

**The effect of feed restriction duration on growth performance,  
physico-chemical characteristics and fatty acid composition of  
meat from broilers**

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**Declaration**

I, Ziphozihle Gobane, vow that this dissertation has not been submitted to any university and that it is my original work conducted under the supervision of Prof V. Muchenje, Prof Aghdasi and Dr L Zhou. All assistance towards the production of this work and all the references contained herein have been duly acknowledged.

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## **Abstract**

### **The effect of feed restriction duration on growth performance, physico-chemical characteristics and fatty acid composition of meat from broilers**

**By**

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The main objective of the study was to determine the effect of feed restriction duration on growth performance, physico-chemical characteristics (colour, ultimate pH, tenderness and cooking loss) and fatty acid composition of meat from broilers. A total of 144 day-old broiler chicks were reared in a deep litter system until slaughter at 42 days. All the chicks were managed in one brooding house for the first 21 days. On day 22, the chicks were randomly allocated to three treatments; the control (T1), one week of feed restriction (T2), and two weeks of feed restriction (T3). Three broiler houses with uniform conditions were sub-divided into three compartments. The birds were randomly allocated to each of the nine compartments. Each treatment was replicated three times with 16 birds per compartment being fed as a group and each bird was regarded as the experimental units. The average daily gain (ADG), average daily feed intake (ADFI) and the feed conversion ratio (FCR) were computed for each chick each week. Chickens were all slaughtered at 42 days of age and the slaughter weight, carcass weight, and internal organs weights were recorded. Physico-chemical qualities of chicken breast meat such as colour ( $L^*$ -lightness,  $b^*$ -yellowness,  $a^*$  redness, saturation index and hue angle) and meat ultimate pH ( $pH_u$ ) measurements were taken over a 10 days shelf-life period. Breast muscle was also sampled for cooking loss, tenderness and fatty acid profiles. There were treatment effects on the growth performance of broiler chickens. There was no significant effect ( $P > 0.05$ ) on the relative weights of the chicken heart, liver, gizzard, feet and heads among the treatment groups except for intestine weight. Treatment 1 had higher live weight than treatment 2 and 3. There was significant effect ( $P < 0.05$ ) on the cooking loss breast muscle, with treatment 1

having highest values. However, feed restriction had no effect ( $P > 0.05$ ) on the WBSF of breast muscle, although it was highest in T 3. Feed restriction had no effect ( $P > 0.05$ ) on hue angle, significant difference ( $P < 0.05$ ) was observed on meat pH<sub>u</sub>, L\*, a\*, b\* and saturation index after 24 hours of storage. Birds that were exposed to two weeks of feed restriction had the highest ultimate pH (5.99) followed by one week restriction (6.01) and the broilers which were fed *ad libitum* (5.89). The pH<sub>u</sub> values in all the treatments were constant from day 1 to day 6 and then T 2 peaked up at day 7 (6.16) before declining at day 8 (5.91). The L\* values in all treatments were constant from day 1 to day 7 and then at day 8, treatment 2 reached its peak L\* (58.49) and then declined on day 9 (44.38) with T 3 having similar values. The b\* values started to decrease from day 3 to day 6 then peaked up again at day 7 except for T 1. There was no significant treatment effects ( $P > 0.05$ ) on the SI and Hue angle on breast muscle. There was no treatment effect on the major fatty acids of breast muscle. It was concluded that a one week feed restriction had similar effects on growth performance and meat quality of broiler chickens as non-restriction broilers. The meat quality of the broiler muscle was within the normal range, feed restriction did not affect meat quality of broiler meat. Feed restriction had a minimal effect on physico-chemical shelf-life indicators of broiler chickens during storage over 10 days. The observation from this study showed that all the treatment had a minimal effect on the fatty acids of the broiler chicken.

**Key words:** Restriction, *ad libitum*, slaughter weight, growth rate, meat quality, shelf-life, breast muscle, health-related indices and fatty acid

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## List of abbreviation

a*	Redness of meat
ADFI	Average daily feed intake
ADG	Average daily gain
AFI	Average feed intake
AI	Atherogenicity Index
b*	Yellowness of meat
CW	Carcass weight
DI	Desaturase Index
FCR	Feed conversion ratio
HA	Hue angle
L*	Lightness of meat
pHu	Ultimate pH
PUFA	Polyunsaturated fatty acids

## **Chapter 1: Introduction**

### **1.1 Background**

The pressure to meet human dietary demands has led to intensive and rigorous livestock selection programs that are aimed at improving efficiency of production by maximising the overall poultry meat/muscle output per each gram of feed given (Nkukwana *et al.*, 2014). These production protocols have resulted in tremendous improvements including lowered feed intake, better feed conversion rates, higher juvenile growth rates, high breast and thigh yields and reduced feed and production costs in commercial poultry breeds (Seyedabadi *et al.*, 2010). However, these improvements have also negatively resulted to important phenotypic changes such as meat quality and increased body fat deposition, high mortality and high incidence of metabolic diseases and skeletal disorders (Zubair and Leeson, 1996). To address the issue of high mortality, body fat deposition, high incidence of metabolic diseases and skeletal disorders many strategies have been put forward, including feed restriction.

Feed restriction protocols, including physically declining access to the feed and water during certain times of the day, uses the concept of catch-up growth or compensatory growth, with its success depending on duration of feed restriction and the age of restriction (Hockings *et al.*, 2002a,b; Giachetto *et al.*, 2003; Leeson and Summers, 2005). Compensatory growth or catch-up growth is defined as abnormally rapid growth relative to age after early growth retardation (McMurtry *et al.*, 1988). Auckland and Morris (1971) reported that broilers exposed to feed restriction for short periods during the early growth phase show improvement of feed efficiency, reduce abdominal, carcass fat in broiler chicken and reach a weight equal to that of broilers fed *ad libitum* at the time of slaughter.

According to Arce-Menocal (1995), feed restriction reduces the chances of metabolic disorders. Feed restriction also prevents feed wastage during maintenance and production of broiler chickens (Urdenata-Rincon and Leeson, 2002). Zubair and Leeson (1994) observed that by restricting broiler chickens there was relative enlargement of digestive organs, especially the gizzard, crop, pancreas and liver which improve feed intake. Khetani *et al.* (2008) found that birds which are restricted of feed would consume more feed to compensate for the time they have been deprived of feed. Feed restriction has been commonly used to optimize lean carcass tissue, reduce metabolic disorders, control body weight, and reduce reproductive problems in both meat-type and egg-type chickens and excessive fat deposition (Zubair and Leeson, 1994).

Shelf-life is the period of time from when the product is packed and stored up to when it can still be used (Singh and Sing, 2005). Changes in shelf-life of meat product are due to several factors which include packaging, oxygen content, and storage temperature (Acuffs, 2006). The lower the oxygen permeability of the packaging material, the more efficient will be the protection of product quality. The best protection will be achieved using oxygen-proof packaging films together with vacuum packaging of the product. The vacuum packed meats have a maximum shelf-life of 15-25 days (Charley, 1982). It has also been reported that unfrozen poultry at low temperature around 0°C extend shelf-life quite markedly.

Shelf-life properties may include appearance, texture, flavour, and colour. Understanding these product properties of shelf-life and meat quality is important in production of a safe and healthy product for human consumption (Dyubele *et al.*, 2010). These meat quality attributes are very important in the decision making, if the meat is to have a longer shelf-life. If there is

discoloration, bruises, pale and dark colour on this attributes the meat will have shorter shelf-life, and less attractive on consumer to purchase.

Economic losses resulting from short shelf-life and subsequent spoilage has been reported in poultry industry with immediate interventions required to minimize economic losses. The success of raising broilers for maximum weight gain depends not only upon the strain of the birds and management but also on feeding patterns and quality (Zubair and Leeson, 1996). The main reason for controlling feed intake in broilers is to prevent high fat deposition in broiler chickens. When feeding broiler chickens, maintenance requirements and production are converted to the fat (Fontana *et al.*, 1992) and the carcass quality is affected (Zubair and Lesson, 1996).

Excessive fat is one of the main problem is faced by the broiler industry resulting in negative perception of the meat by health conscious consumers (Kessler *et al.*, 2000). Occurrence of heart diseases has increased in humans in the past years and has been associated to high fat consumption, especially saturated fat. Quantitative feed restriction of broilers might reduce the amount of fat or abdominal fat in carcasses (Leeson and Zubair, 1997). However, broilers are an important provider of the essential polyunsaturated fatty acids (PUFAs), especially the omega (n)-3 fatty acids, which are beneficial to consumers due to their cholesterol lowering effect and may therefore reduce the risk of cardiovascular diseases (Charlton *et al.*, 2008). In addition, processors face difficulties in processing the meat into different products because of fat as a result of meat texture resulting in reduced shelf life (McMurtry *et al.*, 1988). Therefore, this study is conducted to determine the effect of restricted feeding on growth performance, physico-chemical characteristics and shelf-life and fatty acids of broiler chicken meat.

## **1.2 Problem statement**

Feeding to maximize the weight of a bird to reach slaughter weight in a short time, results in physical deformities such as leg diseases and skeletal diseases. These skeletal diseases affect welfare of the animal causing discomfort in broilers which lowers the growth performance and productivity. Excess fat, is one of the main problems faced by the broiler industry which reduces carcass yield and feed efficiency but thus causing rejection of the meat by consumers because of health related problems faced by humans. Fat also has an effect on carcass quality resulting to lower shelf-life of meat.

## **1.3 Justification**

Animal protein sources like mutton are very expensive, whereas beef has a limited use due to its high cholesterol contents. Broiler meat, therefore, may help in abridging the gap between supply and demand of animal proteins because it is the quickest and more economical source of human protein of high biological value (Mahmood *et al.*, 2005). This results in broiler industries fastening the growth performance of chicken to reach slaughter weight in rapidly thus causing physical damages in broiler chicken. Feed restriction it is used as a method for controlling growth rate in broilers without damaging the performance and meat quality. Farmers can benefit in feed restriction because, feed is expensive by using feed restriction may help in cutting the rate of feed that is used in the farm. It is important to supply a balanced diet to the broiler to maintain a practical and reasonable growth and to prevent nutritional deficiencies. Broilers have a capability to recover body faster after a period of feed restriction. Studies on feeding strategies to improve growth performance and meat quality of broilers are much needed.

## **1.4 Objective**

The broad objective of the study is to determine the effect of restricted feeding duration on growth performance, physico-chemical characteristics, shelf-life indicators and fatty acids profiles of broiler chicken meat.

### **Objectives**

- To determine the effect of feed restriction duration on feed intake, growth rate, feed conversion efficiency, slaughter weight, carcass weight, dressing percentage and organ weight of broiler chickens
- To determine the effect of feed restriction duration on physico-chemical shelf-life indicators on pH<sub>u</sub>, colour, cooking loss, and tenderness of broiler meat
- To determine the effect of feed restriction duration on fatty acids profiles meat from broilers.

### **Hypothesis**

- Feed restriction duration has no effect on feed intake, growth rate feed conversion efficiency and slaughter weight, carcass weight, dressing percentage and organ weight of broiler chickens
- Restricted feeding has no effect on feed restriction duration on physico-chemical shelf-life indicators on pH<sub>u</sub>, colour, cooking loss, and tenderness of broiler meat
- Feed restriction duration has no effect on fatty acids profiles meat from broilers

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## **Chapter 2: Literature Review**

### **2.1 Introduction**

Today, the greatest challenge of the United States Organization for Food and Agriculture (FAO) is food security. It consists on obtaining and ensuring an increasing food production of best quality for the population that is increasing yearly (FAOSTAT, 2010). Poultry meat is highly perishable thus it loses freshness between 4 to 10 days under refrigeration conditions (Marenzi, 1986). Shelf-life of refrigerated fresh poultry can be evaluated through sensory attributes and chemical indicators. Reduced quality of colour, pH, and tenderness determines the rejection of meat by the consumer (Lee *et al.*, 1996).

Improved meat quality attracts more attention from consumers, and excessive fat deposition is usually the factor of poor meat quality of broilers. Studies have shown that feed restriction could decrease fat deposition and increase protein deposition in carcasses, thus resulting in the improved carcass composition and meat quality (Jones and Farrell, 1992; Nielsen *et al.*, 2003).

