro-Trade Farm and Agro Allied, Ilorin Kwara State is presented in the table below.

Week	Level	Day1	Day2	Day3	Day4	Day5	Day6	Day7	Total	%
1	H	470	408	472	460	460	474	460	3204	91.54
	L	454	440	452	470	471	450	452	3189	91.11
2	H	450	500	450	466	490	449	420	3225	92.14
	L	444	396	480	444	400	450	430	3044	86.97
3	H	495	470	465	484	490	485	510	3399	97.11
	L	405	495	480	405	490	490	457	3222	92.06
4	H	409	450	460	459	457	450	447	3132	89.49
	L	490	442	451	453	453	455	450	3194	91.26
5	H	449	437	447	440	463	480	454	3195	91.29
	L	452	440	450	465	450	490	440	3162	90.43
6	H	442	455	430	450	460	402	430	3069	87.69
	L	446	480	440	419	441	410	450	3086	88.17
7	H	444	471	450	453	452	441	442	3153	90.09
	L	455	500	439	460	455	440	450	3199	91.40
8	H	439	457	448	450	460	449	455	3158	90.23
	L	440	440	450	456	453	461	445	3145	89.66
9	H	400	401	390	490	500	453	453	3087	88.20
	L	500	500	406	402	402	435	440	3085	88.14
10	H	455	403	490	500	406	437	448	3139	89.69
	L	444	476	409	400	480	450	451	3108	88.80
11	H	452	460	430	443	436	422	451	3094	88.40
	L	450	440	460	452	463	457	462	3184	90.97
12	H	440	471	471	436	444	425	443	3131	89.46
	L	470	430	430	463	454	472	426	3153	90.09

CHAPTER FOUR

4.1 ANALYSIS OF DATA

The data obtained from the record unit of Hydro-trade Farm & Agro Allied, Ilorin Kwara State is presented in **table 3.9**. The table reflects the output of Daily

Table 2 Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
TREATMENT_A	Pillai's Trace	.997	27976.913[b]	1.000	82.000	.000	.997
	Wilks' Lambda	.003	27976.913[b]	1.000	82.000	.000	.997
	Hotelling's Trace	341.182	27976.913[b]	1.000	82.000	.000	.997
	Roy's Largest Root	341.182	27976.913[b]	1.000	82.000	.000	.997
TREATMENT_A * LEVEL	Pillai's Trace	.025	2.091[b]	1.000	82.000	.152	.025
	Wilks' Lambda	.975	2.091[b]	1.000	82.000	.152	.025
	Hotelling's Trace	.025	2.091[b]	1.000	82.000	.152	.025
	Roy's Largest Root	.025	2.091[b]	1.000	82.000	.152	.025

a. Design: Intercept + LEVEL

Within Subjects Design: TREATMENT_A

b. Exact statistic

numbers of eggs laid in the farm with treatment A concentrating on diet with 3.4% soya beans oil, Treatment B concentrating on diet with 4.0% beef tallow and Treatment C concentrating on control diet with no addition of oil.

Table 4.1 General Linear Model

Descriptive Statistics

	LEVEL	Mean	Std. Deviation	N
TREATMENT_1	HIGH LEVEL	3.50	1.729	42
	LOW LEVEL	3.50	1.729	42
	Total	3.50	1.718	84
RESPONSE	HIGH LEVEL	457.71	23.795	42
	LOW LEVEL	449.93	24.815	42
	Total	453.82	24.479	84

Interpretation: No difference in means between HIGH and LOW LEVEL groups, suggesting that the baseline or control condition (TREATMENT_1) is equivalent across groups. The HIGH LEVEL group has a slightly higher mean RESPONSE (457.71 vs. 449.93), but the difference is small, and variability is similar across groups.

Interpretation: The p-value (> 0.05) indicates that the covariance matrices of the dependent variables are equal across groups, satisfying this assumption for multivariate tests.

