EFFECT OF FEED RESTRICTION ON PERFORMANCE, STRESS AND CLINICAL WELFARE INDICATORS OF ROSS 308 BROILER CHICKENS

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DECLARATION

I declare that the dissertation hereby submitted to the University of Limpopo for the degree of Master of Agricultural Management in Animal Production has not been submitted by me for credit toward a degree at this or any other university; every content in this work has been properly recognised, and it is my original work in both design and execution.

Signature… ………………… Date ……10/12/2024…………………….

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DEDICATIONS

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LIST OF ABBREVIATIONS

ANOVA- Analysis of Variance

CRD-complete randomized design

GML-General Linear Model

LSD-Least significance Difference

DFI – Daily feed Intake

FCR – Feed Conversion Ratio

BWG – Body weight gain

GR – Growth Rate

DP – Dressing Percentage

SPPS- Statistical Package for the Social Sciences

CM- Centimetre

MM- Millimetre

°C-Celsius

ABSTRACT

This study investigates the effect of feed restriction on the growth performance, stress, and welfare indicators of Ross 308 broiler chickens aged 1 to 35 days. The experiment aimed to determine the impact of feed restriction on (1) growth performance, (2) welfare clinical indicators, and (3) gut morphometrics, carcass characteristics, meat quality, and sensory evaluation. A total of 270-day-old Ross 308 broiler chicks were randomly assigned to three treatment groups, with two replications per group. Each treatment group consisted of two separate sets of chicks ,which were independently managed and subjected to the same experimental conditions. The data were analyzed using the General Linear Model (GLM) procedure and Analysis of Variance (ANOVA), with significance considered at the 5% level. The results showed that feed restriction improved daily feed intake, body weight gain, and feed conversion ratio (P<0.05) in comparison to ad libitum feeding. Welfare indicators, including pecking behaviour, body condition, and feather condition, were significantly affected by feed restriction (P<0.05), while gait score, footpad, and skin condition were unaffected (P>0.05). Feed restriction also influenced (P<0.05) gut organ weight and length, as well as carcass weight and chicken pieces, but had no effect on pluck weight or dressing percentage. Meat quality analysis revealed no significant changes in color or pH, while tenderness and juiciness were positively influenced (P<0.05), with no impact on flavor or shear force. In conclusion, feed restriction in Ross 308 broiler chickens improved growth performance, affected specific welfare indicators, and influenced certain carcass and meat quality traits. The results suggest that feed restriction can be used to optimize growth and meat quality while maintaining reasonable welfare standards, although it has mixed effects on certain welfare indicators.

Keywords: Feed restriction, Ross 308 broiler chickens, growth performance, welfare indicators, carcass characteristic, sensory evaluation.

CHAPTER ONE

INTRODUCTION

In chicken production, feed restriction is a frequently employed management technique to maximize growth performance, lower feed costs, and boost feed conversion efficiency. Because it can affect several physiological and behavioral responses, which in turn affect production output, this approach is especially pertinent to broiler chickens (Ramirez et.al, 2020). Because of its quick growth and effective feed conversion, the Ross 308 broiler chicken is a perfect model to study how feed restriction affects important performance and welfare metrics.

The purpose of this study is to assess how feed restriction affects the clinical welfare indices, stress levels, and growth performance of Ross 308 broiler chickens (Nawaz and Amoah,2021). This study aims to determine how feed lrestriction may affect animal comfort and production efficiency by measuring variables such body weight, feed intake, feed conversion ratio, and stress-related indicators (e.g., corticosterone levels, behavioral changes). To make sure that feed restriction techniques don't jeopardize the birds' general health and wellbeing, the clinical welfare indicators—such as indications of stress or discomfort—will also be regularly observed.

1.1. Problem statement

Due to ongoing genetic selection and improvements in diet, modern broiler chicken strains grow extraordinarily quickly (Massuquetto et al., 2019). Ascites, sudden death syndrome, and limb problems can all be decreased by reducing early chicken growth, particularly in broilers (Abou-Kassem, 2021; Cuddington, 2011). Feed restriction benefits include financial savings from increased feed conversion, a decrease in sudden death syndrome, a decrease in mortality losses, ascites, and skeletal sickness (Bhatt and Banday, 2000).

In summary, the potential of limited feed programs as a management tool is strongly correlated with decreased maintenance costs, metabolic diseases, body accumulation of fat, and improved diet effectiveness in broiler chickens (Cuddington, 2004). Furthermore, it offers financial advantages by bringing down the cost of chicken producers' feed, which could be advantageous for the commercial poultry business.

One of the main strategies for changing the broiler chickens' growth curve to improve production efficiency and lower the prevalence of various metabolic illnesses is through feed restriction programs (Goo et al., 2019). They can also be utilised to decrease the negative consequences of the industry's rapid growth, which could be profitable (Massuquetto et al., 2019). However, the best feed restriction period for improved broiler chicken performance is inconclusive. Therefore, determining the impact of feed control on the development, performance and the meat quality of Ross 308 broiler chickens is crucial.

1.2. Rationale

Since feeding is the most expensive element of broiler production, managing feed consumption may necessitate adjusting the diet and nutritional needs (Yakubu et al., 2007). Additionally, ongoing hereditary and nutritional advancements have led to an increase in body abdominal fat, a high mortality rate and physiological challenges that have become a burden in poultry farming (Leeson and Zubair, 1996).

According to Massuquetto et al. (2019), initial dietary limitation strategies minimize belly and body weight in poultry depending on a process known as compensatory development to produce market body weight comparable to regulated groups. Young birds are prone to experience difficulties when there is a lack of food (Omosebi et.al,2014). Sufficient nutrition is crucial because chickens must divide their available energy during development between maintenance, growth, and maturation (Goo et al., 2019).

Temporary feed restriction at a specific stage of broiler chick development slows growth.When high energy diets are provided without reducing feed intake, the risk of metabolic diseases increases. (Goo et al., 2019). These diseases may not only result in economic costs for the producer, but they also have a severe impact on broiler comfort (Massuquetto et al, 2019). According to Leeson and Zubair (1996), chicks fed limited amounts of food during their early growth stages have better feed efficiency and attain slaughter weights comparable to those of chickens fed unlimited amounts of food.

However, Leeson and Zubair, (1996) has demonstrated that chickens subjected to limited amounts of feed gain less weight when compared to those fed *ad libitum* (Emami et al, 2021). Thus, information on the effect of feed restriction is inconclusive. Therefore, it is essential to evaluate the impact of feed restriction on growth performance and meat quality in Ross 308 broiler chickens, as this will aid in developing feeding strategies to enhance broiler production.

1.3 Aim

The aim of this study were to evaluate the effect of feed restriction on growth performance, stress and welfare clinical indicators of Ross 308 broiler chickens.

1.4 Objectives

The objectives of this study were to determine:

i) The effect of feed restriction on growth performances of Ross 308 broiler chickens.
ii) The effect of feed restriction on stress and welfare clinical indicators of Ross 308 broiler chicken
iii) The effect of feed restriction on gut morphometrics, carcass characteristics meat quality and sensory evolution of Ross 308 broiler chickens.

1.5 Hypotheses

The hypothesis of this study were as follows:

i) Feed restriction has no effect on growth performance of Ross 308 broiler chickens.

ii) Feed restriction has no effect on stress and welfare clinical indicators of Ross 308 broiler chickens

iii) Feed restriction has no effect on gut morphometrics, carcass characteristics, meat quality, and sensory evaluation of Ross 308 broiler chickens.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Broiler chickens require optimal raising conditions to maximize their genetic growth potential. However, it is crucial to consider that raising conditions might affect feed utilization, growth performance, and bird well-being. Al-Taleb, (2003) reported that broiler chicken growth and maturity are improved because of genetic progress, nutritional improvements, and regulated environment. Khurshid et al., (2019) noted that when birds are fed *ad libitum*, they grow fast and accumulate body fat , which can result in mortality, incidence of metabolic illnesses such as ascites, sudden death syndrome, and high occurrence of skeletal abnormalities.

Feed restriction was discovered to be an effective management technique for reducing fat accumulation. It is a multifaceted phenomenon that involves genetic, physiological, dietary, metabolic, endocrine, and behavioural interactions. In addition, Al-Taleb, (2003) discovered that feed restriction reduces feed waste, lowering production costs. On the other hand, it was reported that feed restricted birds utilise food more efficiently following the period of restricted feeding because their overall feed intake and feed conversion ratio are lower than those of full-fed birds (Al-Taleb, 2003). This could be because feed restriction induces reduced energy requirements (MacLeod et al.,2019)

According to Saber et al. (2011), early feed restriction programs used to reduce abdominal and carcass fat in broiler chickens rely on the phenomenon called compensatory growth to produce market body weight like control groups. Hassan Abadi and Moghaddam (2006), referred to compensatory growth as a recovery from a growth deficiency resulting from a limited nutrient intake. However, it was found that development in chickens needs energy maintenance, growth and maturation, and food availability. Therefore, the objective of this review is to create attentiveness on the effect of feed restriction on broiler production.