### **2.2 Feed restriction as a feed manipulation strategy**

Feed restriction is a management strategy, which is applied in the poultry industry in order to reduce the feed intake, to limit the early growth, to decrease the incidence of infectious, metabolic and skeletal disorders and to improve the nutrient utilization via compensatory growth (Zulkifli *et al.*, 1993; Zhan *et al.*, 2007; Thompson *et al.*, 2008; Benyi *et al.*, 2010). Feed restriction is a method of feeding whereby it include time, duration and amount of feed to show the impact whether a bird is capable of achieving the same body weight as unrestricted birds (Ballay *et al.*, 1992; Yu and Robinson, 1992).

The main target of feed restriction is to reduce the nutrients in the gastrointestinal tract, so that they can be utilized by neither birds nor intestinal microbiota (Tsiouris, 2010). Thyroid hormones concentration decreases after the feed restriction period but increases and reaches normal levels by refeeding. Feed restriction also increases enzyme secretion such as amylase, sucrase and lipase; it also alters functional development of the enzymes of protein digestion such as dipeptidase and amino peptidase (Pinheiro *et al.*, 2004).

Feed restriction is used in manipulating growth so that market weight can be obtained in 60% less time than broilers of 40 years ago (Baghbanzadeh and Decuypere, 2008). It is practiced in broilers to persuade compensatory growth, improve efficiency utilization, and lower maintenance requirements in the grower and finisher phases (Teimouri *et al.*, 2005). It also leads to reduction in feed and production costs, thereby, producing a lean quality meat at cheaper prices (Zubair and Leeson, 1996; Navidshad *et al.*, 2006; Mahmud *et al.*, 2008).

## **2.3. Feed restriction methods**

### **2.3.1. Physical Feed Restriction**

Physical feed restriction provides a well-deserved amount of feed per bird, which is often just enough to meet maintenance requirements (Plavnik and Hurwitz, 1989). It is also known as qualitative feed restriction where by birds are denied full access to certain nutrients through the provision of a feed diluted mainly with inert fibres (Hocking *et al.*, 2002a, b; Giachetto *et al.*, 2003; Leeson and Summers, 2005). It is a common method used in controlling feed intake in poultry. This method is not simple due to the regular weighing of birds, and calculating feed consumption on a daily basis. Strictness of feed restriction, length of restriction, and age at

marketing are the main factors to take into account in a feed restriction program for broilers (Giachetto *et al.*, 2003).

### **2.3.2 Skip a day restriction**

Skip-a-day is the removal of feed by restricting early growth and reduces the incident of ascites without affecting final body weight (Arce *et al.*, 1992; Ballay *et al.*, 1992; Dozier *et al.*, 2002). It's a method that is done by removing feed for 8-24 hour periods during the starter period reduces early rapid growth and meat yield in broiler chickens. Skip a day feed removal has been reported in other studies to decrease early growth (Oyedepi and Atteh 2005). It's a procedure that depends on weeks, days and time it has been started. This method improves carcass quality and reduce sudden death syndrome which is often associated with birds that are on ad libitum feed intake (Oyedepi and Atteh, 2005).

### **2.3.3 Chemical Methods**

Chemical method, feed must be equally distributed among the birds decreasing the variations in growth like in physical method. This method was suggested by Fancher and Jensen (1988); Pınchasov and Jensen (1989) using 1.5 or 3% glycolic acid as an anorectic agent from 7 to 14 days in order to suppress the feed intake of chicks. Feed intake was severely reduced, resulting in 22% and 50% weight reduction with 1.5% or 3.0% glycolic acid inclusion. Oyawoye and Krueger (1990) showed that 400<sup>+</sup> and 300 mg of phenylpropanolamine hydrochloride or monensin sodium per kg of diet decrease body weight of the broiler chickens at 4 weeks of age.

## **2. 4. Compensatory growth in broiler chickens**

The growth compensation of birds defines as the increased growth rate, when growth has been retarded by nutritional restriction and followed by *ad libitum* feeding (Shariatmadari and

Torshizi, 2004; Zhan *et al.*, 2007). Compensatory growth refers to the accelerated growth in animals of the same age and breed that were previously feed-restricted (Tumova, 2002).

Compensatory growth can be accomplished when birds divert more energy towards growth (Ryan, 1990). The mechanisms involved in the process of growth compensation seem to be related to a reduced maintenance requirement, an increased feed intake relative to body size, alteration in the proportion of fat and protein deposited in the tissues, or improved feed efficiency for growth (Ryan, 1990).

## **2.5 Factors influencing compensatory growth in the broiler chicken**

### **2.5.1 Duration of feed restriction**

It is known that with an extended period of feed restriction it is more difficult for broilers to compensate and reach a normal target market body weight for age (Yu and Robinson, 1992). According to Jones and Farrell (1992); Santoso *et al.*; (1993a), longer periods of feed restriction is more difficult with longer period. Some studies have achieved the compensatory growth of broiler chickens under short period (Santoso *et al.*, 1993a; Deaton, 1995). Feed restriction for a period of six days allowed for complete body weight recovery, while recovery was not achieved when restriction was more prolonged to 12 days (Plavnik *et al.*, 1986). However, other researchers failed to attain compensatory growth in broiler chickens that were restricted during a short period of feed restriction (Yu *et al.*, 1990; Fontana *et al.*, 1992; Palo *et al.*, 1995).

Robinson *et al.* (1992) had feed restricted chicks for 7 days using skip-a-day program or daily limited restriction and reported that birds on the skip-a-day program showed lower weight gain than the birds restricted each day. However Cristofori *et al.* (1997) showed that broilers fed

under a skip-day program (one day fast and one day fed *ad libitum*) from 7 to 28 days of age, and showed that restricted birds did not compensate in final body weight at both 42 to 49 days.

It is recommended feed restriction of not more than seven or five days for male and female broilers, respectively, to allow for full body weight recovery (McMurtry *et al.*, 1988). A short feed restriction program can improve feed efficiency and associated reduction in production costs, as long as the time to reach market weight will not be affected (Plavnik and Hurwitz, 1991).

### **2.5.2 Timing of feed restriction**

Time for starting feed restriction program is very important because the later that birds start feed restriction the less the opportunity to achieve desirable productive performance. According to (Benyi and Habi, 1998), feed restricted birds from 4 to 8 weeks of age were not able to achieve final body weight at 56 days. Plavnik and Hurwitz (1988) observed that starting at 6 days feed restriction at any age between 3 to 11 days of age seems to have complete body weight recovery by 8 weeks of age in male broilers. Thus Rosebrough *et al.* (1986) recommend the beginning of restriction at 5 to 7 days of age.

Restricting broiler chickens to a level that only supports their maintenance requirements from 7 to 21 or 21 to 35 days resulted in lower body weight at both 42 and 49 days, compared to *ad libitum* fed chicks (Cristofori *et al.*, 1997). The lack of recovery in body weight for the restricted birds compared to *ad libitum* fed birds may be related to the time and age at initiation of the restriction period. Robinson *et al.* (1992) observed that the most favorable time to apply a feed restriction program is during the second week, rather than later. Plavnik and Hurwitz (1988) suggested that feed restriction programs may start at 6 days of age, and continue no longer than 7

days in order to allow birds to attain growth compensation by when they reach 49 days. Feed restriction programs beginning at an earlier age rather than later seem to be more beneficial to achieving the objectives on the performance response of broiler chickens.

### **2.5.3 Duration and nature of feed restriction**

It is known that the growth response of broilers after re-feeding is related to the severity of previous restriction. However, the more severe the restriction tends to compromise the ability of the bird to recovery. The level of feed restriction which is estimated just to meet maintenance energy requirements is equivalent to about 167 KJ ME/bird/day in the 6 to 12 day period (approximately 35% of normal intake). Plavnik and Hurwitz (1985, 1988) suggested a calculated value of 1.5 kcal ME/day/g  $BW^{2/3}$  to sustain maintenance energy requirements for male broiler chickens. Using this energy value, birds in fact gain some weight, hence broilers under a feed restriction program may have slightly lower maintenance requirement. This maintenance energy level, however, must have been over estimated because the feed restricted birds gained 2 to 4 g body weight each day during the restriction period. It is also possible, as suggested by some researchers that the birds even though in negative energy balance were able to gain weight due to change in body composition as in used fat reserve and deposited more lean tissue (Lesson *et al.*, 1991; Yu and Robinson, 1992). However, other researchers were unable to demonstrate complete compensatory growth of broilers, which had been subjected to similar degrees of feed restriction (Plavnik *et al.*, 1986; Robinson *et al.*, 1992). Later studies by Plavnik and Hurwitz (1991) showed that milder restriction, which allowed 60 to 70 per cent of normal growth, permits more realistic recovery.

Some restriction that took a period of 6 or 7 days began at 4 days of age, and broiler chickens under this restriction scenario were unable to normalize weight gain, and had a significantly lower body weight at 49 days. These results are in agreement with other researchers who were unable to obtain compensatory growth by broilers subjected to similar degrees of feed restriction (Yu *et al.*, 1990; Robinson *et al.*, 1992; Rosebrough and McMurtry, 1993). Moreover, giving birds the diluted diet in an irregular program improved their ability to adjust and increase their feed consumption (Zubair and Leeson, 1994a). Santoso *et al.* (1993b) fed broilers with a commercial starter diet to 21 days of age. At 7 days of age birds were feed-restricted to 75, 65, 55, or 45% of *ad libitum* intake for 10 days (day 7 to day 17). Body weight of severely restricted (65% and under) male and female broiler chickens was significantly lower than *ad libitum* fed.

The response of broiler chickens to a feed restriction program depends on the severity and length of the restriction period. It seems that the more severe and the longer the duration of a feed restriction program, the less the ability of birds to attain the expected market weight for age.

#### **2.5.4 Condition of re-alimentation**

The level of nutrients used in the re-feeding diets may have an effect on broiler growth. Fontana *et al.* (1992) suggested that protein might be a limiting nutrient in the recovery of restricted birds. However, Plavnik and Hurwitz (1989) showed that higher levels of dietary protein used during re-feeding do not change body weight or feed efficiency at the end of the trial.

Leeson and Zubair (1997), suggested that dietary protein level following restriction, had no meaningful effect on growth rate or feed efficiency, and that increasing the lysine levels during re-feeding actually decrease growth rate in previously restricted birds.

Jones and Farrell (1992) demonstrated that dietary supplementation with lysine and/or methionine during the re-feeding period resulted in higher final body weight and leaner carcasses. More reliable results of compensatory growth have been obtained in studies that have extended the growth period to 7 weeks or more (Upendra kumar *et al.*, 1997; Nirmala *et al.*, 2005).

### **2.5.5 Effect of genetics and sex**

The response of broiler chickens to a period of under nutrition will depend on the genetics and sex of bird used suggested that genetic potential influences broiler growth response because it affects their nutrition requirements (Gous *et al.*, 1999). According to McMurty *et al.* (1988) and Plavnik and Hurwitz. (1991), male broilers have a greater ability to show compensatory growth after a period of under nutrition than females. In a study by Havenstein *et al.* (1993) pointed out that genetic potential rather than nutrition has a greater effect on broiler body composition. Other researchers have not shown differences among strains to compensate body weight and reduce fat deposition (Jones and Farrell, 1992a; Plavnik and Hurwitz, 1992). Cherry *et al.* (1978) reported that broiler females had higher abdominal fat than males when subjected to early feed restriction and also fast growing broiler strain exhibit little compensatory growth when compared with slower growing strains.

Generally male broiler chickens have a greater growth rate and leaner body composition than female broilers do. Male broilers also have a superior capacity to display growth compensation than do females (Plavnik and Hurwitz, 1991; Santoso *et al.*, 1993a,b), although Deaton (1995)

showed that both male and female broilers attained complete compensatory growth at 41 days following just 10% restriction (day 7 to day 14) relative to *ad libitum* daily intake.