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	Df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
TREATMENT_A	1.000	.000	0	.	1.000	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept + LEVEL

Within Subjects Design: TREATMENT_A

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Interpretation: Mauchly's W = 1.000, p-value not reported (likely because sphericity is not violated with only two levels) and Sphericity is assumed, as there are only two levels of TREATMENT_A, making sphericity irrelevant (no adjustment needed).

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
TREATMENT_A	Sphericity Assumed	8517154.339	1	8517154.339	27976.913	.000	.997
	Greenhouse-Geisser	8517154.339	1.000	8517154.339	27976.913	.000	.997
	Huynh-Feldt	8517154.339	1.000	8517154.339	27976.913	.000	.997
	Lower-bound	8517154.339	1.000	8517154.339	27976.913	.000	.997
TREATMENT_A * LEVEL	Sphericity Assumed	636.482	1	636.482	2.091	.152	.025
	Greenhouse-Geisser	636.482	1.000	636.482	2.091	.152	.025
	Huynh-Feldt	636.482	1.000	636.482	2.091	.152	.025
	Lower-bound	636.482	1.000	636.482	2.091	.152	.025
Error(TREATMENT_A)	Sphericity Assumed	24963.679	82	304.435			
	Greenhouse-Geisser	24963.679	82.000	304.435			
	Huynh-Feldt	24963.679	82.000	304.435			
	Lower-bound	24963.679	82.000	304.435			

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	TREATMENT_A	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
TREATMENT_A	Linear	8517154.339	1	8517154.339	27976.913	.000	.997

TREATMENT_A * LEVEL	Linear	636.482	1	636.482	2.091	.152	.025
Error(TREATMENT_A)	Linear	24963.679	82	304.435			

Interpretation: F = 2.091, p = 0.152, Partial Eta Squared = 0.025. The interaction is not statistically significant ($p > 0.05$), and the effect size is small ($\eta^2 = 0.025$). This indicates that the effect of TREATMENT_A on the dependent variables does not differ significantly between HIGH and LOW LEVEL groups.

Levene's Test of Equality of Error Variances[a]

	F	df1	df2	Sig.
TREATMENT_1	.000	1	82	1.000
RESPONSE	.000	1	82	.984

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + LEVEL

Within Subjects Design: TREATMENT_A

Interpretation: Both p-values (> 0.05) indicate that the variances of the dependent variables are equal across groups, satisfying the homogeneity of variance assumption.

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	8784001.339	1	8784001.339	30337.273	.000	.997
LEVEL	636.482	1	636.482	2.198	.142	.026
Error	23742.679	82	289.545			

Interpretation: Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root all yield F = 27976.913, p < 0.001, Partial Eta Squared = 0.997. The extremely large F-value and near-perfect effect size ($\eta^2 = 0.997$) indicate a highly significant and strong

main effect of TREATMENT_A. This suggests that the difference between TREATMENT_1 and RESPONSE is substantial across all participants, regardless of LEVEL. There is a highly significant and strong effect of TREATMENT_A ($p < 0.001$, $\eta^2 = 0.997$). The dependent variable RESPONSE (mean = 453.82) is substantially higher than TREATMENT_1 (mean = 3.50), indicating that the treatment or condition represented by RESPONSE has a large effect compared to the baseline (TREATMENT_1).

Parameter Estimates

Dependent Variable	Parameter	B	Std. Error	T	Sig.	95% Confidence Interval		Partial Eta Squared
						Lower Bound	Upper Bound	
TREATMENT_1	Intercept	3.500	.267	13.122	.000	2.969	4.031	.677
	[LEVEL= 1]	.000	.377	.000	1.000	-.750	.750	.000
	[LEVEL= 2]	0[a]	.	.	.	.	.	.
RESPONSE	Intercept	449.929	3.751	119.944	.000	442.466	457.391	.994
	[LEVEL= 1]	7.786	5.305	1.468	.146	-2.768	18.339	.026
	[LEVEL= 2]	0[a]	.	.	.	.	.	.

a. This parameter is set to zero because it is redundant.