2.2 Effect of feed restriction on growth performance of broiler chicken.

Restricting nutrition temporarily slows down the growth of broiler chicks during their life cycle. Rodrigues (2018) stated that incidence of metabolic disorders is increased. When high energy diets are provided without restrictions on feed intake. Furthermore, it was demonstrated that, from a physiological perspective, feed intake drops as soon as the feeding period ends because the gastrointestinal tract's capacity is reduced.

This leads to inadequate absorption of the supplied feed and, thus, growth retardation (Choct and Rodrigues, 2018).

There is a correlation between growth intensity, feed intake, mortality, carcass yield, meat quality and the efficiency of meat production (Tumova et al., 2019). Feed restriction can lower economic losses by lowering mortality and incidence of metabolic diseases in rapidly expanding populations. Feed restriction has been observed to improve the feed conversion ratio in several species, including broiler chickens. In some cases, the feed conversion ratio was comparable to or better than that of pigs (Le Floc'h et al., 2014), rabbits (Birolo et al., 2016), and broiler chicks (Tumova et al., 2019

Published statistics on growth parameters are inconsistent. According to recent studies, feed restriction in chickens results in growth retardation (Chodova and Tumova, 2018). On the other hand, Tumova et al. (2019) found no evidence of a significant effect of feed restriction on dressing percentage or thigh in relation to carcass composition. In contrast, the restricted birds had higher abdominal fat yield and lower breast yield. Gratta et al. (2019) reported that compared to *ad libitum* fed chickens, early restricted (13 to 23 days of age) chickens had an intermediate carcass weight and breast percentage, while late-restricted (27 to 37 days of age) chicks had a lower carcass weight and breast proportion. This shows that birds that are restricted produce better meat yield compared to those that are not undergoing the process of feed restriction. This could be due to compensatory growth.

Hassanabadi and Moghaddam, (2006), reported that compensatory growth is the body's attempt to make up for a growth shortfall brought on by a restricted diet. To achieve market body weight comparable to control groups, early feed restriction programs used to lower abdomen and carcass fat in broiler chickens rely on a phenomenon known as compensatory growth. Nonetheless, it was discovered that hen development requires food availability, growth and maturation, and energy maintenance (Kooijman,2009).

2.2.1 Effect of feed restriction on feed conversion ratio of broiler chickens.

In broiler chicken production, feed restriction is a popular approach for managing body weight gain and improving feed conversion ratio, which is a measurement of how well an animal turns feed into body mass. Feed restriction impact on FCR may vary depending on the length and degree of the restriction, as well as other factors such as food composition and ambient conditions. (Sahraei, 2012).

Mehmood et al. (2013), reported that broiler chicks with mild to moderate feed limitation have better FCR. This is because limiting feed intake frees up more energy for the birds to use for growth by lowering the amount of energy, they must consume for maintenance tasks like digestion and exercise. Furthermore, feed restriction can assist lower the incidence of metabolic illnesses and enhance the birds' general health, both of which will increase FCR. Nonetheless, a severe or protracted feed limitation may be detrimental to the FCR and overall performance of the bird. Severe restriction can have a detrimental effect on FCR by causing stunted growth, decreased muscle development, and increased susceptibility to illnesses (Mehmood,2013).

Dawood (2024) concluded that optimizing energy usage for growth, mild to moderate feed restriction can raise broiler chickens' feed conversion ratio (FCR). To prevent detrimental impacts on the health and performance of birds, it is crucial to carefully monitor the length and intensity of feed restriction. To meet their energy needs, poultry frequently consume energy, which is linked to higher protein and fat deposition. This is also dependent on the availability of sufficient amounts of other essential components. The most important supplement for animal feeds or diets is protein, with special attention paid to the ratio of energy to protein to reduce calorie intake. This suggests a relationship between a particular protein content and the basic unit of energy in the diet (Dawood, 2024)

2.2.2 Effect of feed restriction on feed intake of broiler chickens

Broiler chicks' feed intake is frequently decreased by feed restriction. Restrictions on feed mean that birds eat less than they would if they had unlimited access to feed. The goal of planned feed intake restriction is to control the birds' body weight and rate of growth (Novel et al. 2009). The amount of feed intake reduction depends on the severity and duration of the restriction. While extreme feed restriction may cause a significant loss in feed intake, mild to moderate restriction may only cause a slight decrease.

Sahrae et al. (2014), suggested that feed restriction can help lower body weight and improve feed conversion ratio (FCR), but it needs to be carefully managed to make sure that the birds have enough feed for growth and health. Avian performance and welfare can be severely impacted by severe or prolonged diet restrictions. Novel et al. (2009) found that early phase 75% *ad libitum* restricted feeding had a greater economic impact than *ad libitum* feeding because it increased feed utilization and achievability. On the other hand, feed restriction may negatively affect breast muscle relative weight (Reece *et al*., 1986) and body weight at marketing age (Pinchasov and Jensen, 1989). Pigeons were given a one-week meal restriction program at the age of six to seven days, Plavnik and Hurwitz (1989) observed that the birds lost a substantial amount of weight by two weeks of age as compared to the control group. Nonetheless, feed efficiency was increased and body weights at market age were comparable.

2.3 Effect of feed restriction on the daily gains of broiler chickens

One major contributing aspect to birds' daily increase is feed restriction. Compared to individuals fed *ad libitum*, it may lead to slower growth rates. This is due to the fact that birds are eating less, which lowers their intake of the minerals and energy needed for quick growth. Novel et al. (2009), found that feed-restricted birds, usually have higher feed efficiency, meaning they convert meals into body mass more effectively, therefore the trade-off is often considered acceptable. Therefore, they can maintain a healthy body weight while consuming less feed overall, even if they grow more slowly (Sahrae et al., 2014).

On the other hand, weighing birds and figuring out daily feed intake make physical feed restriction difficult. Moreover, adequate room for feeders is necessary to reduce competition between restricted birds and uneven flock expansion. According to Bedford and Apajalahti (2022), teachings regarding coccidiostat, micronutrient consumption, and other topics, this technique should be used. The topic of physical feed restriction regimens for broilers has been extensively studied. It is crucial to consider the severity, length, and age of marketing when putting in place a feed restriction program for broilers (Fontana et al.2014). The effect of feed restriction on growth performances, stress, and welfare clinical indicators of Ross 308 broiler chickens.

2.4 Effect of behaviour and welfare of broiler chickens

Several approaches have been investigated to reduce the welfare issues brought on by feed restriction and regulating energy intake (Chandrasiri,2009). Two tactics that can be employed during feed limitation are qualitative feed restriction, which involves lowering the energy content in a certain amount of feed, and quantitative feed restriction, which involves lowering the amount of nutritious feed supplied. In contrast to quantitative feed restriction, Nielsen (2003) contended that the qualitative approach is the most effective approach since it may lead to a higher level of satiety in broilers due to increased gut content. Furthermore, De Jong et al. (2003), stated that quantitative feed restriction can be applied in the field to control chicken growth and enhance feed efficiency. Even with these advantages, feed limitation can lead to hunger and strange behaviours in animals as well as jeopardize their welfare (Sahraei, 2012).

Feed restriction is an effective way to control chicken development and enhance feed efficiency, it also causes aberrant behaviours and hunger in the birds. There is a risk to welfare and health under these circumstances. Eventually, when birds are confined to meals, they begin to exhibit odd behaviours such as excessive drinking, pacing, pecking at fixtures, and increasing hostility. Zukiwsky et al. (2021), suggested that behaviour, physiological indicators, chronic hunger and accompanying feed frustration may be the reason for this. Conversely, the previously withdrawn birds had poor welfare, and the unrestrained birds caused fat and rapid growth-related health problems. Decuypere et al. (2010) reported that feed limitation is necessary for broiler breeder management to maximize reproduction, prevent metabolic disorders, and minimize mortality. However, Reiter and Bessei (2009) reported that the effects are different for male and female chickens. Males grow larger and attain a higher body weight than females (De Jong et al.2013). These differences may be related to aggressive tendencies and locomotor activity.

2.5 Effect of feed restriction on meat quality of broiler chickens

It was discovered that broiler chickens that are fed intensively have higher feed costs and increased fat deposition (Fouad and El-Senousey, 2014). As a result, chickens fed *ad libitum* have shown low-quality meat. One solution to these issues is feed restriction. Omosebi et al. (2014) found that excessive fat deposition in unrestrained birds results in decreased carcass yield and meat rejection by consumers. Feed limitation is a practical way to save feed costs, lessen the amount of fat that accumulates on the carcass, and enhance the quality of the meat.

Depending on how it is implemented including the amount, period, and age of the rabbits feed limitation had an impact on the quality of the meat. Chodová and Tumová, (2013) discovered that changes in growth rate had an impact on the meat quality of broiler andrabbits. Extended periods of restricted feed result in decreased growth and slaughter weight, causing low meat quality and dressing percentage. However, the quality of meat is unaffected by a brief feed limitation. Tumová et.al, (2013) suggested that physical characteristics such as pH level, meat colour, and muscle fibre in broiler rabbits can all be used to characterize the quality of meat. Melesse et al., (2011) stated that meat quality of poultry is influenced by heredity. It is a complex phenomenon because it involves genetic, physiological, nutritional, metabolic, endocrinal, and behavioural relationships.