## **2.6. Effects of feed restriction on meat quality attributes of broiler chicken.**

### **2.6.1 Colour, pH cooking loss and tenderness**

Meat quality is a complex feature which consists of several meat quality indicators and it is affected by a number of factors like pre-slaughter stress, slaughter methods, storage condition, environmental condition such as feed, housing as reviewed by Rosenvold and Andersen (2003). These factors negatively affect meat quality and shelf-life (Qiao *et al.*, 2002). Producers should be concerned with factors that may negatively affect quality attributes to ensure optimum quality, because it is necessary to consider the entire production chain from farm to fork (Qiao *et al.*, 2002).

Several studies have proven that muscle pH is strongly associated with animal species, genetic factors, and management techniques before and after slaughtering and conditions of meat storage. Low ultimate pH reduces the importance of myoglobin in selectively absorbing green light, resulting in meat that appears less red and more yellow (Castellini *et al.*, 2002). High pH levels bacteria grow more rapidly and the meat will have a shorter shelf-life. Cornforth (1994) also stated that meat with high pH has a higher water-binding capacity hence making it water binding. Monitoring the pH of a freshly slaughtered carcass is important in producing a quality meat product for the consumer.

Colour is one of the major attribute or important factor for selection and initial evaluation of meat quality, consumers relate colour to freshness (Carpenter *et al.*, 2001). Meat colour is affected by the extreme environmental temperatures and stress due to live handling which

influences the meat to be discoloured (Nerín *et al.*, 2006). It is an important attributes according to which consumer will elect poultry products, other attributes such as tenderness, cooking loss and shelf-life are important to the consumer after purchasing the product (Jeremiah, 1982). Discoloured part that is most affected is frequently the breast muscle. Breast muscle accounts for a large portion of the live weight (5%), and it is more sensitive to factors that contribute to discoloration. Changes in meat colour are due to oxidation of red oxymyoglobin to metmyoglobin (MMG), which gives meat an unattractive brown colour. Discoloration of poultry can be related to the amount of these pigments that are present in the meat, the chemical state of the pigments. The colour has an effect on the decision purchase, consumer look at the meat before purchase the product and also weather the meat has a good shelf-life.

### **2.6.2 Cooking loss**

Cooking loss is the amount of moisture released by the meat during cooking when the muscle proteins denature, causing structural changes in the tissue of the meat (Honikel, 2004) and it is often ignored by meat scientists and technologists. Cooking loss is a good indicator for the production yield of cooked meat products. During heating meat proteins denature and cause structural changes such as transversal and longitudinal shrinkage of muscle fibers and connective tissue shrinkage. The amount of moisture lost during cooking is determined by the  $pH_u$  of the meat. Meat with a high  $pH_u$  will have a lower cooking loss compared to meat with a low  $pH_u$  (Honikel, 2004; Lawrie and Ledward, 2006).

The cooking involve the process of physico-chemical changes between food components causing the effect of heat transfer to improve their palatability and digestibility. Cooking loss reduces heat damage to proteins, diminishes the loss of liquids and aroma compounds at the same time

providing longer shelf life comparing to traditional cooking methods (Creed and Reeve, 1998). The cooking loss depends on the raw meat quality as reported by Aaslyng *et al.* (2003) meat with high cooking loss will have lower WCH.

According to (Bender, 1992; Barbantia and Pasquini, 2004; Obuz *et al.*, 2004), major components of cooking losses are thawing, dripping and evaporation. Drip loss results from gravity action on the extracellular water and is affected by muscle shortening (Honikel, 2009). It is a good indicator for the weight loss accumulation during raw meat storage. Thawing loss is the loss of fluid resulting from the formation of exudates following freezing and thawing. (Hui, 2004). Improper thawing can damage the physicochemical and microbiological properties of frozen food (Hong *et al.*, 2009; Hong *et al.*, 2002). Evaporation is the loss of fluid from the meat surface through its conversion to gaseous form (Yu *et al.*, 2005).

### **2.6.3 Tenderness**

Tenderness is a major quality factor, it's the most important sensory characteristic of meat, and most important factor in consumers satisfaction (Barbanti and Pasquini, 2005). It can be attributed to a person perception of meat such as softness to tongue, resistance to tooth pressure and adhesion (Muchenje *et al.*, 2008). The most satisfying factor of tenderness in meat is mainly caused by changes in structure of connective tissues solubilised by heat, while at the same time heat denaturation of myofibrillar proteins generally causes meats toughening. Jelenikova (2008) reported that meat with pH ranging from 5.8 to 6.1 is most tender while the pH values from 6.1 to 6.3 are associated with the toughest meat. Maltin *et al.* (2003) reported that post-mortem factors such as sarcomere length, temperature, pH and proteolysis have a major impact on tenderness.

The shear force value is an indication of the degree of toughness or tenderness (Omojola and Adesehinwa, 2003).

#### **2.6.6 Fatty acids profiles in meat quality**

Poultry meat has many desirable nutritional characteristics such as low lipid content and relatively high concentrations of polyunsaturated fatty acids. Fat is an unpopular constituent of meat for consumers, being considered unhealthy. Yet fat and fatty acids, whether in adipose tissue or muscle, contribute importantly to various aspects of meat quality and are central to the nutritional value of meat. It is reported that poultry and pork have a favourable balance between polyunsaturated fatty acids and saturated fatty acids (Wood and Esner, 1997) and that when grain based or grass based diets are fed they normally lead to a relatively more n-6 or n-3 fatty acids, respectively. In meat containing more unsaturated fatty acids there is a risk that their profile will change during storage (Jeremiah, 1980), the higher the amount of unsaturated fatty acid present, the greater the risk of oxidation, causing rancidity and colour deterioration (Eder *et al.*, 2005)

There is increased interest in the ways to manipulate the fatty acid composition of meat. This is because meat has a major source of fat in the diet and especially of saturated fatty acids, which have been implicated with disease like cancers and especially coronary heart disease (Department of Health 1994). Nutritionists have focused on the type of PUFA and the balance in the diet between n-3 PUFA formed from  $\alpha$ -linolenic acid (18:3) and n-6 PUFA formed from linoleic acid (18:2) (Williams, 2000). The ratio of n-6:n-3 PUFA is also a risk factor in cancers and coronary heart disease, especially the formation of blood clots leading to a heart attack (Enser, 2001).

Fatty acid are involved in various aspects of meat quality, they have very different melting points. Variation in fatty acid composition has an important effect on firmness or softness of the fat in meat, especially the subcutaneous and carcass fat but also the intramuscular fat. The ability of unsaturated fatty acids, especially those with more than two double bonds, to rapidly oxidize, is important in regulating the shelf life of meat (rancidity and colour deterioration). However, this tendency to oxidize is important in flavour development during cooking. The fat ingested by monogastric animals undergoes relatively few modifications in the intestinal tract, in such a way that dietary fatty acid profile is reflected in their body composition (Mourot and Hermier, 2001).

Therefore feed restriction causes fat deposition in broilers. It increased the SFA ratio in chicken meat and decreased the total PUFA and n-3 fatty acid ratios. Fat is a means of storing energy for periods of limited food supply. Similarly, Zhan *et al.* (2006) confirmed that broilers that are on feed restriction, resulted in an increased fat ratio in breast meat.

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### **Chapter 3: The effect of quantitative feed restriction duration on growth performance and carcass characteristics of broiler chickens**

#### **Abstract**

The objective of the study was to determine the effect of quantitative feed restriction duration on growth performance and carcass characteristics of broilers. A total of 144 day-old broiler chicks were reared in a deep litter system until slaughter at 42 days. The birds were randomly allocated to each of the nine compartments. Each treatment was replicated three times with 16 birds per compartment being fed as a group and each bird was regarded as the experimental units. Birds were fed with starter, grower and finisher diets. The average daily gain (ADG), average daily feed intake (ADFI) and the feed conversion ratio (FCR) were computed for each week. Chickens were all slaughtered at 42 days of age and the slaughter weight, carcass weight, and internal organs weights were measured. The body weight gained by the birds in T1 (control) was similar as the birds that were restricted for a week. The treatments had a significant effect on the average daily gain in week 4, 5 and 6. The ADG for T2 was higher ( $P < 0.05$ ) at week 5 after 1 week of restriction, than TRT1 and 3. The feed conversion ratio was significantly higher in T 3 after 2 weeks of restriction. In T 2 and 3, feed intake was significantly lower than in birds fed *ad libitum* at week 4 at the start of the treatment. There was no significant effect ( $P > 0.05$ ) on the relative weights of heart weights, liver, gizzard, feets and heads among the treatment groups except for intestine weight which was lower ( $P < 0.05$ ) in T 1 than T 2 and 3. It was concluded that broilers that were restricted for one week had a positive results in growth performance, similar as in broilers that were not restricted. Feed restriction had minimal effect on the organ weights of broiler chickens.

***Keywords:*** Feed restriction, duration, body weight gain, average daily gain, feed conversion ratio and broilers

### 3.1 Introduction

The growth productivity of broilers is influenced by improving growth performance: body weight (BW), average daily gain (ADG) and feed conversion rate (FCR). The FCR is a major factor in reducing production cost and improving the broilers growth effectiveness. Feed cost represents about 70% of the cost of production broilers (Aggrey *et al.*, 2010). The benefits of feed restriction are the monetary savings from raising feed conversion (Proudfoot *et al.*, 1983). The main reason for controlling feed intake in broilers is to prevent wastage of feed. Therefore, the present study was carried out to evaluate the effect of different durations of feed restriction on growth and carcass characteristics of broiler chicks.

Feed restriction suppresses growth during the restriction period, but the growth reduced can be compensated with greater future intake (Govaerts *et al.*, 2000). Negative effects of feed restriction include chronic hunger, and feeding frustration, increased aggression and overdrinking (Savory *et al.*, 1993). Negative physiological effects include adrenal hypertrophy and persistent increases in corticosterone secretion after 24 h restriction or feed-off days or increased susceptibility to *Staphylococcus aureus* after 48 h (Gross and Siegel, 1982).

Feed restriction provides the opportunity to take advantage of compensatory growth. Compensatory growth refers to the period of rapid growth, relative to age, exhibited by mammals and birds after a period of nutritional restriction. The factors most critical to compensatory growth include the age at which the restriction is applied, the sex and genotype of the animal, the length and severity of the restriction the quality and length of re-feeding of the re-alimentation diet (Wilson *et al.*, 1990). It can be accomplished when birds divert more energy towards growth (Ryan, 1990).

Carcass characteristics are important factors to consider when evaluating alternative feeding programs (Ledin *et al.*, 1984a). Zubair and Leeson (1994b) observed that by restricting broiler chickens there is relative enlargement of digestive organs, especially the gizzard, crop, pancreas and liver which improve feed intake. Internal organs are significantly affected by restriction during re-alimentation period the stomach growth rapidly and the other organs except kidneys (Ledin, 1984b). Feed restriction has been studied to improve economical and biological performances.

## **3.2 Material and Methods**

### **3.2.1 Study site description**

The study was conducted at the University of Fort Hare based in Alice, in the Eastern Cape, South Africa. The site is 520 m above sea level and is located 32.48°S and 26.53°E. The average rainfall is approximately 480 mm per year, and mostly comes in summer. Mean temperature of the farm is about 18.7°C per year. The topography of the area is generally flat with a few steep slopes.

### **3.2.2 Feed restriction treatments**

A total of 144 day-old broiler chicks were purchased from Umthiza Agricultural Co-operation located in Alice town in the Eastern Cape Province, South Africa. All the chicks were managed in one brooding house for the first 21 days. On day 22, the chicks were randomly allocated to the following three treatments; the control (T1), one week of feed restriction (T2), and two weeks of feed restriction (T3), three broiler houses were sub-divided into three compartments each. The birds were randomly allocated to each of the nine compartments. The birds were randomly allocated to each of the nine compartments. Each treatment was replicated three times with 16 birds per compartment being fed as a group and each bird was regarded as the experimental unit. The stocking density was 16 broiler/m<sup>2</sup> in all the treatments. Lights were provided throughout the study, infrared lamps were removed after two weeks. All the birds were housed in a low-cost housing unit, where ventilation and temperature was not artificially controlled. Treatment 1 group was fed *ad libitum* with a constant access to the water, for T2 birds were deprived of feed from 19h00 until 07h00 and from the 22nd to the 28th day, and in the T3 birds were deprived feed from 19h00 until 07h00 and from the 22nd to the 35th day. The feed consumed by each bird was measured weekly.