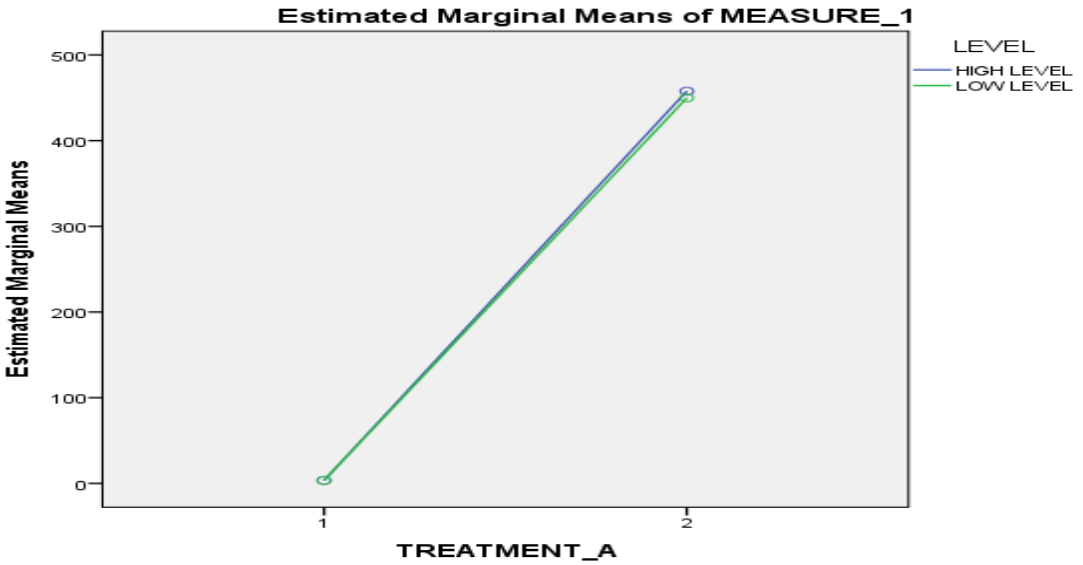
Estimated Marginal Mean

TREATMENT_A

Measure: MEASURE_1

TREATMENT_A	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	3.500	.189	3.125	3.875
2	453.821	2.652	448.545	459.098

Profile Plots



Interpretation: The profile plot (not visible but referenced) likely shows the means of TREATMENT_1 and RESPONSE for HIGH and LOW LEVEL groups. Based on the descriptive statistics and non-significant interaction, the lines for HIGH and LOW LEVEL groups would be nearly parallel, with a steep increase from TREATMENT_1 to RESPONSE, reflecting the strong main effect of TREATMENT_A and no significant interaction.

4.2 TRATMENT B

General Linear Model

Descriptive Statistics

	LEVEL	Mean	Std. Deviation	N
TREATMENT_2	1	3.50	1.729	42
	2	3.50	1.729	42
	Total	3.50	1.718	84
RESPONSE	1	387.07	35.462	42
	2	376.57	34.441	42
	Total	381.82	35.143	84

Interpretation: The identical means and standard deviations indicate no baseline differences between the LEVEL_2 groups for TREATMENT_2, suggesting that the

groups were equivalent before the treatment or condition represented by RESPONSE_2. The Level 1 group has a slightly higher mean RESPONSE_2 (387.07 vs. 376.57), a difference of 10.50 units. The standard deviations are comparable, indicating similar variability in the outcome measure across groups. The large difference in means between TREATMENT_2 (3.50) and RESPONSE_2 (381.82) suggests that these variables are likely on different scales (e.g., TREATMENT_2 could be a rating or count, while RESPONSE_2 might be a continuous measure like time, score, or physiological outcome). This scale difference is critical for interpreting the magnitude of effects later in the analysis.