2.5.1 Effect of feed restriction on sensory evaluation of broiler chicken

Depending on the length and degree of the limitation, feed restriction can have varying effects on how broiler chicken is sensory evaluated. Meat from broiler chickens that have been fed restrictions may have different sensory qualities. Broiler chicken meat flavour can also be impacted by feed restriction. As evidenced by Tumova et al. (2021) recent researcher, the flavour of the meat may change from that of meat from birds that are fed freely to something that may be more intense or distinct in character. It has been found by Chen et al. (2022) that feed restriction can also have an impact on the juiciness of broiler chicken meat. But, in contrast to birds that are fed freely, the meat from birds that had their nutrition restricted may be less juicy.

Keady et al. (2017) stated that feed-limited hens have redder flesh, which may be related to a tendency for restricted females to have more red muscle Fibers and less development. These results suggest that feed restriction had no effect on meat physical measures. Feed restriction has the potential to affect broiler chicken meat's overall sensory acceptability. When compared to meat from birds that are fed freely, consumers may see meat from feed-restricted birds in a different way.

The texture of the meat from broiler chickens may alter because of feed restriction. Compared to birds fed *ad libitum*, the meat from birds on a restricted diet may be more stringy or rough. Considerable emphasis has been paid to the application of FR to reduce fat deposition. The 30% energy-restricted Arbor Acre broiler group's subcutaneous fat thickness and percentage of abdominal fat were found to be 35% and 75.57%, respectively, compared to the ad libitum group (Chen et al., 2022).

The leg muscle ratio and breast muscle ratio did not significantly differ between the FR broiler chickens and broiler chickens fed *ad libitum*. Due to increased physical activity in search of feed, feed restriction tended to enhance the percentage of muscle and decrease the percentage of belly fat in bearded chickens. These findings were in line with research by Chen et al. (2022), Englmaierová et al, (2014) and Mir et al. (2017), who showed that FR of Bearded chickens during the finisher phase increased the carcass performance to a considerable level.

Restrictive feeding has also been demonstrated in other research to enhance the economic performance of hens at various growth stages (Zhan et.al,2007). It is crucial to remember that these outcomes can change depending on the particulars of the feed limitation, including its length, severity, and the birds' ages. The sensory characteristics of broiler chicken meat can also be influenced by other elements like cooking methods and processing processes (Mir et.al,2017).

2.3 Conclusion

Feed restriction in broiler breeders is crucial for optimal reproduction and preventing metabolic disorders and mortality. But feed restriction this strategiesy may results in poor welfare. Several studies showed that it reduces production costs, improves meat quality, and reduce disease incidences. Information on effect of feed restriction on growth, welfare, gut morphology, sensory evaluation and meat colour of broiler chicken is inconclusive. Therefore, it is important to determine the effect of feed restriction on performance, and clinical welfare indicators of Ross 308 broiler chickens.

CHAPTER THREE

The Effect of Feed Restriction on Growth Performances of Ross 308 Broiler Chickens.

3.1 Introduction

Broiler chickens are characterised by a fast growth rate and reach their maturity at day 42. Unfortunately, this faster growth rate is linked to metabolic stress, more body fat being deposited, a higher death rate, more metabolic illnesses, and skeletal disorders (Scott, 2002), the latter of which are more common in broilers raised on an *ad libitum* basis (Cuddington, 2004; Nielsen et al., 2003). Up to 70% of the total cost of producing chickens is incurred by feeding them. Improved growth performance and lower feed costs can be achieved through a variety of strategies, such as using substitute feed restriction.

Feed restriction was discovered to be an effective management technique for reducing fat accumulation (Nielsen et al., 2003). It is a multifaceted phenomenon that involves genetic, physiological, dietary, metabolic, endocrine, and behavioural interactions. In addition, Al-Taleb, (2003) discovered that feed restriction reduces feed waste, lowering production costs. On the other hand, it was reported that restricted birds utilize food more efficiently following the period of restricted feeding because their overall feed intake and feed conversion ratio are lower than those of full-fed birds (Al-Taleb, 2003).

The impact of feed restriction on growth performance has been inconclusive. Therefore, this study's main objective was to investigate how feed restriction affected the growth performances of Ross 308 broiler chickens.

3.2 Materials and Methods

3.2.1 Study site

This study was conducted at the University of Limpopo Experimental Farm, Limpopo Province, South Africa. Summer minimum temperature is high, exceeding 13◦C Winter minimum temperature can be cold (0.6◦C) with a mean summer temperature of 27◦C and a mean winter temperature of 18 ◦C (SA Weather Service,2015).

3.2.2 Acquisition of materials and chicken procedures

A total of 270-day-old Ross 308 broiler chicks were purchased from Angela Feeds in Polokwane and commercial feeds to conduct this investigation. Materials such as home cleaners, 250-watt infrared lights, feeders, and drinkers were purchased at Angela Feeds in Polokwane, South Africa.

3.2.3 Preparation of the Experimental House

The experimental house was cleaned thoroughly with water and disinfectant After cleaning, the house was left open for a week to interrupt the life cycle of any pathogens that the disinfectant did not manage to eradicate. The experimental house was divided into fifteen-floor pens, each measuring around 2.5 $m^{2.}$ Fresh sawdust was used and spread to a thickness of 7cm depth. All materials including drinkers and feeders, were thoroughly cleaned, and sanitized to ensure hygiene.

3.2.4 Experimental diets, design, and procedure

A total of 270-day-old Ross broiler chicks were assigned to three different treatments in a complete randomized design (CRD) replicated six times with forty-two chicks per pen. A total number of six pen houses were used each pen measuring 6m^2. The chicks were provided with three dietary treatments depending on the length of feed restriction as shown in **Table 3.1** and water was offered *ad libitum* (**Figure 3.1**). The floor pen was covered with sawdust of 6cm thickness. The infrared light was accessible daily.

Table 3.1: Dietary description

Diets code	Diets description
T_1:C	Chickens fed commercial feeds *ad libitum*
T_2:FRD1	Chickens restricted to feed for a period of one day
T_3:FRD2	Chicken restricted to feed for a period of two days

Figure 3.1: water and light supplied *ad libitum*

3.2.5 Growth measurement

The average daily gains were determined using (McDonald et al., 2010) final weight minus initial weight divided by number of experimental days.

The average daily feed intake was calculated by subtracting the weight of leftovers from the amount supplied per day and dividing the total by the number of chickens per pen. An electronic scale (CDN SD2206 22 lb. Compact Digital Portion Control Scale) was used to measure both daily feeds and leftovers.

$$\text{ADFI} = \frac{\text{Feed Offered(g)} - \text{Feed Refusal(g)}}{\text{Number of chicks (per pen)}}$$

The feed conversion ratio (FCR) was calculated using the daily average feed intake and average gain. To get the FCR value, the average feed intake was divided by the average gain. (McDonald et al., 2010).

$$\text{FCR} = \frac{\text{Average Feed Intake}}{\text{Average Daily Gain}}$$

3.3 Data analysis

The collected data on, growth performance of Ross 308 broiler chicken were analysed using SPSS General Linear Model (GML) procedure of statistical analysis of variance (ANOVA) version 9.3.1 software program. The least significant difference (LSD) test was used to separate means. Means were considered significant at 5% level of significance. The statistical model that is given below was used to examine the data that was obtained.

$Y_{ij}=\mu+T_{(I)}+e_{ij}$

Where, Y_{ij}= Growth performance, clinical welfare indicators, and

μ= Total mean

$T_{(i)}$ = Effect of feed restriction

e_{ij}= Error

3.4 Results

3.4.1 Growth performance

The effects of feed restriction on feed intake, daily weight gain and feed conversion ratio of Ross 308 broiler chicken are presented in **Table 3.2** Feed restriction had an effect (P<0.05) on initial weight (weight at 21 days). Broiler chickens that were fed T_1:C demonstrated the lowest initial mean weight(P<0.05) compared to broiler chickens that were subjected to T_2:FRD1 and T_3:FRD2. However, the initial weights for chicken in T_2:FRD1 and T_3:FRD2 were similar (P>0.05).

Feed restriction had an effect (P<0.05) on final weight. Broiler chickens that were fed T_1:C demonstrated the highest mean weight (P> 0.05) but was statistically similar to birds in T_2:FRD1 feed restriction. Broiler chickens that were subjected to T_3:FRD2 feed restriction demonstrated the lowest mean weight (P<0.05).

Feed restriction had an effect (P<0.05) on average daily feed intake. Broiler chickens that were fed T_1:C indicated normal feed intake that correlates with higher growth rates and good FCR. However, broiler chickens that were subjected to T_2:FRD1 showed reduced feed intake that correlates with poor weight gain, and slower growth. T_3:FRD2 indicated extremely low feed intake that correlates with inefficient FCR.

Feed restriction had an effect (P<0.05) on average body weight gain. Broiler chickens that were fed T_1:C demonstrated the highest mean ADG which indicates excellent growth performance, followed by chickens on T_2:FRD1. Broilers in T_3:FRD2 demonstrated the lowest ADG which indicates poor growth performance.