### **3.2.3 Management of birds**

Day old-chicks were placed in the brooding house, offered water with stress pack immediately on arrival and feed was provided two hours later. They were kept in the brooding house for 21 days before they are allocated to their respective treatment groups. All the birds were housed in a low-cost housing unit, where ventilation and temperatures were not artificially controlled. Infrared lights were used to provide heat during the brooding period from day old until the second week of age. Feed was supplied continuously by constantly topping up the empty troughs. Feed wastages were minimized by filling the troughs to about three quarter full. Birds were fed with broiler starter from day-old until day 21, grower feed from day 22 until day 35, and with broiler finisher from day 36 up until day 42.

**Table 1. 1** Feed specification (guaranteed levels of nutrients) of the three phase diet that was fed to chickens

<b>Nutrients (g/kg)</b>	<b>Starter</b>	<b>Grower</b>	<b>Finisher</b>
Protein(minimum)	190	170	160
Protein(minimum)	190	170	160
Total Lysine(minimum)	12	9	9
Total Methionine(minimum)	5	4	4
Moisture(maximum)	120	120	120
Fat(minimum)	25	25	25
Fibre (maximum)	50	70	70
Calcium(minimum)	8	8	7
Calcium(minimum)	12	12	12
Phosphorus(minimum)	6	5	5

*Epol Manufacture*

### **3.2.5 Growth performance**

One bird was regarded as the experimental unit, chicks were weighed and feed measured weekly according to the replicates numbers using a normal scale. Body weight gain (BWG), feed intake (FI), average daily gain (ADG) and feed conversion efficiency (FCE) of the chicks were recorded at the beginning of each week, starting from placement until slaughter. Body weight gain was determined by subtracting the final body weight (g) from the initial body weight (g); average daily gain (ADG) is equal to week 2 weight - week 1 weight / no. days between; feed conversion efficiency (FCE) by dividing average feed intake (g) by the average body weights (g); and feed intake (FI) was determined by subtracting given feed (g/day) from the remaining feed (g/day).

### **3.2.6 Slaughter procedure**

The meat yield and carcass characteristics was determined at the end of the experiment according to the methods described by Ayanwale *et al.* (2003), by randomly selecting one bird from each replicate. The selected birds were starved of feed and water over night for 12 hours. Before slaughtering, the individual weight of the birds was recorded. Slaughtering was done following the normal procedures of the abattoir, where they were first stunned with an electrical stunner (50-70volts) under the beak for 5seconds to reduce unconscious before slaughter. The unconscious chickens were then attached by their legs onto a conveyor line. While hanging, the throats were cut using a sharp knife, only one person was responsible for the throat cutting and one person for stunning. While they were hanged, it gave time for the chickens to bleed. After plucking the feathers, the fully dressed weights of the carcasses were taken and recorded, and carcasses were then separated into breast, thigh, feet, head and the internal organs (viscera). The parts were individually weighed and the weights were expressed as percentages of the live

weight of the carcass. Dressing percentage was calculated as proportion of carcass weight to live weight of each bird.

### **3.2.7 Determination of carcass and organ weights**

### **3.3 Statistical Analysis**

The AFI, BWG, ADG, FCE and the carcass characteristics (slaughter weight, carcass weight, dressing %) and intestinal organs (liver weight, heart weight, gizzard weight) were analyzed using one-way analysis of variance (ANOVA) SAS (2003). The least significant difference (LSD) method was used to compare the means.

The statistical model that was used is,  $Y_{ij} = \mu + \tau_i + \beta_j + E_{ij}$ .

Where,

\* $Y_{ij}$ = response variables (AFI, BWG, ADG & FCE), carcass characteristics and internal organs

\*  $\mu$  =constant

\*  $\tau_i$  = overall mean

\*  $\beta_j$  = effect of week

\* $T_i$ = treatment effect (Control, birds restricted for one week, birds restricted for two weeks)

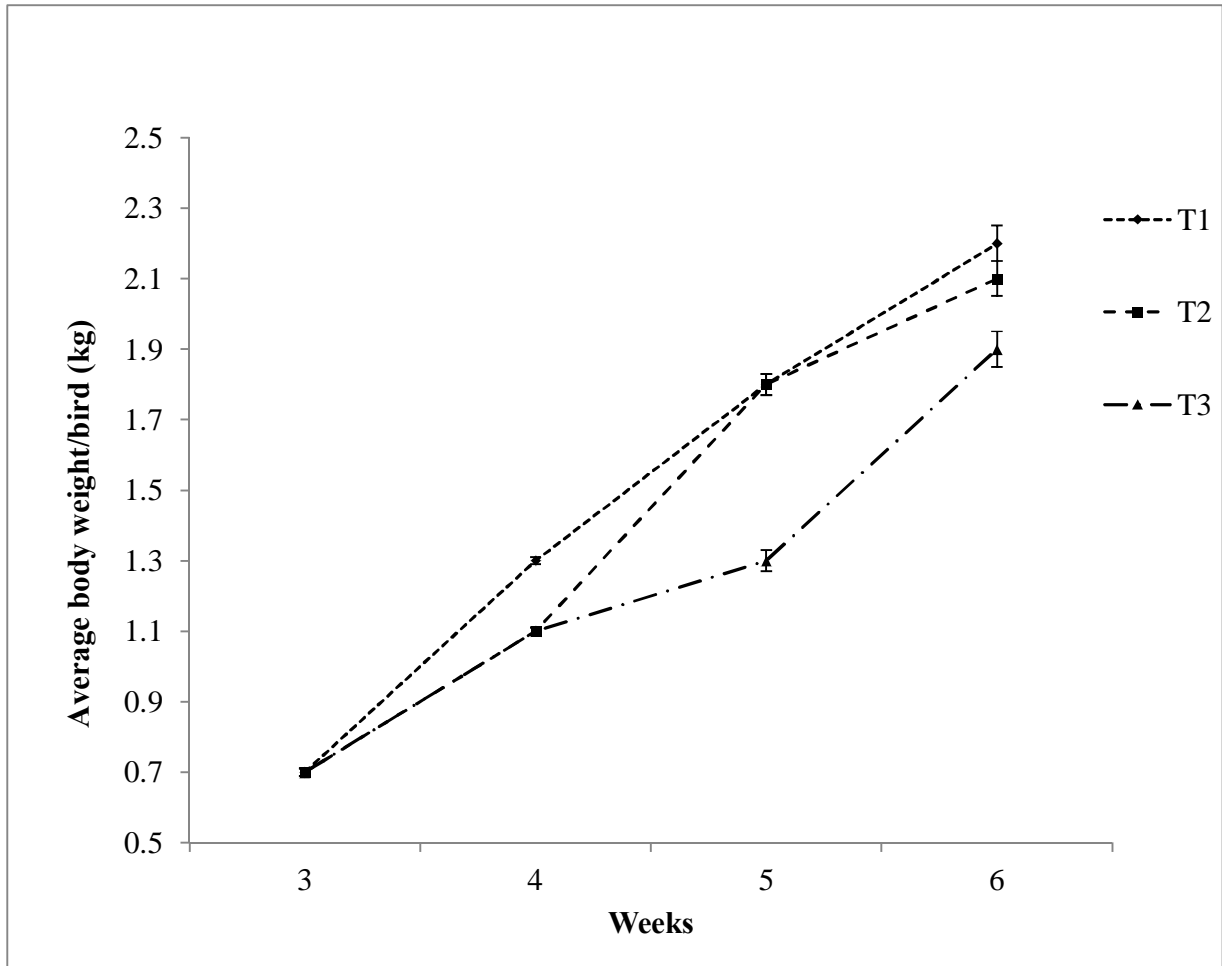
\* $E_{ij}$ = standard error

### 3.4. Results and discussion

The effect of quantitative feed restriction on body weight gain during feeding broiler chicken is presented in Figure 3.1. The lowest body weight gain was observed from the birds in T 3 which were kept under two weeks of feed restriction and they had one week of sustaining before slaughter. These results concur with Newcombe *et al.* (1992) and Palo *et al.* (1995) who observed reduced weight gain in restricted broilers compared to that of full-fed control birds. On the other hand, these results are not in accordance with those of Fontana *et al.* (1992), Zhong *et al.* (1995); Khetani *et al.*, (2009) and Zubair and Leeson (1996), who observed similar weight gain in feed restricted and *ad libitum* fed birds.

The T 2 birds which were restricted for one week compensated and reached the same weight as the unrestricted birds at week 5 and 6. Therefore this implies that the period of restriction did not affect the market body weight and similar results were observed in several studies (Plavnik and Hurwitz *et al.*, 1985; Mazzuco *et al.*, 2000). The T 3 groups were unable to totally compensate for the loss of weight gain during the restriction period. Similar findings by Yu *et al.* (1990) and Fattori *et al.* (1990) also showed that there was not a complete body weight recovery after feed restriction in chickens with longer period. Lee and Leeson (2001) also observed considered that full body weight recovery could be more consistent if short restriction periods were used instead of the long ones.

Accumulation of feed intake on the treatments of broiler chickens is shown in Figure 7.1 in the appendix. The feed consumed by one week restriction were less than consumed by control group, even though they reached the same slaughter weight. Using feed restriction for one week had a good effect.



**Figure 3. 1.** Growth curves of birds exposed to different feed restriction durations T 1 -birds fed *ad libitum*, T 2 -birds restricted of feed for one week, T 3- birds restricted of feed for two weeks

The effect of feed restriction on average daily gain of broiler chicken is presented in Table 3.1. The treatments had a significant effect ( $P < 0.05$ ) on the average daily gain in week 4, 5 and 6. Feed restriction for TRT 3 was significantly ( $P < 0.05$ ) reduced on the ADG of broiler chicken at week 4. After feed restriction period in week 5, specifically in TRT3 group had lower ADG than other treatments. Similar results in weight gain were reported by Lee and Leeson (2001) and Urdaneta-Rincon and Leeson (2002) when broilers were fed with quantitative feeding from day 1 until day 14 of age. The TRT3 broiler chickens had higher ADG than other groups at week 6; T 2 had high ADG at week 5. A study by Yu and Robinson, 1992, postulated that the accelerated growth rate might be associated with relatively lower overall maintenance energy needs in feed restricted chickens compared to that in the control group.

**Table 3. 1:** Least square means and standard errors of average daily gain of birds subjected to control, one week and two weeks of feed restriction treatments from week three until six weeks of age.

Weeks	Treatments		
	T1 (Control)	T2 (One week)	T3 (Two weeks)
<b>Week3(g/bird/day)</b>	57.4± 4.67	55.7.4±4.59	60.9±4.75
<b>Week4(g/bird/day)</b>	87.1 <sup>b</sup> ± 4.67	57.6 <sup>a</sup> ±4.67	53.4 <sup>a</sup> ±4.67
<b>Week5(g/bird/day)</b>	78.5 <sup>b</sup> ±4.67	102.9 <sup>c</sup> ±4.67	36.0 <sup>a</sup> ±5.11
<b>Week6(g/bird/day)</b>	60.9 <sup>b</sup> ± 4.67	44.3 <sup>a</sup> ±4.75	93.5 <sup>c</sup> ±4.75

Means in the same row with similar superscripts are not significantly different ( $P>0.05$ ) from each other.

The effect of quantitative feed restriction on feed conversion efficiency of broiler chicken is shown in Table 3.2. At week 4 there was a significant effect ( $P < 0.05$ ) between treatments, with treatment 1 having highest value. At week 5, T 2 had higher feed conversion efficiency when compared to than T 1 and 3. This maybe may be due to the fact that this group received feed to maintain their body weight after restriction period. Also for T 3 after 2 weeks of restriction the feed conversion efficiency was high, so after the restriction period feed conversion was improved. According to Rincon and Leeson, 2002, feed restriction improves feed efficiency in chickens, which cause high feed intake after the restriction period. Therefore, T2 after feed restriction had high conversion efficiency, which made it reach the same slaughter weight as the control group.