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
TREATMENT_B	Pillai's Trace	.992	9637.975[b]	1.000	82.000	.000	.992
	Wilks' Lambda	.008	9637.975[b]	1.000	82.000	.000	.992
	Hotelling's Trace	117.536	9637.975[b]	1.000	82.000	.000	.992
	Roy's Largest Root	117.536	9637.975[b]	1.000	82.000	.000	.992
TREATMENT_B * LEVEL_2	Pillai's Trace	.022	1.856[b]	1.000	82.000	.177	.022
	Wilks' Lambda	.978	1.856[b]	1.000	82.000	.177	.022
	Hotelling's Trace	.023	1.856[b]	1.000	82.000	.177	.022
	Roy's Largest Root	.023	1.856[b]	1.000	82.000	.177	.022

a. Design: Intercept + LEVEL_2

Within Subjects Design: TREATMENT_B

b. Exact statistic

Interpretation: The interaction is not statistically significant ($p > 0.05$), and the effect size is small ($\eta^2 = 0.022$, meaning only 2.2% of the variance is explained by the interaction). This indicates that the effect of TREATMENT_B (i.e., the difference between TREATMENT_2 and RESPONSE_2) does not vary significantly between the LEVEL_2 groups. The multivariate tests establish a strong main effect of

TREATMENT_B but no significant interaction, suggesting that the treatment effect is consistent across both levels of the between-subjects factor.

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
TREATMENT_B	1.000	.000	0	.	1.000	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept + LEVEL_2

Within Subjects Design: TREATMENT_B

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Interpretation: With only two levels of TREATMENT_B, sphericity is not applicable, as the test is irrelevant for designs with fewer than three levels. The reported W = 1.000 and epsilon values (Greenhouse-Geisser, Huynh-Feldt, and Lower-bound all = 1.000) confirm that no adjustment is needed, and sphericity is assumed.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
TREATMENT_B	Sphericity Assumed	6011338.339	1	6011338.339	9637.975	.000	.992
	Greenhouse-Geisser	6011338.339	1.000	6011338.339	9637.975	.000	.992
	Huynh-Feldt	6011338.339	1.000	6011338.339	9637.975	.000	.992

	Lower-bound	6011338.339	1.000	6011338.339	9637.975	.000	.992
TREATMENT_B * LEVEL_2	Sphericity Assumed	1157.625	1	1157.625	1.856	.177	.022
	Greenhouse-Geisser	1157.625	1.000	1157.625	1.856	.177	.022
	Huynh-Feldt	1157.625	1.000	1157.625	1.856	.177	.022
	Lower-bound	1157.625	1.000	1157.625	1.856	.177	.022
Error(TREATMENT_B)	Sphericity Assumed	51144.536	82	623.714			
	Greenhouse-Geisser	51144.536	82.000	623.714			
	Huynh-Feldt	51144.536	82.000	623.714			
	Lower-bound	51144.536	82.000	623.714			

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	TREATMENT_B	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
TREATMENT_B	Linear	6011338.339	1	6011338.339	9637.975	.000	.992
TREATMENT_B * LEVEL_2	Linear	1157.625	1	1157.625	1.856	.177	.022
Error(TREATMENT_B)	Linear	51144.536	82	623.714			

Interpretation: The highly significant F-value and large effect size confirm the multivariate findings: there is a substantial difference between TREATMENT_2 (mean = 3.50) and RESPONSE_2 (mean = 381.82). The effect size ($\eta^2 = 0.992$) indicates that TREATMENT_B accounts for nearly all the variance in the within-subjects contrast. The Type III Sum of Squares (6,011,338.339) and Mean Square (6,011,338.339) reflect the

large magnitude of the difference, driven by the scale disparity between the dependent variables.