Feed restriction had an effect ($P<0.05$) on feed conversion ratio (FCR). Broiler chickens that were fed T_1:C demonstrated the lowest mean ratio compared T_2:FRD2. However, broiler chicken subjected T_3:FRD2 demonstrated the highest mean ratio.

Table 3.2: The feed restriction on feed intake, daily gain weight and feed conversion ratio of Ross 308 broiler chicken.

		Treatment		
Variables	**#T₁:C**	**#T₂:FRD1**	**#T₃:FRD2**	**P-value**
Initial weight (21 days/g/chicks)	$637.97^{a}\pm81.3$	$752.2^{b}\pm90.3$	$737.1^{b}\pm104.6$	0.001
Final weight (g/chicks)	$2128.8^{b}\pm170.1$	$1999.3^{b}\pm130.1$	$1322.3^{a}\pm238.6$	0.001
ADFI (g/chicks)	$125.2^{c}\pm0.5$	$116.4^{b}\pm0.0$	$76.0^{a}\pm0.0$	0.001
ABGW (g/chicks)	$71.0^{c}\pm9.3$	$59.4^{b}\pm5.3$	$27.6^{a}\pm12.4$	0.001
FCR	$1.5^{a}\pm0.2$	$1.8^{a}\pm0.2$	$2.0^{b}\pm1.7$	0.001

a, b, c: Means in the same row not sharing common superscript are significantly different($P<0.05$).

#: Treatment code described in chapter 3, Table 3.1 (T1:C =control; T2:FRD1=skip a day; T3:FRD2=skip two days.)

3.5 Discussion

The current investigation found that feed restriction influenced initial and final weight. Broiler chickens that were subjected to T_2:FRD1 and T_3:FRD2 demonstrated higher initial weight. However, at the end of the experiment, broiler chickens fed T_1:C had the highest final mean body weight, while broiler chicken subjected to T_2:FRD1 and T_3:FRD2 had poor final body weight. This could be attributed to abundant feed, which meets their full requirement for optimal growth and energy.

The results of broiler chicken subjected to T_2:FRD1 indicate that there was a complete performance while those subjected to T_3:FRD2 did not compensate for final wight. The final weight of broiler chickens decreased with increasing feed restriction. Given that dietary intake determines eventual weight gain, this was to be expected. As a result, broiler chickens that received less feed had lower final weights

Zukiwsky et al. (2021) reported similar results in restricted broilers from 7 to 35 days with reduced final weight. This finding suggests that the intensity of feed restriction is just as significant as the duration of the restriction for broiler growth performance. Furthermore, Arrazola et al. (2020) propose that feed-restricted birds may have used nutrients more effectively to promote weight after being returned to feed, potentially leading to compensating for growth. Samara et al. (2024) found comparable results in restricted birds with high initial weights and poor final weight.

In this current study, feed restriction influenced average daily feed intake. Broiler chicks fed T_1:C showed regular feed intake, which correlates with greater growth rates and improved FCR. Broilers subjected to T_2FR1 showed reduced feed intake compared to the T_1:C group. This reduced feed intake was associated with a lower body weight gain, an increased FCR, and slower overall growth. The increased FCR in this group shows that the feed restriction may have disrupted their nutrient intake, making them less efficient in converting feed into body mass.

Ramirez et al., (2023) discovered similar results on T_2:FRD1, with reduced feed intake, lower weight gain, and increased feed conversion ratios (FCR) due to altered nutrient intake patterns. On the contrary, Bartov et al. (2021) reported that feed restriction did not always result in inferior growth or increased FCR. Instead, birds on the T_2:FRD1 diet adjusted their intake following restriction days, demonstrating efficient food use and competitive ultimate body weights again. This shows that, under certain conditions, feed restriction may have no effect on growth efficiency. In contrast, Zukiwsky et al. (2021) discovered that feed restriction had no significant influence on the FCR of black and white broiler chickens fed T_1:C of maternal age and sex. Feed restriction often results in an apparent decrease in maintenance requirement due to a depressed metabolic rate, suggesting that birds become more and more efficient in utilizing reduced feed. Feed restriction changed broiler feeding behaviour quickly with an increase in feed intake, in anticipation of the lack of feed availability.

In this present study, feed restriction influenced average body weight gain. Broiler chickens that were assigned to T_1:C demonstrated the highest body weight gain compared to those that were subjected to T_2:FR1 and T_3:FR2. These results shows that body weight decreases with an increased level of feed restriction. Benyi et.al (2010), Jalal et.al (2012) and Njoku et.al (2012) reported similar results in body weight gain decreased with an increase in the level of feed restriction with a significant decline of 10% feed restriction and above.

The highest feed consumption was observed in the control group and the lowest in the group, where 20% of feed restriction was observed. Contrary to the study Rahimi et.al., (2015) reported decreased body weight in broiler chickens fed T1:C compared to those subjected to T_2:FRD1 and T_3:FRD2. On the other hand, Zhao et.al (2011) found similar results in slow-growing purpose birds, that experienced reduced body weight gain in restricted compared to those that were T_1: C. The contrasting results may be due to the intensity or level of feed restriction. This could be explained by the fact that intentional feed restriction may result in compensatory growth, allowing birds to gain body weight when birds refeed due to improved feed utilization. When birds are subjected to early feed restriction, they exhibit slow growth followed by a period of rapid growth and weight gain as they approach market weight to compensate for the delayed growth during early restriction period (Gous and Cherry, 2004).

This translates into reduced maintenance requirements and improved feed utilization potential by birds due to smaller body weights (Lippens et al., 2000). The results in this study by, however, show no indication of improved utilization by feed restricted birds, despite their significantly lower body weights compared to the T_1: C. The reason for this discrepancy is due to the fact that feed-restricted birds consumed more feed in their attempt to compensate for the time they would have been deprived of feed, thus, birds were less efficient in feed utilization and the process did exhibit compensatory growth.

In this study, it was noted that there was a difference in FCR among the treatments. Broiler chickens assigned T_1:C demonstrated the lowest FCR than T_2:FRD1 and T_3:FRD2. This might be because the broiler chicken assigned to T_1:C was converting feed into body weight more efficiently than broiler chicken subjected to, skip and daily feed restriction programs are considered the most and least severe, respectively. This is in agreement with de Beer and Coon (2007), who stated that birds fed T_2:FRD1are less efficient than T_1:C fed pullets due to the constant need for deposition and mobilization of the nutrients

In the current study, broiler chickens subjected to T_2:FRD1 and T_3:FRD2 demonstrated a higher FRC ratio suggesting that broiler chickens' nutrients more effectively promote weight after being returned to feed, potentially leading to compensating growth (Saber et al., 2011). Jang et al. (2009) reported similar results. On the contrary, the study of Saber et al. (2011) reported no significant difference in male broiler chickens (cobb-500).

3.6 Conclusion and Recommendations

It is concluded that feed restriction affected growth performance. Broiler chickens that were subjected to T_3:FR2 had the lowest performance in feed intake upon refeeding and did not contribute any significant improvements in growth performance, implying that the physiological demands of broiler chicken growth necessitate constant nutrient availability. However, feed restrictions such as T_2:FRD1 appeared to be beneficial and could be practiced and it can therefore be recommended to farmers. This study gives vital insights; however, there is a significant lack of research on the impact of feed restriction on the growth performance of Ross 308 broiler chickens.

CHAPTER FOUR

Effect of Feed Restriction on stress and Clinical Welfare Indicators of Ross 308 Broiler chickens

4.1 Introduction

Broiler chickens, particularly the Ross 308 strain, are commonly used in the poultry business due to their quick growth and great feed efficiency (Alhotan, 2021). However, the rigorous selection for development frequently causes concerns about animal welfare, such as metabolic abnormalities, limb health problems, and overall well-being. Feed limitation is routinely used in broiler management to address these difficulties, however, the influence on clinical welfare indices is still inconclusive.

Feed restriction strategies, whether quantitative or qualitative, aim to control growth rates, reduce the incidence of metabolic diseases (such as ascites and sudden death syndrome), and improve overall health outcomes (Abushihab, 2024). However, the practice also raises critical questions about its potential effects on welfare indicators such as stress response, feather condition, leg health, and behavior (Biasato et al.,2022). Understanding the balance between growth performance and welfare implications is essential for optimizing management practices and ensuring ethical standards in poultry production.

Therefore, this study looks at how feed restriction affects the clinical welfare of Ross 308 broilers by evaluating variables like behavioural reactions, health, and physiological stress markers. Furthermore, the study aims to investigate how feed limitation impacts the overall welfare of Ross 308 broiler chickens.

4.2 Materials and Methods

4.2.1 Study site

The study site is as described in Chapter 3, Section 3.2.1.

4.2.2 Acquisition of materials

Acquisition of materials e is as described in Chapter 3, Section 3. 2.2

4.2.3 Preparation of the Experimental House

The preparation of the experimental house is as described in Chapter 3, Section 3.2.3.

4.2.4 Experimental diets, design, and procedure

Experimental diets, design, and procedures are as described in Chapter 3, Section 3.2.4

4.2.3 Clinical welfare and indicators measurement

The chickens in the study were evaluated at 6 weeks of age for the presence of feather condition, pecking, footpad, skin condition, gait score, and body condition score as shown in **Figure 4.1**. Four trained observers were evaluating the birds. Prior to the study, the observers were trained on the techniques that were utilized for the current study, including how to discriminate between scores using real birds and images while discussing various scenarios as shown in **Table 4.1**. Furthermore, the birds in each pen were distributed evenly among the observers to minimise any potential observer effect.