**Table 3. 2:** Least square means and standard errors of feed conversion efficiency of birds subjected to control, one week and two weeks of feed restriction treatments from week three until six week of age

Weeks	Treatments		
	T1 (control)	T2 (one week)	T3 (two weeks)
Week3(g/bird/day)	1.84± 0.11	1.81± 0.11	1.70 ±0.12
Week4(g/bird/day)	0.57 <sup>a</sup> ±0.11	0.73 <sup>b</sup> ±0.11	0.69 <sup>c</sup> ± 0.11
Week5(g/bird/day)	0.74 <sup>a</sup> ±0.11	0.53 <sup>a</sup> ±0.11	1.51 <sup>b</sup> ±0.13
Week6(g/bird/day)	1.55 <sup>b</sup> ±0.11	1.83 <sup>b</sup> ±0.12	0.8 <sup>a</sup> ±0.12

Means in the same row with similar superscripts are not significantly different (P>0.05) from each other

The effect of feed restriction on the average feed intake of broiler chickens is presented in Table 3.3. In T 2 and 3 feed intakes was significantly lower than in birds fed *ad libitum* at week 4. After one week of feed restriction from 21- 28 day TRT2 birds totally compensated, feed intake was high on day 35. At week 5, T 3 groups had significantly reduced feed intake than TRT1 & 2 after the duration of feed restriction period. At day 42 there was no significant P <0.05) difference feed intake for T1 and 2, with T3 having the highest feed intake. The highest feed intake can be related to the hypertrophy of the gastrointestinal tract that occurs after the restriction period when the birds are fed *ad libitum*. The responses observed in the present study partially agree with other researchers (Zhan *et al.* 2007; Camacho *et al.* 2004; Sahraei and Shariatmadari, 2007) which conclude that feed restriction increases feed intake.

**Table 3. 3:** Least square means and standard errors for average daily feed intake average daily gain subjected to control, one week and two weeks of feed restriction treatments from week three until six weeks of age

Weeks	Treatments		
	T1 (control)	T2 (one week)	T3 (Two weeks)
Week4(g/bird/day)	152.5 <sup>c</sup> ± 5.18	118.0 <sup>b</sup> ± 5.18	107.3 <sup>a</sup> ± 5.18
Week5(g/bird/day)	164.8 <sup>b</sup> ± 2.69	165.9 <sup>b</sup> ± 2.69	117.3 <sup>a</sup> ± 2.69
Week6(g/bird/day))	183.8 <sup>a</sup> ± 1.86	183.1 <sup>a</sup> ± 1.86	186.3 <sup>b</sup> ± 1.86

Means in the same row with similar superscripts are not significantly different (P>0.05) from each other.

The effect of quantitative feed restriction on carcass characteristics of broiler chicken is presented in Table 3.4. The carcass weight of broilers was found to be higher ( $P < 0.05$ ) in TRT1 followed by T2 with T3 group having significantly lower carcass weights. The dressing percentage was found to be highest T 2 group, although there was no significant difference effect on slaughter weight between *ad libitum* and one week restriction of broilers. These results contradict with Mahamood *et al.* (2007) who found that feed restriction had no effect on the dressing percentage of broiler chickens. There was no significant effect ( $P > 0.05$ ) on the relative weights of the heart, liver, gizzard, feet and heads among the treatment groups except for intestine weight which was lower ( $P < 0.05$ ) in T 1 than T 2 and 3 that were under restriction. This may be caused by an increase in feed conversion ratio in restricted broilers. Mazeti and Furlan (2008) also observed a higher relative weight in restricted animals, compared with birds at *ad libitum*. The results are in accordance with observations by Susbilla *et al.* (1994) and Jones (1995) who found no significant difference in relative weights of the liver at slaughter due to feeding regimes. Mahamood *et al.* (2007) also found no significant difference in gizzard weight and heart.

**Table 3. 4:** Least square means and standard errors of dressing percentage and organ weights as proportions of live weights, subjected to control, one week and two weeks of feed restriction treatments from week three until six weeks of age.

<b>Carcass characteristics (kg)</b>	<b>T1 (Control)</b>	<b>T2 (one week)</b>	<b>T3 (Two weeks)</b>	<b>P-value</b>
<b>Dressing percentage</b>	78.0 <sup>b</sup> ±1.17	80.6 <sup>b</sup> ±1.17	74.9 <sup>a</sup> ±1.17	0.0035
<b>Slaughter Weight</b>	2.28 <sup>b</sup> ± 0.04	2.15 <sup>b</sup> ± 0.45	1.96 <sup>a</sup> ± 0.05	0.0001
<b>Carcass Weight</b>	1.78 <sup>b</sup> ±0.03	1.73 <sup>b</sup> ±0.03	1.47 <sup>a</sup> ±0.04	0.0001
<i>Organ weight as proportion of live weight</i>				
<b>Liver Weight</b>	0.017 ±0.001	0.0017± 0.001	0.018 ±0.001	0.815
<b>Heart Weight</b>	0.004± 0.002	0.004 ±0.002	0.004 ±0.001	0.999
<b>Gizzard Weight</b>	0.024 ± 0.001	0.026 ±0.001	0.025 ±0.001	0.772
<b>Intestine Weight</b>	0.020 <sup>a</sup> ±0.001	0.026 <sup>b</sup> ±0.001	0.026 <sup>b</sup> ± 0.001	0.010
<b>Feet Weight</b>	0.036± 0.002	0.038 ±0.002	0.040 ±0.002	0.403
<b>Head Weight</b>	0.026± 0.001	0.027 ±0.001	0.027 ±0.001	0.796

<sup>abc</sup>Means in the same row with similar superscripts are not significantly different (P>0.05) from each other

### **3.5. Conclusion**

Feed restriction had an effect on growth performance of broiler chicken; furthermore, the weight gained by the birds in unrestricted feeding was similar to the broilers that were restricted for one week. The broilers that were restricted for two weeks were not able to compensate and reach the slaughter weight when compared to the other treatments. The feed conversion efficiency was highest at week 5 for one week restricted birds, which is why there was high average daily gain. The ADG for one week restriction was high at week 5, after one week of feed restriction period similarly ADG for two weeks restriction was high in week 6 after one week of feed restriction, although it did not reach the same slaughter weight as other treatments. Feed restriction had minimal effect on the organ weights of broiler chickens, although intestines were affected by restriction. The study showed that one week restriction bird had better results compared with two weeks of restricted birds. According to the study feed restriction for one week may be suitable for the growth performance of broiler chicken. However, can it be suitable for the meat quality of broiler chickens.

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#### **Chapter 4: Effect of quantitative feed restriction duration on physico-chemical shelf life indicators of broiler meat**

##### **Abstract**

The objective of the study was to evaluate the effect of restricted feeding duration on physico-chemical shelf-life indicators of broiler meat. A total of 144 day old broiler chicks were reared in a deep litter system until slaughter at 42 days. Chicks were randomly allocated to three treatments which were replicated three times with 16 birds per replicate. The three treatments were the control (T1), one week of feed restriction (T2), and two weeks of feed restriction (T3). Birds were fed with starter, grower and finisher diets. The parameters for meat quality were analysed using one-way analysis of variance. After slaughter breast muscle where sampled for WBSF and cooking loss after 10 days of storage, breast muscles were also sampled for the determination of colour ( $L^*$ ,  $a^*$ ,  $b^*$ ), saturation index, hue angle ( $H_o$ ) and pH for 10 consecutive days after slaughter. Significant effect ( $P < 0.05$ ) was found in cooking loss, with WBSF having no significant effect ( $P > 0.05$ ) for breast muscles. Using quantitative feed restriction had a significant effect ( $P < 0.05$ ) on the pHu, lightness, redness, yellowness and saturation index of the meat, however, hue angle was not affected by the treatment. The pH level on breast meat from treatment 3 were 5.95 after slaughter with treatment 1 and 2 having higher values (6.05, 6.1, respectively). The pH levels in all the treatments were generally constant after 24hours to day 5 (5.87-6.05). The lightness levels in all the treatments were generally constant from day1 to day 7 (42.56 ó 44.53). At day 8 the  $L^*$  (lightness) values in treatment 2 reached its peak (58.49) then declined on day 9. The  $b^*$  values started to decrease from day 3 to day 6 then peaked up again at day 7 except for treatment 1. There was no significant effect on the saturation index and hue angle on breast muscle. In conclusion, feed restriction did not affect meat quality after 24

hours, all the values were within normal range, and feed restriction had a minimal effect on shelf-life of broiler chickens during 10 days of storage.

**Keywords:** Shelf-life, meat colour, meat quality, meat pH, cooking loss and tenderness

#### **4.1 Introduction**

Broiler chickens have been improved in many traits such as daily weight gain, feed efficiency and resistance to disease. However, the high selection intensity for growth rate has caused many problems; especially the decreasing development of meat quality attributes (Rance *et al.*, 2002). Meat quality attributes such as juiciness, tenderness, drip loss, cooking-loss, ultimate pH and shelf-life are the major parameters considered in the assessment of meat (Muchenje *et al.*, 2008; Muchenje *et al.*, 2009). They are important to the consumer as well as to the processor when producing value-added meat products (Allen *et al.*, 1998).

The feeding method is a very important factor of poultry growth, production and meat quality since the feed composition can affect or change strongly the characteristics of chicken quality (Jaturasitha *et al.*, 2004; 2008). The effect of feed restriction on meat quality depends on implementation, on the intensity of feed restriction, its duration, and age when it is applied. Feed restriction can enhance meat quality by reducing the amount of total carbohydrate available for postmortem conversion of glycogen to lactic acid (DeSmet *et al.*, 1996). Feed restriction is seen as a tool for raising muscle ultimate pH and reducing the incidence of pale, soft and exudative (PSE) pork (Warriss, 1982). On the other hand, long feed restriction increase the prevalence of DFD (dark, firm, dry) pork due to muscle glycogen exhaustion (Eikelenboom *et al.*, 1991; Gispert *et al.*, 2000; Guàrdia *et al.*, 2005). Feed restriction is also observed in reduced growth and enhanced fat deposition when animals were fed a reduced energy feed.

Poultry meat is a perishable product consisting of carbohydrates, protein, lipids, and water. Product conservation must meet certain standards in order to preserve its quality until consumption by the final user. Shelf-life is the period of time between packaging of a product and its end use while the product properties remain acceptable for the product user (Lorenzo and Gomez, 2012). The shelf-life properties may include colour, appearance, texture, flavour and nutritive value (Singh and Singh, 2005) hence consumers judge meat quality from these properties. According to Cross *et al.* (1986), those meat properties are among the most important and perceptible that influences the initial and final quality judgment by consumers.

To extend shelf-life, there are common methods to store fresh meat like the vacuum packaging, modified atmosphere packaging (MAP) and by using an active packaging (Marsh and Bugusu, 2007). Active packaging consists of incorporating active agents into packaging, which interact with meat through various mechanisms such as eliminating undesirable compounds or adding beneficial compounds to the product (Vermeiren *et al.*, 1999). Packaging extends the shelf-life and improves safety or sensory properties while maintaining the quality of the product (Anonymous, 2001).

Feeding strategy is also important in the management which is most actively used as a quality control tool in the production of meat. Therefore, the aim of this study was to determine the effect of quantitative feed restriction on the physico-chemical shelf-life indicators of broiler chicken.

#### **4.2.1 Study site and management of broiler chicks**

The information on the study site, experimental animals and management of the chickens is described in Sections 3.2.1 and 3.2.2.

#### **4.4.2 Slaughter procedure**

The information on the slaughtered procedure is described in Section 3.2.6

#### **4.2.3 Procedures after slaughter**

The chickens were slaughtered at the end of the experiment (day 42). After plucking, evisceration and dressing, the carcasses were stored at 4°C overnight. The left breasts were deboned, the skins removed and cut into halves longitudinally in preparation for the shelf-life trial. Each of the halves of the left breasts were weighed (WB) and packed. The trays were then stored at 4°C over 10 days. Every day each sample per treatment was randomly removed from the cooler to measure the shelf-life of meat.

### **4.3. Meat quality measurement**

#### **4.3.1 Meat pH measurement**

The pH of meat was determined from the chicken breast daily after slaughter for 10 consecutive days. The measurement were carried out using a portable pH meter (crison ph25, crison instruments SA, Spain) equipped with a penetrating electrode. The pH meter was calibrated using pH 4, pH 7 and pH9 standard solution (crison instruments SA, Spain).