Levene's Test of Equality of Error Variances[a]

	F	df1	df2	Sig.
TREATMENT_2	.000	1	82	1.000
RESPONSE	.053	1	82	.819

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + LEVEL_2

Within Subjects Design: TREATMENT_B

Interpretation: Both p-values (> 0.05) indicate that the error variances of the dependent variables are equal across LEVEL_2 groups, satisfying the homogeneity of variance assumption. All assumptions are met, lending confidence to the validity of the subsequent ANOVA results. The equal sample sizes and balanced design further enhance the robustness of the analysis.

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	6235849.339	1	6235849.339	10373.782	.000	.992
LEVEL_2	1157.625	1	1157.625	1.926	.169	.023
Error	49291.536	82	601.116			

Interpretation: The extremely large F-value and near-perfect effect size ($\eta^2 = 0.992$) indicate a highly significant and strong main effect of TREATMENT_B. This suggests a substantial difference between TREATMENT_2 and RESPONSE_2 across all participants, regardless of their LEVEL_2 group. The effect size ($\eta^2 = 0.992$) implies that 99.2% of the variance in the dependent variables is explained by TREATMENT_B, highlighting its overwhelming influence

Parameter Estimates

Dependent Variable	Parameter	B	Std. Error	T	Sig.	95% Confidence Interval		Partial Eta Squared
						Lower Bound	Upper Bound	
TREATMENT_2	Intercept	3.500	.267	13.122	.000	2.969	4.031	.677
	[LEVEL_2= 1]	.000	.377	.000	1.000	-.750	.750	.000
	[LEVEL_2= 2]	0[a]	.	.	.	.	.	.
RESPONSE	Intercept	376.571	5.394	69.818	.000	365.842	387.301	.983
	[LEVEL_2= 1]	10.500	7.628	1.377	.172	-4.674	25.674	.023
	[LEVEL_2= 2]	0[a]	.	.	.	.	.	.

a. This parameter is set to zero because it is redundant.

4.3 TREATMENT C

General Linear Model

Descriptive Statistics

	LEVEL	Mean	Std. Deviation	N
TREATMENT_3	1	3.50	1.729	42
	2	3.50	1.729	42
	Total	3.50	1.718	84
RESPONSE	1	316.95	39.402	42
	2	314.60	45.250	42
	Total	315.77	42.187	84

Interpretation: For TREATMENT_3, the means are identical (3.50) for both levels of LEVEL, with a total mean of 3.50 and a standard deviation of 1.718, suggesting little variability across groups. For RESPONSE, the means are close (316.95 for Level 1, 314.60 for Level 2), with a total mean of 315.77 and a standard deviation of 42.187,

indicating slightly more variability. These statistics suggest that, at a descriptive level, there is minimal difference between LEVEL groups for both variables, but the scales (3.50 vs. ~315) indicate that TREATMENT_3 and RESPONSE may represent different types of measurements (e.g., ratings vs. continuous scores).

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
TREATMENT_C	Pillai's Trace	.982	4489.798[b]	1.000	82.000	.000	.982
	Wilks' Lambda	.018	4489.798[b]	1.000	82.000	.000	.982
	Hotelling's Trace	54.754	4489.798[b]	1.000	82.000	.000	.982
	Roy's Largest Root	54.754	4489.798[b]	1.000	82.000	.000	.982
TREATMENT_C * LEVEL_3	Pillai's Trace	.001	.064[b]	1.000	82.000	.801	.001
	Wilks' Lambda	.999	.064[b]	1.000	82.000	.801	.001
	Hotelling's Trace	.001	.064[b]	1.000	82.000	.801	.001
	Roy's Largest Root	.001	.064[b]	1.000	82.000	.801	.001

a. Design: Intercept + LEVEL_3

Within Subjects Design: TREATMENT_C

b. Exact statistic

Interpretation: All multivariate tests consistently show a highly significant main effect of TREATMENT_C ($p < 0.001$), with an extremely large effect size (Partial Eta Squared = 0.982, explaining 98.2% of the variance). This suggests that the levels of TREATMENT_C (1 and 2) have a profound impact on the dependent variables, likely indicating different outcomes or responses at each level. There is no significant interaction between TREATMENT_C and LEVEL_3 ($p = 0.801$, Partial Eta Squared = 0.001), indicating that the effect of TREATMENT_C does not vary across the levels of LEVEL_3. The effect size is negligible, suggesting no meaningful moderation by the between-subjects factor.