In practice, the light was turned on one hour earlier than usual, at 7:00 a.m., and the birds were fed immediately. At 8:00 a.m., one of the two unit's lights was turned off, and the two daily caretakers captured the birds in four pens and placed them in crates. The light intensity was increased to twenty-eight lux, and four observers began assessing the wellness of chickens in separate cages. When an observer was done with one-quarter of the birds in a pen, they were moved on to the next four pens. The birds in the four pens were slaughtered when their welfare assessments were completed. The method continued until the welfare of all birds in both units had been determined.

Figure 4.1a: The pictures above shows the present of feather condition, pecking, footpad, skin condition, gait score and body condition score.

Figure 4.1b: The pictures above shows the present of feather condition, pecking, footpad, skin condition, gait score and body condition score.

Table 4.1: Measurements for welfare indicators

Scores	Feather Condition Score	Body Condition Score (BCS)	Gait Score	Footpad and Skin Condition	Pecking Behaviour
5	Fully feathered, smooth, and clean, no signs of wear or loss.	Overweight: Breast muscle feels thick, keel bone barely detectable.	Unable to walk or reluctant to move	Clean, intact feet and skin with no signs of irritation.	Balanced pecking order, no signs of aggression.
4	Slight feather wear, minimal loss, no bare patches.	Good: Keel bone is covered but slightly detectable.	Severe difficulty walking, significant limping.	Minor redness or slight wear on feet or skin.	Mild pecking or chasing, but no injuries.
3	Noticeable feather wear or loss, small bare patches.	Fair: Keel bone is more prominent, but with some covering of muscle.	Noticeable difficulty walking, but the bird can still move.	Moderate redness, calluses, or minor footpad lesions.	Moderate pecking, some birds show minor feather loss or scratches
2	Significant feather loss, large bare	Thin: Keel bone is very prominent	Slight abnormality in walking,	Significant redness, lesions, or swelling on	Frequent aggressive pecking, visible

	patches, or damaged feathers.	with little muscle covering.	mild limping	feet and skin.	feather damage or injuries
1	Severe feather loss, large bare areas, and broken or damaged feathers.	Emaciated: Keel bone is sharp and prominent with no muscle covering.	No issues, normal movement.	Severe footpad dermatitis, open sores, or deep lesions.	Severe pecking, visible injuries, cannibalism, or isolation of birds.

4.2.4 Data analysis

The collected data on effect of feed restriction on stress and Clinical Welfare Indicators of Ross 308 Broiler chickens was analysed using the SPSS General Linear Model (GML) procedure of statistical analysis of variance (ANOVA) version 9.3.1 software program. Least significance Difference (LSD) test was used to separate means. Means were considered significant at 5% level of significance. The statistical model that is given

below was used to examine the data that was obtained.

$Y_{ij}=\mu+T_{(i)+eij}$

Where, Yij= stress and Clinical Welfare

μ= Total mean

$T_{(i)}$ = Effect of feed restriction

e_{ij}= Error

4.3 Results

4.3.1. WELFARE AND CLINICAL INDICATORS

The effect of feed restriction on feather condition, pecking, gait score, body condition, footpad, and skin condition of Ross 308 broiler chickens are presented in **Table 4.3.1**. Feed restriction had an effect ($P<0.05$) on feather conditions of broiler chickens. Broiler chickens that were fed T_1:C had the highest mean score of 4.5 which indicates slight feather wear or minimal loss. However, broiler chickens that were on T_2:FRD1 and T_3:FRD2 demonstrated similar mean scores ($P>0.05$) of 3.6 and 3.5 which indicated noticeable feather loss respectively.

Feed restriction had an effect ($P<0.05$) on pecking. Broiler chickens that were fed T_1:C demonstrated a mean score of 4.9 which indicates mild pecking or chasing, but no injuries. Broiler chicken that was subjected to T_2:FRD1 had a mean score of 2.5 which indicates frequent aggressive pecking, visible feather damage and injuries. Furthermore, broiler chickens that were subjected to T_3:FRD2 had a mean score of 1.3 demonstrating severe pecking visible injuries, cannibalism, and isolation of birds.

Feed restriction had no effect ($P>0.05$) on the footpad and skin condition of broilers. Broiler chickens that were fed T_1:C had a mean score of 5.0 which indicates clean, intact feet and skin with no signs of irritation. Broiler chickens that were subjected to T_2:FRD1 and T_3:FRD2 had a similar ($P=0.05$) mean score of 4.7 demonstrating minor redness or slight wear on feet or skin.

Feed restriction had no effect ($P>0.05$) on gait score. Broiler chickens that were fed T_1:C demonstrated a mean score of 0.0 indicating no issues and normal movement. However, broiler chickens that were subjected to T_2:FRD1 and T_3:FRD2 demonstrated means 0.10 and 0.3 which indicate no issues, and normal movement respectively.

Feed restriction had an effect ($P<0.05$) on body condition score. Broiler chickens that were fed T_1:C had a mean score of 4.0 which indicates good body condition score, kneel bone was covered but slightly detectable and broiler chickens that were subjected to T_2:FRD1 demonstrated a 3.5 fair body condition score, kneel bone was more prominent, with some covering of muscle. However, T_3:FRD2 had a mean score of 2.4 thin body condition score, kneel bone is very prominent with little muscle covering respectively.

Table 4.2. Effect of feed restriction on feather condition, pecking, gait score, body condition, footpad& skin condition of Ross 308 broiler chickens

		Treatments		
Variable	**T_1:C**	**T_2:FRD1**	**T_3:FRD2**	**P-value**
Feather condition	4.5^{b}±0.5	3.6^{a}±0.5	3.5^{a}±0.5	0.001
Pecking	4.9^{c}±0.5	2.5^{b}±0.6	1.3^{a}±0.5	0.001
Footpad & skin co	5.0^{b}±0.2	4.7^{a}±0.5	4.7^{a}±0.5	0.010
Gait score	0.0^{a}±0.0	0.1^{a}±0.4	0.3^{a}±0.4	0.010
Body condition score	4.0^{c}±0.0	3.5^{b}±0.5	2.4^{a}±0.5	0.001

$^{a, b, c}$: Means in the same row not sharing common superscript are significantly different(P<0.05).

#: Treatment code described in chapter 4, Table 4.2 (T_1:C =control; T_2:FRD1=skip a day; T_3:FRD2=skip two days.)

4.4 Discussion

In the present investigation, feed restriction altered feather condition ,leading to a reduction in feather quality and potentially affecting overall welfare indicators in Ross 308 broiler chickens. Broiler chickens fed T_1:C showed mild feather with low loss. This could be due to the availability of nutrients required for feather growth and maintenance. Broiler chickens subjected to T_2:FRD1 and T_3:FRD2 had showed substantial feather loss, which could be attributed to numerous reasons, including nutritional inadequacies, particularly in protein, vitamins, and minerals essential for feather development.

Trocino et al. (2020) hypothesized that feed restriction is associated with higher stress and aggression in hens. This can lead to increased pecking behaviour, in which chickens peck at each other's feathers, causing feather damage or loss (Girard et al., 2017). Increased feather pecking is a known problem in feed-restricted birds, since they may become frustrated due to hunger or boredom, resulting in destructive behaviours. Furthermore, De Jong and Guémené (2011) showed similar feather-pecking results in laying hens after protracted diet limitation.

The current study examined broiler pecking behaviour. Broiler chickens subjected to T_2:FRD1 and T_3:FRD2 indicated frequent aggressive pecking, visible feather damage and injuries. Van Krimpen et al., (2005) suggest that dietary deficits which result in a restricted amount of nutrients such as protein, amino acids, or minerals, may promote feather pecking and cannibalism. On the other hand, Mohebodini et al. (2009) found that the period of feed restriction may affect pecking behaviour.

As a result, feather coverage reduction and the development of skin lesions in vent and tail areas are indirect markers of feather pecking and severe pecking behaviour caused by feed restriction. However, findings from Zhan et al. (2007) contradicts that when the number of fasting days is progressively increased, birds do have more difficulty learning the feeding pattern. Furthermore, T_1:C chickens indicated mild pecking or chasing, but no injuries (Jang,2009). This pecking behavior could be due to higher feed competition and associated meal-time stress experienced by these birds. Zhan et al. (2007) demonstrated similar results that feed intake can influence pecking behaviour, with increased feather pecking in birds.

Feed restriction has an impact on body condition. Broiler chickens fed T_1:C had higher scores indicating good body condition score, kneel bone is covered but slightly detectable. Broiler chickens subjected T_2:FRD1 and T_3:FRD2 diet demonstrated fair body condition score, kneel bone is more prominent but with some muscle covering, and thin body condition score.