#### 4.3.2 Meat colour measurements

Measurements for breast meat colour coordinates (lightness, L\*; redness, a\* and yellowness, b\*) were measured using a colour-guide 45/0 BYK-Gardner GmbH machine, with a 20mm diameter measurement area and illuminant D65-day light, 10° standard observer. Three readings were taken by rotating the colour Guide 90° between each measurement in order to maintain a representative average of the colour. The machine was calibrated each day before taking measurements. The green, black and white standard colour samples provided for this purpose will be used. The saturation index (SI) and hue angle (HA) was calculated using the following formulae: SI index=  $[(a^*2+b^*2)0.5]$  and Hue Angle  $[(\tan^{-1}(b^*/a^*))]$  according to Boccard *et al.* (1981).

#### 4.3.4 Determination of cooking loss and tenderness

The meat samples were placed in a plastic bag and cooked using a water bath at 75 °C for 45 minutes (Ding, Kou, Cao & Wei, 2010). Cooking loss was then calculated using the following formulae:

$$\text{Cooking loss (CL) \%} = \frac{\text{weight before cooking} - \text{weight after cooking}}{\text{Weight before cooking}} \times 100$$

The tenderness of breast muscle was determined using the Instron- Warner-Bratzler Shear Force (WBSF). Following cooking, sub samples of specified core diameter were cored parallel to the grain of the meat. Three sub samples measuring 10 mm core diameter were cored parallel to the grain of the meat. The samples were sheared perpendicular to the fibre direction using a Warner Bratzler (WB) shear device mounted on an Instron (Model 3344) Universal Testing apparatus

(cross head speed at 400mm/min, one shear in the centre of each core). The mean maximum load (N) was recorded for the batch.

#### 4.4 Statistical analysis

The effect of feeding on pH, colour, analysed using PROC GLM procedures of SAS (2003) and pair wise comparisons of LSMeans were done.

The statistical model used was

$$Y_{ij} = \mu + \alpha_i + \beta_j + e_{ij}$$

Where

$Y_{ij}$  = meat colour ( $L^*$ ,  $a^*$ ,  $b^*$ ), SI, HA, pH, cooking loss and tenderness

- $\mu$  = constant
- $\alpha_i$  = effect of feeding (Control, birds restricted for one week, birds restricted for two weeks)
- $\beta_j$  = effect of days (1-10)
- $e_{ij}$  = random error

#### 4.5 Results and Discussion

Table 4.1 shows effect of treatment on cooking loss and tenderness of broiler chicken meat. There was a significant difference ( $P < 0.05$ ) on the cooking loss of the breast muscle. However, WBSF of breast muscle were not affected by treatment. The WBSF were observed to be high in TRT 3 ( $13.6 \pm 0.77$ ) compared to TRT1 and TRT2 ( $12.0 \pm 0.77$  and  $12.1 \pm 0.77$ , respectively). This is in agreement with findings by Kristensen *et al.* (2004) and Therkildsen *et al.* (2004) who reported that when exhibiting feed restriction there is an increase in muscle protein turnover and this therefore improve WBSF in broilers. Cooking loss values were ranging at 13.4, 14.3 and 16.1 for TRT 1, TRT 2 and TRT 3, respectively they were lower than the values reported by other authors (Barbanti *et al.*, 2005).

**Table 4. 1** Least square means and standard errors of cooking loss (CL) and warner braztler shear force (WBSF) of broiler as affected by treatment. T1 -birds fed ad libitum, T2 óbirds restricted for one week, T3-birds restricted for two weeks

Parameters	Treatments			P-Value
	T1	T2	T3	
Cooking Loss (CL %)	16.1 ±0.66 <sup>b</sup>	14.3 ±0.66 <sup>a</sup>	13.4± 0.66 <sup>a</sup>	0.015
WBSF(N)	12.0 ±0.77	12.1 ± 0.77	13.6 ±0.77	0.255

<sup>abc</sup> Means with different superscripts in a row are significantly different at (P < 0.05)

The effect of treatment on pH, colour, saturation index and hue angle of chicken breast meat after 24 hours of storage are shown in Table 4.2. Though HA was not affected by treatment ( $P > 0.05$ ), significant difference ( $P < 0.05$ ) was observed for the effect of treatment on meat pH<sub>u</sub>, L\* (lightness), a\* (redness), b\* (yellowness) and SI (saturation index). The current results for breast ultimate pH was significantly different ( $P < 0.05$ ) between T1 (5.89) and T2 (5.99), while T2 (5.99) was not significantly different to T3 (6.01), the highest results was found in T3, this may be due to stress of restriction. The results from this study agree with the study by Maltin *et al.*, 2003, anaerobic glycolysis generates lactate that accumulates, lowering the intracellular pH, so that by 24 h post-mortem, the pH falls to an ultimate pH (pH<sub>u</sub>) of about 5.4 to 5.7.

The meat in T1 showed higher values of redness and yellowness (6.63, 15.89), compared with T2 (2.86, 13.23) and T3 (4.94, 14.73). Furthermore, T1 was observed to have a low pH<sub>u</sub>, resulting in meat that appears less red and more yellow, which is in agreement with other studies where a sample with low pH<sub>u</sub> is expected to reduce the importance of myoglobin in selectively absorbing green light. Though lightness values were significant ( $P < 0.05$ ), the lowest L\* values were found in meat from T3 (42.06), compared with T1 (42.56) and T3 (43.26). This may be caused by pre-slaughter handling and long withdrawal of feed resulting in chickens being stressed.

**Table 4.2** Least square means and standard errors for pHu, L\*(lightness), a\*(redness), b\*yellowness), SI (saturation index) and HA (hue angle) of meat samples (breast Chicken) as affected by treatment after 24hours of storage. T1 -birds fed ad libitum, T2 ó Birds restricted of feed for one week, T3- Birds restricted of feed for two weeks

Attributes	Treatments			SEM
	T1	T2	T3	
<b>pHu</b>	5.89 <sup>a</sup>	5.99 <sup>b</sup>	6.01 <sup>b</sup>	0.007
<b>L*</b>	42.56 <sup>a</sup>	43.26 <sup>b</sup>	42.06 <sup>a</sup>	0.837
<b>a*</b>	6.63 <sup>c</sup>	2.86 <sup>a</sup>	4.94 <sup>b</sup>	0.136
<b>b*</b>	15.89 <sup>b</sup>	13.23 <sup>a</sup>	14.73 <sup>ab</sup>	0.176
<b>SI</b>	17.19 <sup>c</sup>	13.57 <sup>a</sup>	15.73 <sup>b</sup>	0.193
<b>HA</b>	0.97	0.99	0.97	0.002

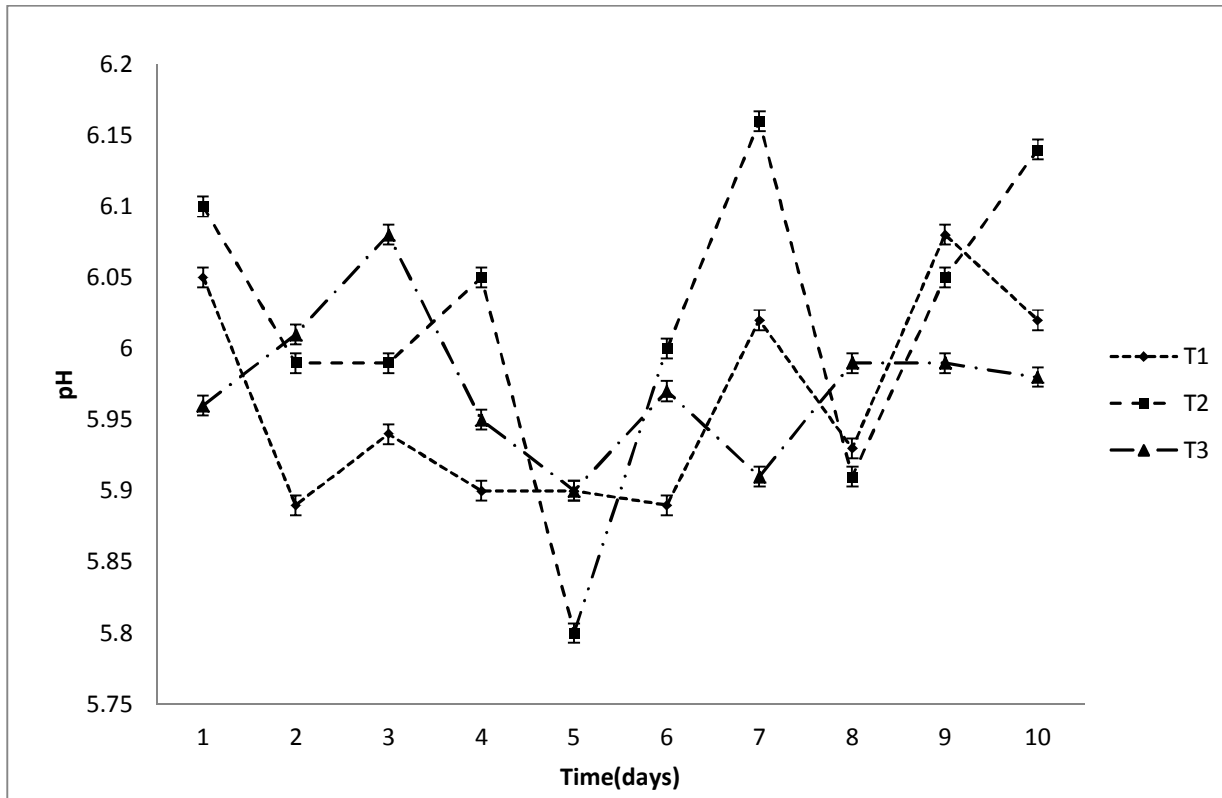
<sup>abc</sup> Means with different superscripts in a row are significantly different (P < 0.05) SEM= standard error of means; pHu=ultimate pH

Effect of refrigeration storage over 10 days on pH of broiler chicken (42 days) is presented in Figure 4.1. The pH levels in all the treatments were generally constant after 24 hours to day 5 (5.87-6.05), with treatment 3 declining on day 5 with treatment 1 and 3 having higher values. On day 7 treatment 2 reached its peak then declined on day 8 having the lowest values than TRT 1 and 3. Edward (1984); Greer and Murray (1988) stated that lower pH meat have a shorter shelf-life compared to higher pH product, which may be due to less enzymatic reduction and faster rate of myoglobin oxidation which is favoured at lower pH. The pH was high on day 1, 7 and 10 in treatment 2, compared to treatment 1 and 3. This may be caused by the storage conditions resulting meat with higher pH. According to Chodová, and T mová, 2013, feed restriction affects muscle fiber characteristics, and it can change the percentage of oxidative fibers and leads to higher pH value.