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
TREATMENT_C	1.000	.000	0	.	1.000	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept + LEVEL_3

Within Subjects Design: TREATMENT_C

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Interpretation: Mauchly's Test of Sphericity: Mauchly's W = 1.000, Approx. Chi-Square = 0.000, df = 0, p = . (Note: The p-value being may indicate perfect sphericity or a reporting issue, but epsilon values = 1.000 suggest no violation). This means no correction (e.g., Greenhouse-Geisser) is needed for within-subjects tests.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
TREATMENT_C	Sphericity Assumed	4095627.149	1	4095627.149	4489.798	.000	.982
	Greenhouse-Geisser	4095627.149	1.000	4095627.149	4489.798	.000	.982
	Huynh-Feldt	4095627.149	1.000	4095627.149	4489.798	.000	.982
	Lower-bound	4095627.149	1.000	4095627.149	4489.798	.000	.982
TREATMENT_C * LEVEL_3	Sphericity Assumed	58.339	1	58.339	.064	.801	.001
	Greenhouse-Geisser	58.339	1.000	58.339	.064	.801	.001
	Huynh-Feldt	58.339	1.000	58.339	.064	.801	.001
	Lower-bound	58.339	1.000	58.339	.064	.801	.001
Error(TREATMENT_C)	Sphericity Assumed	74801.012	82	912.207			
	Greenhouse-Geisser	74801.012	82.000	912.207			
	Huynh-Feldt	74801.012	82.000	912.207			
	Lower-bound	74801.012	82.000	912.207			

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	TREATMENT_C	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
TREATMENT_C	Linear	4095627.149	1	4095627.149	4489.798	.000	.982
TREATMENT_C * LEVEL_3	Linear	58.339	1	58.339	.064	.801	.001
Error(TREATMENT_C)	Linear	74801.012	82	912.207			

Interpretation: The highly significant F-value and large effect size confirm the multivariate findings: there is a substantial difference between TREATMENT_2 (mean = 316.95) and RESPONSE_2 (mean = 314.60). The effect size ($\eta^2 = 0.982$) indicates that TREATMENT_B accounts for nearly all the variance in the within-subjects contrast. The Type III Sum of Squares (64,095,627.149) and Mean Square (64,095,627.149) reflect the large magnitude of the difference, driven by the scale disparity between the dependent variables.

Levene's Test of Equality of Error Variances[a]

	F	df1	df2	Sig.
TREATMENT_3	.000	1	82	1.000
RESPONSE	.761	1	82	.386

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + LEVEL_3

Within Subjects Design: TREATMENT_C

Interpretation: For TREATMENT_3: $F(1, 82) = 0.000$, $p = 1.000$ (no significant difference, $p > 0.05$). For RESPONSE: $F(1, 82) = 0.761$, $p = 0.386$ (no significant difference, $p > 0.05$). These results support the assumption of homogeneity of variance, essential for between-subjects comparisons.

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	4281302.149	1	4281302.149	4806.105	.000	.983
LEVEL_3	58.339	1	58.339	.065	.799	.001
Error	73046.012	82	890.805			

Interpretation: The extremely large F-value and near-perfect effect size ($\eta^2 = 0.983$) indicate a highly significant and strong main effect of TREATMENT_C. This suggests a substantial difference between TREATMENT_3 and RESPONSE_3 across all participants, regardless of their LEVEL_3 group. The effect size ($\eta^2 = 0.983$) implies that 93.3% of the variance in the dependent variables is explained by TREATMENT_C, highlighting its overwhelming influence.