This is most likely due to feed restriction, which resulted in lower feed intake, and the birds did not obtain enough nutrients to sustain their rapid growth (Ferket and Gernat, 2006). In contrast to the current findings, Zhan et al. (2007) shown that two days of feed restriction can reduce body weight. This could be the result of birds depleting their energy reserves (including fat and muscle) to sustain essential metabolic activities. Furthermore, in the current study body weight have appeared to be more resilient to broiler chicken that were subjected to T_2:FRD1 and T_3:FRD2

4.5 Conclusion and recommendation

This chapter highlights the complex interplay between feed restriction and clinical welfare indicators in Ross 308 broiler chickens. Feed restricted broiler chickens often display increased stress responses, abnormal behaviours, and persistent hunger, indicating potential compromises to the birds' quality of life. Behavioural manifestations, including aggression and stereotypic behaviours, further emphasize the importance of addressing welfare issues alongside physical health.

Therefore, striking a balance between growth control and animal welfare is crucial. Implementing feed restriction strategies, coupled with environmental enrichment and vigilant monitoring, can help mitigate negative impacts. Future research should focus on refining feed management protocols that optimize both performance and welfare, ensuring that ethical standards are upheld in modern broiler production systems.

CHAPTER FIVE

Effect of feed restriction on gut morphology, sensory evaluation, carcass characteristics, and meat quality of Ross 308 broiler chicken

5.1 Introduction

Feed restriction is a widely used management practice in broiler production, aimed at controlling growth rates and improving feed efficiency. Ross 308 broilers are known for producing a lot of meat and growing quickly. Feed limitation is commonly utilized to maximize meat quality, improve health outcomes, and minimize metabolic problems (Chodova et al,2021). However, Choi et al., (2023) stated that the implications of feed restriction extend beyond growth control, affecting key parameters such as gut morphology, sensory characteristics, and overall meat quality.

Gut morphology plays a critical role in nutrient absorption and overall bird health. Alterations in feeding regimes can influence the development and integrity of the gastrointestinal tract, impacting its functionality and potentially affecting bird performance (Salem,2023). Structural changes in the gut, such as variations in villus height and crypt depth, can serve as important indicators of digestive efficiency and health under restricted feeding conditions.

Additionally, feed restriction has significant implications for meat quality and sensory attributes. Factors such as tenderness, juiciness, and flavor can be influenced by dietary management, impacting consumer acceptance and market value (Hoppu et.al,2021). Understanding the relationship between feeding strategies and these parameters is essential for producers aiming to balance production efficiency with product quality.

This chapter explores the effects of feed restriction on gut morphology, sensory evaluation, and meat quality in Ross 308 broiler chickens, aiming to provide insights into optimizing feeding practices for improved health outcomes and meat characteristics.

5.2 Materials and Methods

5.2.1 Study site

The study site is as described in Chapter 5, Section 5.2.1.

5.2.2 Acquisition of materials

Acquisition of materials is as described in Chapter 5, section 5.2.2

5.2.3 Preparation of the Experimental House

The preparation of the experimental house is as described in Chapter 5, section 5.2.3

5.2.4 Experimental diets, design, and procedure

Experimental diets, design, and procedures described in Chapter 5, Section 5.2.4

5.2.5 Gut morphometrics

Weight and length measurements were taken for the entire gut segment. The weight and length of the small and large intestines were measured separately with an electronic scale (CDN SD2206 22 lb. Compact Digital Portion Control Scale) and a measuring tape. The proventriculus, gizzard, and liver were cleaned and then weighed on an electronic scale.

5.2.6 Measurement of carcass characteristics

At day 35, a total of 30 chickens per treatment were randomly selected for determination of carcass characteristics. The live weights were measured for individual chickens using a weighing scale (CDN SD2206 22 lb. Compact Digital Portion Control Scale). The chickens were then slaughtered by cervical dislocation and feathers were manually removed with hands as shown **figure 5.6.1** below. The individual carcass weights were measured using an electronic weighing scale (CDN SD2206 22 lb. Compact Digital Portion Control Scale). The removal of carcass components such as thighs, wings, breasts, and drumsticks followed feather plucking was done using a sharp knife. Individual carcass pierces were measured per bird and expressed as a percentage. The dressing percentage was calculated as follow:

$$\text{Dressing Percentage (\%)} = \frac{\text{Live weight}}{\text{Carcass weight}} \times 100$$

Figure 5.6.1: Carcass with removed feather

5.2.7 Meat quality measurements

Meat colour was determined using Minolta (CR-100) Chroma Meter. Three measurements were taken from the breast and the colours were recorded as L* to indicate lightness, a* for redness, and b* for the yellowness of the meat (Norouzi et al., 2014; Sharbati et al., 2015).

The pH on (breast) were measured using a digital pH meter (Crison, Basic 20 pH meter). The pH-measuring electrode was inserted into the breast , and the readings were taken at approximately 1 minute after the insertion of the electrode (Wattanachant et al., 2005). The pH was taken approximately an hour,12 and 48 hours after slaughtering.

5.2.8 Shear force

Shear force assessment was done according to Warner-Bratzler Shear Force determination procedures (Dawson et al., 1991). Frozen samples of chicken breast meat were thawed for 24h at 2°C. The samples were removed, tagged and used for cooked Warner Bratzler Shear Force (WBSF) measurements. Cooked meat was prepared by boiling breast cuts in a cylindrical pot using an electric stove. An electric A stove was set on for 25 min prior to preparation. The cuts were boiled to an internal temperature of 35°C, then turned and finished at 70°C. Cooked cuts were cooled down to room temperature (18°C) for at least 2 hours before WBSF measurements. Three cylindrical samples (12.5 mm core diameter) of each cut were cored parallel to the grain of the meat and sheared perpendicular to the fibre direction using a Warner-Bratzler shear device mounted on a Universal Instron Apparatus (cross head speed =

200 mm / min, one shear in the centre of each core). The reported value in kg represents the average of three peak force measurements of each sample.

5.2.9 Sensory evaluation

Broiler chicken breast meat samples were collected immediately following slaughter to ensure the preservation of meat quality, frozen at -40◦ for 5 days, then thawed for seven hours before cooking. The breast meat was chopped and cooked for approximately 60 minutes, with the samples rotating at regular intervals. The samples were then chopped into 5 cm cubes and immediately served to trained sensory panelists. Sensory evaluation was collected using the procedures described by Pavlova et al. (2013). Because it is easier to manage, only one breast was evaluated at a time. A group of ten semi-trained assessors evaluated the meat's aroma, tenderness, juiciness, and flavour. Before proceeding to the next treatment, each panellist was given a glass of lemon juice to wash away the taste of the previous one and avoid flavour confusion

Table 5.1: Evaluation scores used by the sensory panel.

Score	Tenderness	Juiciness	Flavour	Overall
1	Too tough	Much too dry	Very bad flavour	Strongly dislike
2	Tough	Dry	Poor flavour	Dislike
3	Neither tough nor tender	Neither dry nor juicy	Neither bad nor good flavour	Neither dislike nor like
4	Tender	Juicy	Good flavour	Like
5	Too tender	Too juicy	Very good flavour	Strongly like

Source: Wattanachant et al. (2004)

5.3 Data analysis

The collected data on gut morphology, sensory evaluation, carcass characteristics, and meat quality of Ross 308 broiler chickens was analysed using SPSS General Linear Model (GML) procedure of statistical analysis of variance (ANOVA) version 9.3.1 software program. Least significance Difference (LSD) test was used to separate means. Means were considered significant at 5% level of significance. The statistical model that is given below was used to examine the data that was obtained.

$Y_{ij}=\mu+T_{(i)+eij}$

Where, Y_{ij}= gut morphology, sensory evaluation, carcass characteristics, and meat quality

μ= Total mean

$T_{(i)}$ = Effect of feed restriction

e_{ij}= Error

5.4 Results

5.4.1 Gut morphometrics

The effect of feed restriction on gizzard, liver, proventriculus, small intestine and large intestine of Ross 308 broiler chickens are presented in **Table 5.2**

Feed restriction had an effect ($P<0.05$) on Gizzard weight. Broiler chickens fed T_1:C demonstrated the highest mean weight ($P<0.05$) compared to T_2:FRD1 and T_3:FRD2. However, Broiler chickens that were subjected to T_2:FRD1 and T_3:FRD2 demonstrated similar mean weights ($P=0.05$), respectively.

Feed restriction had an effect ($P<0.05$) on liver and proventriculus weight. Broiler chickens fed T_1:C had the highest mean weight ($P<0.05$). Broiler chickens subjected to T_3:FRD2 had the lowest mean weight ($P<0.05$) compared to broiler chickens subjected to T_2:FRD1.

Feed restriction had an effect ($P<0.05$) on small intestine and large intestine weight. Broiler chickens fed T1: C demonstrated the highest mean weight ($P<0.05$). Broiler chicken subjected to T_2:FRD1 and T_3:FRD2 had the lowest mean weight ($P<0.05$).

Feed restriction had an effect ($P<0.05$) on small intestine and large intestine length. Broiler chickens that were fed T_3:FRD2 had the lowest mean length ($P<0.05$). However, T_1:C and T_2:FRD2 demonstrated similar lengths ($P=0.05$)..

Table 5.2. Effect of feed restriction on gizzard, liver, proventriculus, small intestine and large intestine of Ross 308 broiler chickens.