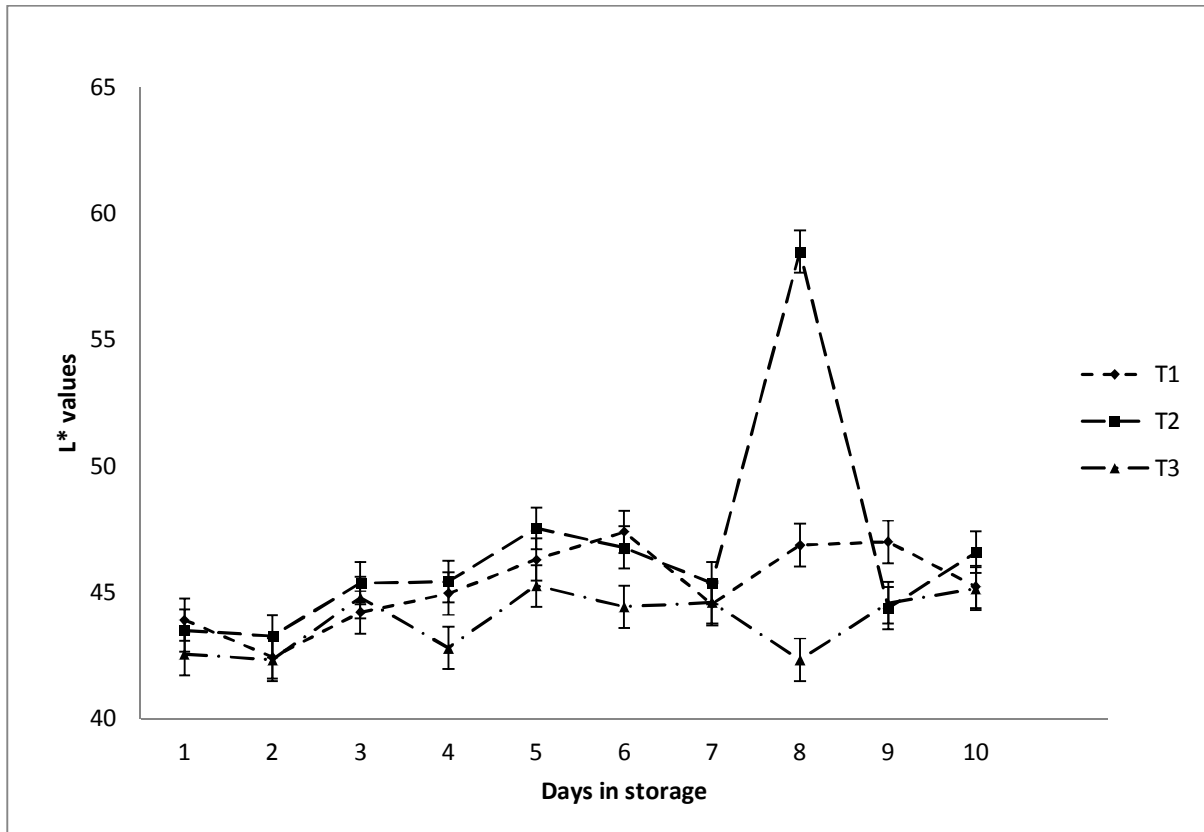
Treatment 3 had a lower pH towards the end of the storage. According to a study by (Ouhyoun, 2003) a decrease in pH of meat, may be due to stimulation of glycolytic pathway of muscle energy metabolism. Furthermore, restricted feeding favour the oxidative metabolism pathway, as proven by the higher percentage of oxidative fibers in muscles of feed restricted compared to *ad libitum* fed animals (Metzger *et al.*, 2009).

The pH of breast muscle sample for shelf-life in all the treatments ranged from 5.8 to 6.1. Elena *et al.* (2012) stated that meat is considered to have a very good quality at a pH of 6.2 when pH value is higher than 6.7 meats became unpalatable.

Effect of refrigeration storage over 10 days on the Lightness ( $L^*$ ) of broiler chicken (42 days) is presented in Figure 4.2. The lightness levels in all the treatments were generally constant from day 1 to day 7 (42.56 to 44.53). There was a treatment difference effect ( $P < 0.05$ ) on day 8, with treatment 2 reaching its peak (58.49) then declined on day 9 with treatment 1 and 3 having the lowest values. In addition, the high level of  $L^*$  (lightness) on day 8, caused a decrease in pH (5.94) during storage. This is in agreement with other researchers (Qiao *et al.*, 2001; Medic *et al.*, 2009; Salakavo *et al.*, 2009) reported that breast meat with higher  $L^*$  values have lower pH. In this experiment, the values of  $L^*$  were within the range of meats characterized as normal (42.56-58.49).



**Figure 4.1:** Effect of treatment during storage time (days) on the pH levels of broiler breast muscle. T1 -birds fed *ad libitum*, T2 -birds restricted of feed for one week, T3- birds restricted of feed for two weeks

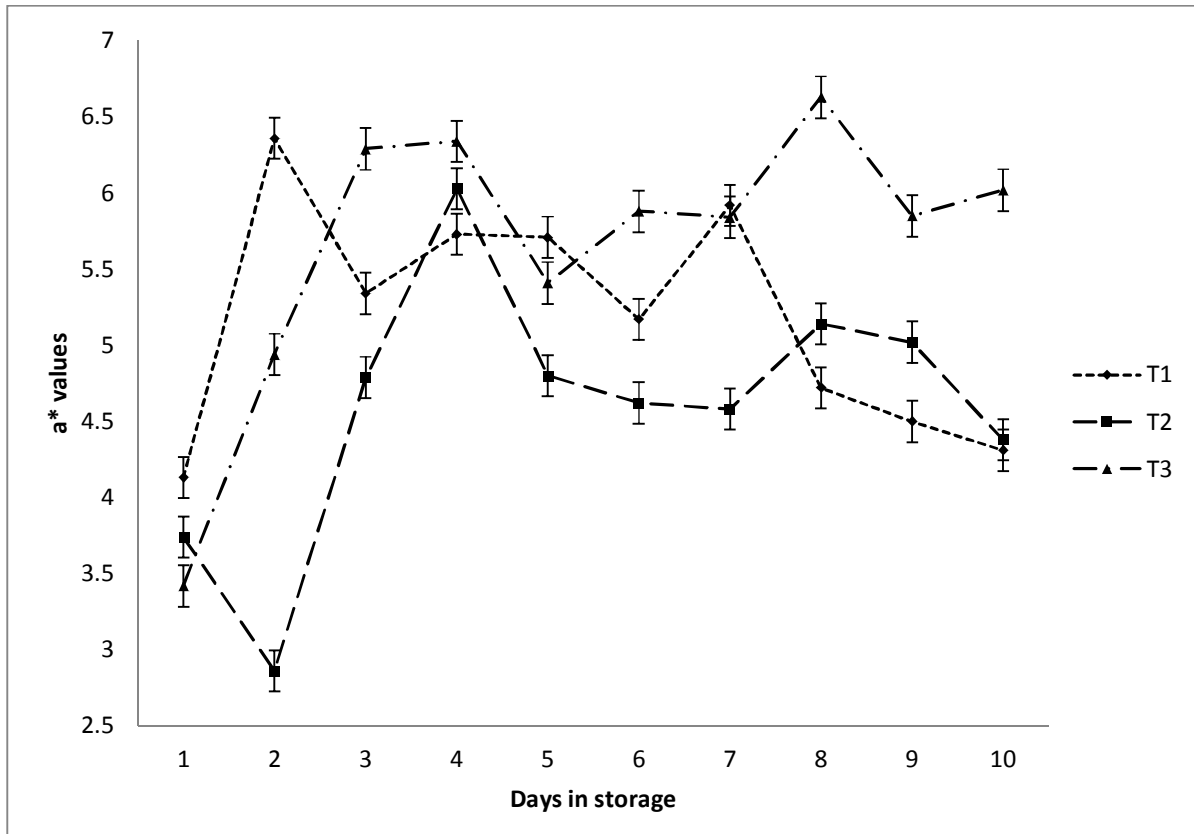


**Figure 4.2:** Effect of treatment during storage time (days) on the Lightness (L\* values) of broiler breast muscle. T1 -birds fed *ad libitum*, T2 -birds restricted of feed for one week, T3-birds restricted of feed for two weeks

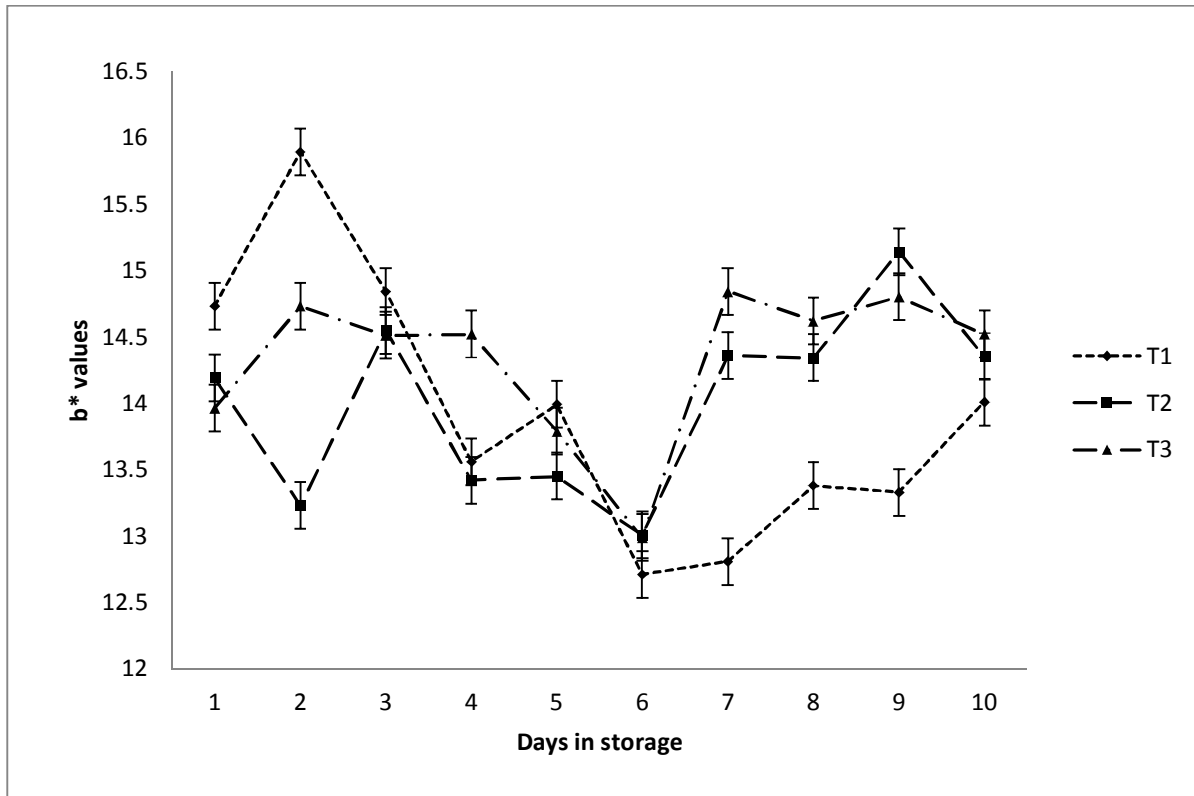
Effect of refrigeration storage over 10 days on the redness ( $a^*$ ) of broiler chicken (42 days) is presented in Figure 4.3. The colour component  $a^*$  is associated with the amount and chemical state of myoglobin, the main pigment of muscle tissue (Genot, 2003; Lawrie, 2005). The highest redness ( $a^*$ ) values were observed at day 8 with treatment 3. Increases in the values of  $a^*$  are due to the oxidation of myoglobin during the storage, resulting in browning of the meat (Genot, 2003). The lowest values were found in treatment 2 after 24 hours of storage.

Effect of refrigeration storage over 10 days on the yellowness ( $b^*$ ) of broiler chicken (42 days) is presented in Figure 4.4. The  $b^*$  values started to decrease from day 3 to day 6 then peaked up again at day 7 except for treatment 1. In day 2 treatment 1 was significantly higher ( $P < 0.05$ ) compare with treatment 2 and 3 at 2 days of storage time.