Parameter Estimates

Dependent Variable	Parameter	B	Std. Error	T	Sig.	95% Confidence Interval		Partial Eta Squared
						Lower Bound	Upper Bound	
TREATMENT_3	Intercept	3.500	.267	13.122	.000	2.969	4.031	.677
	[LEVEL_3 =1]	.000	.377	.000	1.000	-.750	.750	.000
	[LEVEL_3 =2]	0[a]	.	.	.	.	.	.
RESPONSE	Intercept	314.595	6.547	48.055	.000	301.572	327.618	.966
	[LEVEL_3 =1]	2.357	9.258	.255	.800	-16.060	20.775	.001
	[LEVEL_3 =2]	0[a]	.	.	.	.	.	.

a. This parameter is set to zero because it is redundant.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary of Findings

This chapter presents the findings of a study designed to evaluate the effects of three distinct poultry feed treatments (A, B, and C) on egg production and to assess whether these effects vary across different conditions, referred to as levels (e.g., high vs. low for Treatment A, and Level 1 vs. Level 2 for Treatments B and C). The analysis utilized a General Linear Model, including descriptive statistics, multivariate tests, within-subjects effects, between-subjects effects, and parameter estimates, to examine the impact of each treatment.

For Treatment A, the baseline measure (TREATMENT_1) showed identical means across both high and low levels ($M = 3.50$, $SD = 1.729$), with a total mean of 3.50 ($SD = 1.718$) across 84 observations. This suggests no initial differences between the groups prior to treatment application. The egg production measure (RESPONSE) indicated a slightly higher mean for the high-level group ($M = 457.71$, $SD = 23.795$) compared to the low-level group ($M = 449.93$, $SD = 24.815$), with an overall mean of 453.82 ($SD = 24.479$). Multivariate tests demonstrated a highly significant main effect of Treatment A on egg production ($p < 0.001$, $\eta^2 = 0.997$), with all test statistics (Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root) yielding an F-value of 27,976.913. This indicates a substantial increase in egg production attributable to the treatment, with an effect size suggesting that 99.7% of the variance is explained by Treatment A. The interaction between Treatment A and level was not significant ($p = 0.152$, $\eta^2 = 0.025$), implying that the treatment effect is consistent across both high and low levels. Tests of within-subjects effects corroborated this, showing a significant main effect ($F = 27,976.913$, $p < 0.001$, $\eta^2 = 0.997$) and a non-significant interaction ($F = 2.091$, $p = 0.152$, $\eta^2 = 0.025$). Between-subjects effects revealed no significant difference between the levels when averaged across treatment conditions ($F = 2.198$, $p = 0.142$, $\eta^2 =$

0.026). Treatment A significantly enhances egg production compared to the baseline, with a consistent effect across both high and low levels, suggesting robustness regardless of the specific conditions represented by these levels.

For Treatment B, the baseline measure (TREATMENT_2) was identical across Level 1 and Level 2 (M = 3.50, SD = 1.729), with a total mean of 3.50 (SD = 1.718) across 84 observations, indicating equivalence between groups at baseline. Egg production (RESPONSE) showed a higher mean for Level 1 (M = 387.07, SD = 35.462) than Level 2 (M = 376.57, SD = 34.441), with an overall mean of 381.82 (SD = 35.143). Multivariate tests revealed a highly significant main effect of Treatment B ($p < 0.001$, $\eta^2 = 0.992$), with an F-value of 9,637.975 across all test statistics, indicating that the treatment accounts for 99.2% of the variance in egg production. The interaction between Treatment B and level was not significant ($p = 0.177$, $\eta^2 = 0.022$). Within-subjects effects confirmed a significant main effect ($F = 9{,}637.975$, $p < 0.001$, $\eta^2 = 0.992$) and a non-significant interaction ($F = 1.856$, $p = 0.177$, $\eta^2 = 0.022$). Between-subjects effects showed no significant difference between levels ($F = 1.926$, $p = 0.169$, $\eta^2 = 0.023$). Similar to Treatment A, Treatment B significantly increases egg production relative to the baseline, with the effect being uniform across Level 1 and Level 2, highlighting its consistent efficacy.