	Treatment			
Variables	**T1:C**	**T2:FRD1**	**T3:FRD2**	**P-value**
Gut organ weight (g)				
Gizzard	$61.8^{b}\pm6.4$	$44.5^{a}\pm12.3$	$45.9^{a}\pm9.5$	0.001
Liver	$54.1^{b}\pm10.3$	$50.5^{b}\pm8.0$	$43.6^{a}\pm6.3$	0.001
Proventriculus	$10.4^{b}\pm1.3$	$8.3^{a}\pm2.0$	$7.2^{a}\pm1.6$	0.001
Small intestine	$120.0^{b}\pm15.1$	$95.6^{a}\pm18.2$	$81.6^{a}\pm18.2$	0.001
Large intestine	$11.8^{b}\pm4.5$	$11.6^{b}\pm3.2$	$6.5^{a}\pm1.9$	0.001
Gut organ length (cm)				
Small intestine	$201^{b}\pm6.9$	$193^{a}\pm9.9$	$185^{a}\pm6.2$	0.001
Large intestine	$11.5^{b}\pm0.8$	$11.0^{b}\pm0.4$	$5.5^{a}\pm0.1$	0.001

a, b, c: Means in the same row not sharing common superscript are significantly different(P<0.05).

#: Treatment code described in chapter 5, Table 5.4.1 (T1:C =control; T2:FRD1=skip a day; T3:FRD2=skip two days.)

5.4.2 Measurement of carcass characteristics

The effect of feed restriction on pluck weight, carcass weight, dressing percentage, drumstick, wing, thigh and breast of 308 broiler chickens are presented in **Table:5.2** Feed restriction had no effect (P>0.05) on pluck weight. Broiler chickens subjected to T_2:FRD1 and T_3:FRD2 had a lower (P<0.05) mean pluck weight while broiler chickens that were fed T_1:C had the highest mean pluck weight (P>0.05).

Feed restriction had an effect (P<0.05) on carcass weight. Broiler chickens subjected to T_2:FRD1 and T_3:FRD2 had a lower (P<0.05) mean weight while broiler chickens that were fed T_1:C had the highest mean (P>0.05) carcass weight. However, feed restriction had no effect (P>0.05) on dressing percentage.

Feed restriction had an effect (P<0.05) on wing and drumstick weight. Broiler chickens that were subjected to T_2:FRD1 and T_3:FRD2 had the lowest mean weight (P<0.05). whereas broiler chickens that were fed T_1:C had the highest mean weight (P<0.05) respectively.

Feed restriction had an effect (P<0.05) on the thigh and breast. Broiler chickens that were subjected to T_1:C demonstrated the highest mean weight (P<0.05) while broiler chickens that were fed T_2:FRD1 and T_3:FRD2 had the lowest mean weight (P<0.05) respectively.

Table 5.3. Effect of feed restriction on pluck weight, carcass weight, dressing percentage, drumstick, wing, thigh and breast of 308 broiler chickens.

		Treatments		
Variables	**T_1:C**	**T_2:FRD1**	**T_3:FRD2**	**P-value**
Pluck weight	2863.5±3823.5	1862.3±131.6	1862.4±115.1	0.263
Carcass weight	1580.4^a±132.0	1448.3^a±122.6	1451.1^a±116.1	0.001
Dressing %	187.0±222.2	914.1±4072.1	781.4±2918.0	0.355
Wing	148.5^b±29.6	144.3^b±30.0	101.4^a±12.0	0.001
Drumstick	427.0^b±83.1	172.2^a±25.9	194.2^a±194.2	0.001
Thigh	154.1^b±22.4	160.5^b±29.5	118.0^a±16.2	0.001
Breast	312.5^b±61.8	167.6^a±24.2	127.4^a±16.8	0.001

a, b, c: Means in the same row not sharing common superscript are significantly different(P<0.05).

#: Treatment code described in chapter 5, Table 5.4.2. (T1:C =control; T2:FRD1=skip a day; T3:FRD2=skip two days.)

5.4.3 Meat quality measurements

The effect of feed restriction on the meat colour of Ross 308 broiler chicken is presented on **Table 5.4.** Feed restriction did not affect meat lightness (P>0.05). Broiler chickens in the T2:FRD1 and T3:FRD2 groups exhibited significantly higher (P=0.05) meat lightness compared to those in the T1:C group, which had poorer meat lightness (P>0.05). Similarly, feed restriction had no impact on the red color of the meat

(P>0.05). Broiler chickens in the T3:FRD2 group sowed a higher (P>0.05) red color compared to those in the T1:C and T2:FRD1 groups.

However, broiler chicken assigned to T2:FRD1 demonstrated poor (P0>.05) red color. Feed restriction had no effect (P>0.05) on the yellowness of the meat. Broiler chickens fed T_1:C had low (P>0.05) yellowness. However, broiler chicken subjected to T_2:FRD1 and T_3:FRD2 had the highest (P>0.05) yellowness.

Feed restriction had no effect (P> 0.05) on meat pH values. Broiler chicken fed T_1:C, T_2:FRD1 and T_3:FRD2 had similar pH values (P=0.05) at 1,12 and 48 hours of testing, respectively.

Table 5.4 The effect of feed restriction on meat colour Ross 308 broiler chicken

	Treatment			
Variables	**T_1:C**	**T_2:FRD1**	**T_3:FRD2**	**P-value**
Breast colour				
L*	55.9^a±4.52	58.9^a±6.2	58.8^a±5.9	0.17
a*	2.9^a±0.64	2.7^a±0.9	3.2^a±1.8	0.42
b*	2.7^a±2.19	3.3^a±1.78	3.9^a±2.14	0.21
Breast pH				
pH,1 hour	6.6^a±0.14	6.1^a±0.15	6.44^a±0.13	0.39
pH,24 hours	6.6^a±0.06	6.6^a±0.10	6.6^a±0.01	0.45
pH,48 hours	6.6^a±0.06	6.6^a±0.10	6.6^a±0.09	0.51

$^{a, b, c}$: Means in the same row not sharing common superscript are significantly different(P<0.05).

#: Treatment code described in chapter 5, Table 5.4.3 (T_1:C =control; T_2:FRD1=skip a day; T_3:FRD2=skip two days.)

Hunter LAB test: L* lightness; a*: redness and b*: yellowness

5.4.4 Sensory evaluation.

The effect of feed restriction on chicken juiciness, flavour, tenderness and shear force of Ross 308 broiler chicken is presented on **Table 5.5** Feed restriction had an effect (P<0.05) on Ross 308 broiler chicken tenderness. Broiler chicken subjected to

T_2:FRD1 scored 4.0 which indicates good flavour and T_3:FRD2 scored 3.0 which indicates meat was neither tough nor tender; respectively. However, broiler chicken fed T1:C scored 2.7 which indicates that the meat was tough.

Feed restriction had an effect ($P<0.05$) on Ross 308 broiler chickens' juiciness. Broiler chicken assigned to T_1:C, scored 4.0 which indicated juicy. However, broiler chickens subjected to T2:FRD1 and T_3:FRD2 demonstrated similar scores of 3.2 and 3.3 which indicated that the meat was neither dry nor juice, respectively.

Feed restriction had no effect ($P>0.05$) on Ross 308 broiler chickens' flavor. Broiler chickens fed T_1:C and T_3:FRD2 demonstrated similar scores of (3.2,3.3 and 3.6) which indicate that the meat is neither bad nor good, respectively.

Feed restriction has no effect ($P>0.05$) on Ross 308 broiler chickens shear force. Broiler chicken fed T_1:C had the highest ($P>0.05$) shear force value. However, broiler chickens subjected to T_2:FRD1 and T_3:FRD2 had similar ($P>0.05$) shear force value, respectively.

Table 5.5 The effect of feed restriction on tenderness, juiciness, flavour, and sheer force of Ross 308 broiler chickens.

		Treatment		
Variables	**T_1:C**	**T_2:FRD1**	**T_3:FRD2**	**P-value**
Tenderness	$2.7^a\pm0.9$	$4.0^a\pm0.6$	$3.0^a\pm0.8$	0.026
Juiciness	$4.0^a\pm1.1$	$3.2^b\pm1.1$	$3.3^b\pm1.0$	0.049
Flavour	$4.0^a\pm1.2$	$3.3^a\pm1.0$	$3.6^a\pm0.9$	0.543
Shear force	15.0 ± 4.3	14.5 ± 3.6	14.3 ± 6.6	0.904

$^{a, b, c}$: Means in the same row not sharing common superscript are significantly different($P<0.05$).

#: Treatment code described in chapter 5, Table 5.4.4 (T_1:C =control; T_2:FRD1=skip a day; T_3:FRD2=skip two days.)

5.5. Discussion

Results of the present study indicate that feed restriction influenced the gut organ weight of Ross 308 broiler chickens. Broiler chickens fed T_1:C showed increase in gizzard weight to T_2:FRD1 and T_3:FRD2. However, David and Subalini (2015) found that birds fed *ad libitum* had lower relative gizzard weights, whereas birds subjected to food restriction for three and five hours had higher weights. Jalal and Zakaria, (2012) revealed comparable outcomes, with the gizzard weights of the control group being numerically greater than those of the restricted group. In contrast to our findings, Aghil (2011) indicates that the weights of the small intestine, gizzard, and carcass were larger in birds that were subjected to diet restriction. This may have been due stimulated organ growth as a compensatory mechanism.

It was evident from this investigation that feed restriction affected the liver. Broiler chicken fed T_1:C showed an increased liver weight while broiler chicken subjected to T_2:FRD1 and T_3:FRD2 showed a lowest. A significant increase in the liver weight in the birds fed T_1: C might be due to the increase feed intake when compare to T2:FRD1 and T_3:FRD2. Jalal and Zakaria, (2012) reported similar results in 50% feed restricted birds with low liver and heart wights. Several previous studies (Saleh et al., 2005; Mahmood et al., 2007; Onbasilar et al., 2009) have found that the liver weights of restricted and unrestrained broilers do not differ much. The differences in these results are probably caused by the feed restriction programs used and the age at which the birds were killed.

In th current study it was noticeable that broiler chickens fed T_1:C and T_2:FRD1 showed an increased gastrointestinal tract length compared to broiler chickens subjected T_3:FRD2. According to Wang and Peng (2008), the gastrointestinal system plays an important role in the final stage of nutritional digestion and assimilation. An increased gastrointestinal tract length in chicken exposed to T_2:FRD1 may be a sign of higher nutritional absorption during the re-feeding period because the gut organs are the primary site for nutrient intake and is crucial for the re-absorption of water and electrolytes. In contrast, Azouz, (2019) showed that broiler chickens subjected to feeding restriction had longer gastrointestinal tract. However, Novele et al. (2008) found no impact of 25% and 50% feed restriction on broiler chicken gastrointestinal tract length. Furlan et al. (2001) also reported that dietary restriction affects the normal process of digestion and absorption and increases the feed conversion ratio as reported in some research on feed restriction in broilers. Jalilvand et al. (2017) reported that dietary restriction did not affect intestinal morphology.

Feed restriction influenced carcass weight. Broiler chickens subjected to T_2:FRD1 and T_3:FRD2 demonstrated poor carcass weight. Similar results were reported by Batorek et.al. (2012) in pigs. Contrary to the present findings, Camacho et al. (2004), found favourable carcass weight in feed-restricted broiler chicken. The current study found that broiler chicks fed T_1:C had the highest carcass weight. Moreover, Boostani et al. (2010) showed similar findings on carcass weight in broiler chickens fed T_1: C. Massuquetto et al. (2019) suggested that when broiler chicken is restricted feed, they consume more energy for upkeep, leaving little energy for growth.

Feed restriction influenced wing, drumstick, breasts, and thighs weight. However, broiler chickens fed T_1:C obtained higher weight compared to broiler chickens T_2:FRD1 and T_3:FRD2. These findings agree with those of Urdaneta-Rincon and Leeson (2002), who reported low breast weight in broiler chickens subjected to T_2:FRD1 and T_3:FRD2. Camacho et al. (2004) and Hajati (2010), reported similar results in breast with higher weight in broiler chickens fed T_1: C. These findings revealed that broiler chickens with high breast and thigh weights have low wing and drumstick weight.

This finding suggests that feed restriction specifically decreased the growth of breast muscle, and the degree of feed restriction again determines the effect. Boostani et al. (2010) reported similar results in birds under $R_{21\text{-}35d}$ and $R_{14\text{-}28d}$ treatments that had lower breast weight and abdominal fat weight as compared to T_1:C, respectively. These results indicate that complete compensation did not occur in broiler chickens

The pH level is an important reference for the assessment of meat quality (Yuan et al., 2022), because the ultimate pH directly affects various meat quality traits, including colour, tenderness, juiciness, and shelf life (Fletcher, 2002; Barbut et al., 2008). However, in this present study feed restriction had no effect on breast pH and colour. The results revealed that there was no significant difference among the treatment for meat guilty. Poltowicz et al. (2015) showed no effect of restricted feeding of chickens on the pH and colour of breast muscles, which was also confirmed by the present study.

According to Results of the present study, feed restriction influenced meat tenderness and juiciness of Ross 308 broiler chickens. Broiler chicken fed at T_1:C indicated the highest shear force and tough nor tenderness, juicy and flavor was neither bad nor good. Contrary to the study Lippens et al. (2000) found no effect of feed restriction on broiler chicken meat tenderness. However, broiler chicken subjected to T_2:FRD1 and

T3:FRD2 indicated low shear force tender, neither dry nor juicy and flavour was neither bad nor good. Butzen et.al. (2013) suggest that temporary feed restriction contributed to a marked reduction in meat shear force.

5.6 Conclusion and Recommendations

In conclusion, feed restriction significantly affected the organ weights, carcass characteristics, and meat quality of broiler chickens. The control group, which was fed *ad libitum*, performed better than the skip-a-day and skip-two-day groups in terms of organ weights and carcass characteristics. Broiler chickens exposed to feed restriction showed lower chicken piece weights, indicating that they did not compensate for the reduced feed intake during re-feeding.

However, meat juiciness and tenderness were notably influenced by feed restriction, with feed-restricted chickens showing fewer desirable results. On the other hand, broiler chickens fed the T1:C diet exhibited the highest gut weight and length, carcass weight, enhanced tenderness and juiciness, and overall better meat quality and acceptance. These findings suggest that while feed restriction affects some physiological parameters, it has a relatively minor impact on meat quality, especially when specific feeding strategies, like T1:C, are employed.

CHAPTER SIX

GENERAL DISCUSSION

6.1 General discussion

Feed restriction programs are a management strategy that has a high correlation with increased diet effectiveness in broiler chickens, reduced maintenance costs, metabolic disorders, and body fat formation. Additionally, it provides financial benefits by lowering the price of feed for chicken producers, which may benefit the commercial poultry industry. Feed restriction programs are one of the primary methods for altering the growth curve of broiler chickens in order to increase production efficiency and reduce the incidence of different metabolic diseases (Goo et al., 2019). Additionally, they can be used to lessen the negative effects of the industry's potentially lucrative rapid growth (Massuquetto et al., 2019).

Chapter 3,This study examined the effects of feed restriction on growth performance indicators such as initial and final weight, average daily feed intake, average daily gain, and feed conversion ratio (FCR) in Ross 308 broiler chickens. Feed restriction had a significant ($P<0.05$) impact on performance parameters, with varying degrees depending on the level of restriction. Broiler chickens exposed to T1:FRD1 and T2:FRD2 had a lower final body weight and average daily gain, which is consistent with the expected effects of reduced nutrient intake. However, feed conversion efficiency may improve under T1:FRD1 due to lower maintenance energy requirements and increased metabolic efficiency.

Chapter 4, This study investigated the effects of feed restriction on welfare indicators such as feather condition, pecking behavior, footpad and skin condition, gait score, and body condition score of Ross 308 broiler chickens. The findings revealed that feed restriction had a significant impact on some welfare parameters while leaving others unaffected. Broiler chickens treated with T2:FRD1 and T3:FRD2 had significantly lower body condition scores, aggressive pecking, and increased feather loss, indicating a poor welfare outcome. These findings indicate that feed restrictions must be carefully managed to avoid affecting bird welfare.

Chapter 5, The study evaluated the effects of feed restriction on gut morphology, carcass characteristics, meat quality, and sensory evaluation of Ross 308 broiler chickens. T2:FRD1 and T2:FRD2 show significant reductions in gizzard, liver, proventriculus, and intestinal weights and lengths, highlighting the negative effects of restricted feeding on digestive organ development. Broiler chickens treated with

T2:FRD1 showed less pronounced effects, indicating that it may still support moderate organ development.

However, broiler chickens treated with T3:FRD2 showed significant reductions in organ size, which could impair digestion, metabolism, and nutrient absorption, ultimately reducing overall growth performance. These findings highlight the importance of balancing feed restriction strategies to ensure organ development and broiler productivity. Feed restriction significantly impacted ($P<0.05$) carcass characteristics. T2:FRD2 showed a lower carcass weight for wings and drumsticks. Feed restriction had no significant effect ($P<0.05$) on pluck weight or dressing percentage.

T2:FRD1 resulted in higher thigh and breast weights, indicating that feed restriction may stimulate compensatory growth in specific muscle groups, potentially increasing production of valuable meat cuts. In this study, feed restriction had no effect on meat color or ph. Feed restriction significantly affected meat sensory attributes, including flavor and tenderness ($P<0.05$). This suggests that feed restriction can be implemented without affecting meat quality perception. The similarity of sensory traits between T2:FRD1, T3:FRD2, and T1:C demonstrates the viability of feed restriction in broiler management when consumer acceptance is a priority. However, feed restriction had no effect on shear force.

In conclusion, feed restriction has the potential to improve feed efficiency and limit excessive fat deposition, but it also hinders gut development and growth performance. Crucially, meat quality and sensory characteristics were essentially unaffected, confirming the viability of feed restriction programs from an economic and consumer-driven standpoint. To reduce adverse welfare effects, restriction protocols must be carefully implemented, as evidenced by the welfare concerns and behavioral changes that have been observed. In order to reduce welfare concerns while preserving productivity and meat quality, future research could examine the application of alternative feeding techniques like intermittent or compensatory feeding.

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