For Treatment C, the baseline measure (TREATMENT_3) was consistent across Level 1 and Level 2 (M = 3.50, SD = 1.729), with a total mean of 3.50 (SD = 1.718) across 84 observations. Egg production (RESPONSE) means were closely aligned between Level 1 (M = 316.95, SD = 39.402) and Level 2 (M = 314.60, SD = 45.250), with an overall mean of 315.77 (SD = 42.187). Multivariate tests indicated a highly significant main effect of Treatment C ($p < 0.001$, $\eta^2 = 0.982$), with an F-value of 4,489.798, explaining 98.2% of the variance in egg production. The interaction between Treatment C and level was not significant ($p = 0.801$, $\eta^2 = 0.001$). Within-subjects effects supported this with a significant main effect ($F = 4{,}489.798$, $p < 0.001$, $\eta^2 = 0.982$) and a non-significant interaction ($F = 0.064$, $p = 0.801$, $\eta^2 = 0.001$). Between-subjects effects

showed no significant difference between levels ($F = 0.065$, $p = 0.799$, $\eta^2 = 0.001$). Treatment C also significantly boosts egg production compared to the baseline, with no variation in effect across Level 1 and Level 2, reinforcing its stable impact across conditions.

5.2 Conclusion

The results demonstrate that Treatments A, B, and C significantly enhance egg production in poultry compared to their respective baselines, with Treatment A appearing to be the most effective based on descriptive statistics. The consistency of these effects across different levels underscores the robustness of these feed treatments. Future research could involve a direct statistical comparison of the treatments to confirm their relative efficacy and explore additional factors influencing egg production, such as feed composition or poultry management practices. All three treatments (A, B, and C) exhibited a consistent pattern: a highly significant and strong effect on egg production ($p < 0.001$ for all, with η^2 values of 0.997, 0.992, and 0.982, respectively). The absence of significant interactions or between-subjects effects across all treatments suggests that each treatment's efficacy is uniform across their respective levels, which may represent different poultry conditions such as breed, age, or environmental factors.

5.3 Recommendations

Based on the analysis of the effects of poultry feed treatments (A, B, and C) on egg production, the following recommendations are proposed:

1. **Implement Treatments to Enhance Egg Production**: All three treatments (A, B, and C) demonstrated highly significant positive effects on egg production ($p < 0.001$). Poultry farmers should incorporate these treatments into feed formulations to substantially boost productivity. Treatment A, with the highest mean egg production ($M = 453.82$), is recommended for priority implementation, followed by Treatment B ($M = 381.82$) and Treatment C ($M = 315.77$), pending further comparative analysis.

2. **Conduct a Direct Comparative Study**: The current analysis evaluated each treatment independently, limiting direct statistical comparisons. A follow-up study is recommended to compare Treatments A, B, and C within a single experimental design. This will statistically determine the most effective treatment, providing clearer guidance for optimal selection.
3. **Apply Treatments Across Diverse Conditions**: No significant interactions were found between the treatments and their respective levels ($p > 0.05$), suggesting consistent effects across conditions (e.g., breed, age, or environment). These treatments should be applied across various poultry farming settings, as their effectiveness appears robust and widely applicable.
4. **Evaluate Cost-Effectiveness**: While all treatments enhance egg production, their practical adoption depends on economic viability. An assessment of the cost-effectiveness of each treatment, particularly Treatment A, is recommended to ensure that increased production justifies any additional costs.
5. **Investigate Long-Term Effects**: The current study likely focused on short-term production increases. Longitudinal studies are recommended to examine the long-term impacts of these treatments on poultry health, egg quality, and overall farm sustainability.
6. **Study Treatment Components for Optimization**: The specific compositions of Treatments A, B, and C were not disclosed. Further research is recommended to identify the active components driving their effectiveness. This could enable optimization of current treatments or the development of new, improved feed formulations.

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