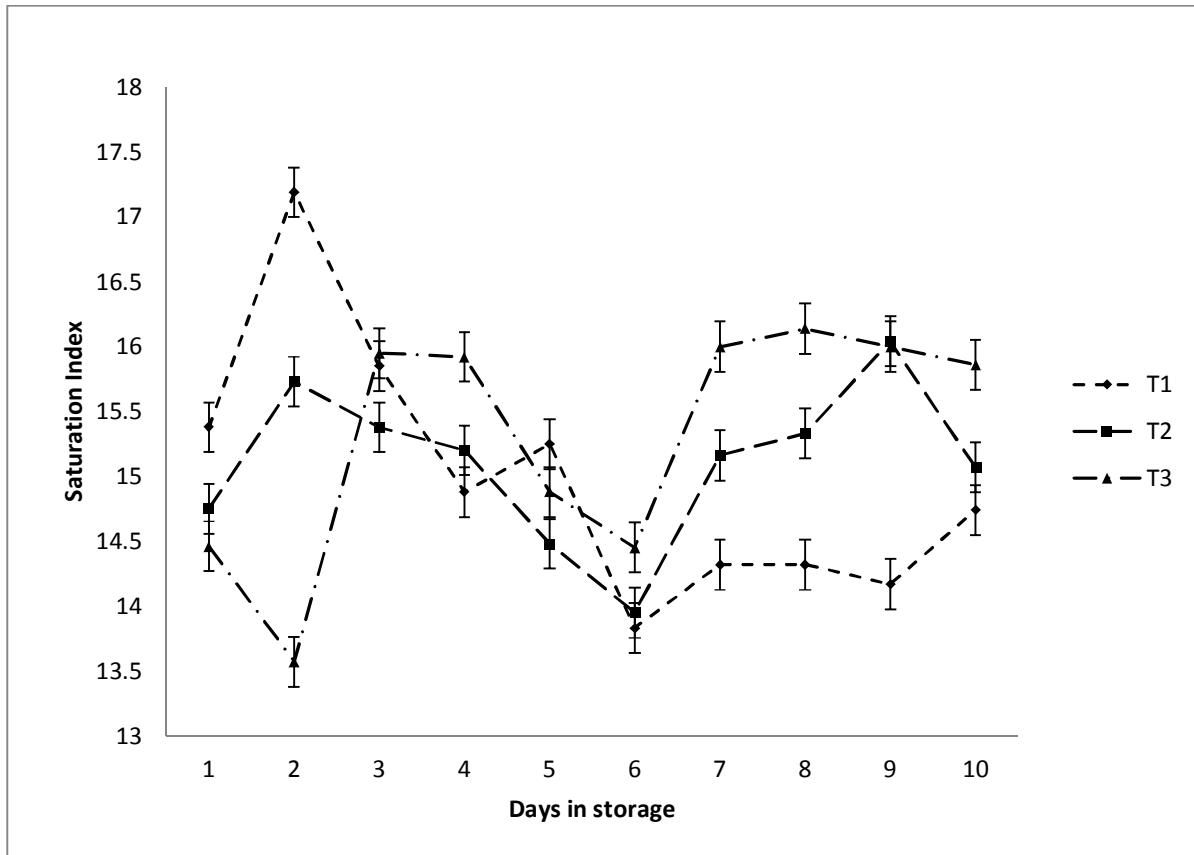
Effect of refrigeration storage over 10 days on the saturation index of broiler chicken (42 days) is presented in Figure 4.5. Saturation index was found to be high on day 2 in TRT 1 and lowest on day 2 with treatment 3. Effect of refrigeration storage over 10 days on the Hue angle of broiler chicken (42 days) is presented in Figure 4.6. The highest values of hue angle were found to be in treatment 2 at the end of the storage, with lowest being treatment.



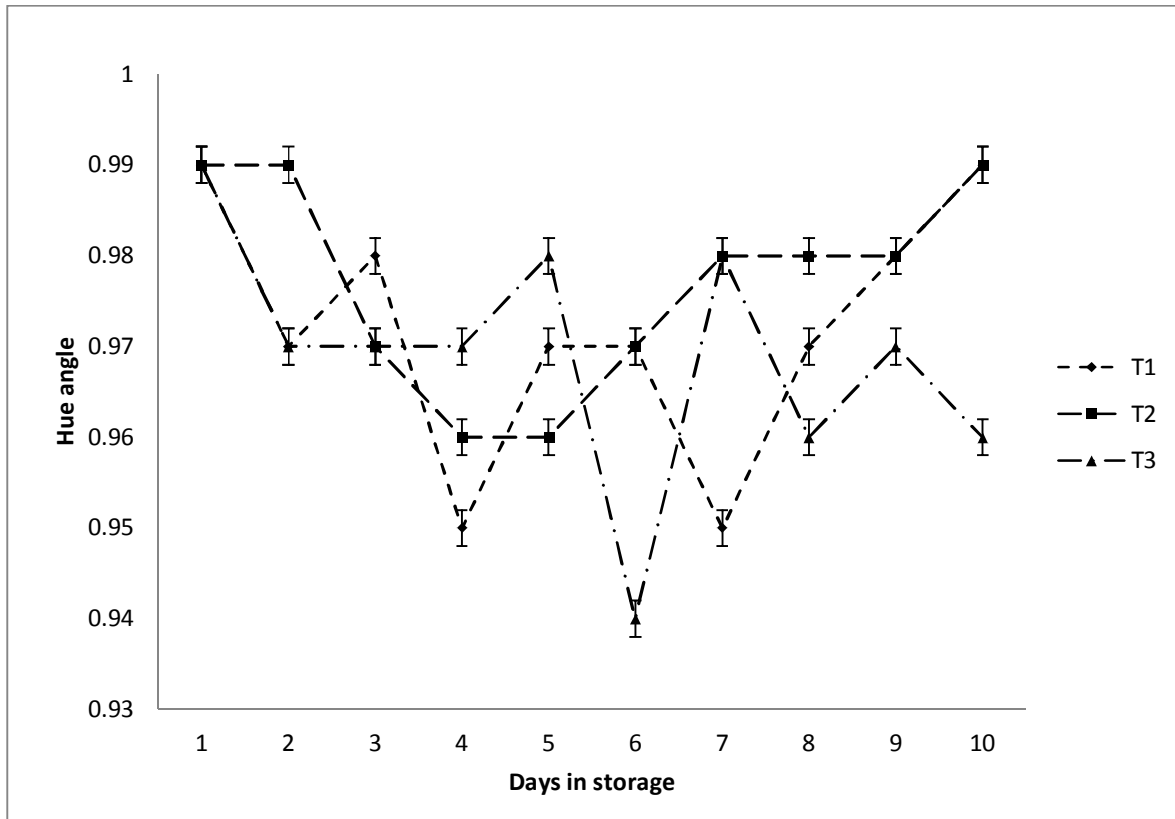
**Figure 4. 3:** Effect of treatment during storage time (days) on the redness (a\* values) of broiler breast muscle. T1 -birds fed *ad libitum*, T2 -birds restricted of feed for one week, T3- birds restricted of feed for two weeks



**Figure 4. 4:** Effect of treatment during storage time (days) on the yellowness (b\* values) of broiler breast muscle. T1 -birds fed *ad libitum*, T2 -birds restricted of feed for one week, T3- birds restricted of feed for two weeks



**Figure 4. 5:** Effect of treatment during storage time (days) on the Saturation index of broiler breast muscle. T1 -birds fed *ad libitum*, T2 -birds restricted of feed for one week, T3- birds restricted of feed for two weeks



**Figure 4. 6:** Effect of treatment during storage time (days) on the Hue angle of broiler breast muscle. T1 -birds fed *ad libitum*, T2 -birds restricted of feed for one week, T3- birds restricted of feed for two weeks

#### **4.6. Conclusion**

In conclusion, feed restriction had a minimal effect on physico-chemical shelf-life indicators of breast muscle during storage over 10 days. The highest values for pH during storage were observed from birds that were restricted for one week. The ultimate pH was slightly higher on the two weeks restricted broilers, but on one week and control broilers were in an acceptable range. Meat quality measurements, like colour were not affected by feed restriction, but in an acceptable range. Cooking loss values in all the treatments were lower than the recommended values by other researchers. It can be concluded that feed restriction had minimal effect on meat quality.

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## **Chapter 5: Effect of feed restriction duration on fatty acids profiles of broiler chicken meat**

### **Abstract**

The objective of the study was to determine the effect of quantitative feed restriction duration on fatty acid profiles and health related indices of broilers chicken meat. A total of 144 day old broiler chicks were reared in a deep litter system. The chicks were randomly allocated to three treatments; the control (T1), one week of feed restriction (T2), and two weeks of feed restriction (T3). Birds were slaughtered at 42 days of age; fatty acid analysis was done on the breast muscle of broiler chicken. The treatments had an effect ( $P < 0.05$ ) on C20:4C5, 8, 11, 14, (N-6) and C18:3 c 6, 9, 12 (n-6). There was no treatment effect on the SFA, MUFA, PUFA, (n-6), (n-3), PUFA/MUFA and n-6/n-3. Treatment 3 had the highest proportions of PUFA. There was no significant difference ( $P > 0.05$ ) in treatments observed in both the atherogenic index (AI) and desaturase index (DI) of breast meat in current study. It can be concluded that feed restriction did not affect fatty acid profiles of breast chicken meat.

**Keywords:** Fatty acids profiles, feed restriction, atherogenic, desaturase and breast muscle

## 5.1. Introduction

The fatty acid compositions of foodstuffs are important for healthy human. Nutritionists recommend a small portion in fat intake in SFA and trans fatty acids, which are associated with an increased risk of cardiovascular disease and some cancers (Burlingame *et al.*, 2009; Brouwer *et al.*, 2010; USDA and HHS, 2010; Mapiye *et al.*, 2011). Nutritionists urge consumers to take polyunsaturated fatty acids, including the omega-3 classes; the feed used for the rapid development of the offspring contains these fatty acids (Barroeta, 2007). The n-3 and n-6 FAs play an important role in human nutrition, both being precursors of eicosanoids, prostaglandins, leucotriens, and thromboxanes that regulate the cardiovascular and immunological processes (Grashorn, 2007) and are rich in poultry meat.

Fatty acid composition and concentration of several nutrients depend largely on the diet fed of the birds (Anna Haug, 2007) and there has been increased recent interest in manipulating the fatty acid (FA) composition of meat. Interest in meat fatty acid composition is mainly from the need to find ways to produce healthier meat with a higher ratio of polyunsaturated (PUFA) to saturated fatty acids and a more favorable balance between n-6 and n-3 PUFA.

Handling of feed to improve fatty acid of meat is of importance. Excessive fattening is undesirable for both bird health and meat quality (Shahin and Elazeem, 2005; 2006). Therefore, quantitative feed restriction of broilers might reduce the amount of fat or abdominal fat in carcasses. Early feed restriction has been proven by many investigators that it improves growth characteristics with lower fat accumulation as it is described in Chapter 3 (Plavnik and Hurwitz, 1985, 1988, 1989; Santoso *et al* 1993; Santoso *et al.*, 1995a,b), and they also showed that early feed restriction resulted in lower hepatic acetyl-CoA carboxylase activity, a rate limiting enzyme for fatty acid synthesis.

Meat healthiness is largely related to its fat content and its fatty acid composition (Fisher *et al.*, 2000). Having an influence in feeding may reduce negative effects caused by feedstuffs such as excessive carcass fatness that can be perceived negatively by consumers (Malan, 2003). Therefore, the objective of the study was to determine the potential of feed restriction on fatty acids profile of broiler meat.

## **5.2 Material and Methods**

### **5.2.1 Study site and management of broiler chickens**

The study site and experimental procedures are described in chapter 3, Sections 3.2.1 and 3.2.2.

### **5.2.2 Fatty acid profile determination**

The total lipid from breast muscle samples of the feed restriction treatments was extracted using Soxhlet extraction according to AOAC (2003) procedures for determination of fats. Total lipid from breast muscle samples were quantitatively extracted, according to the method of Folch *et al.* (1957), using chloroform and methanol in a ratio of 2:1. An antioxidant, butylated hydroxytoluene was added at a concentration of 0.001 % to the chloroform: methanol mixture. A rotary evaporator was used to dry the fat extracts under vacuum and the extracts were dried overnight in a vacuum oven at 50°C, using phosphorus pentoxide as a moisture adsorbent. Total extractable fat was determined gravimetrically from the extracted fat and expressed as percent fat (w/w) per 100 g tissue. The extracted fat from feed, subcutaneous fat and muscle was stored in a polytop (glass vial, with push-in top) under a blanket of nitrogen and frozen at -20°C pending fatty acid analyses.

A lipid aliquot (20 mg) of feed, subcutaneous and muscle lipid was transferred into a Teflon-lined screw-top test tube by means of a disposable glass pasteur pipette. Fatty acids were

transesterified to form methyl esters using 0.5 N NaOH in methanol and 14 % boron trifluoride in methanol (Park and Goins, 1994). FAMES from subcutaneous fat, feed and muscle were quantified using a Varian 430 flame ionization GC, with a fused silica capillary column, Chrompack CPSIL 88 (100 m length, 0.25 mm ID, 0.2 μm film thicknesses). Analysis was performed using an initial isothermic period (40°C for 2 minutes). Thereafter, temperature was increased at a rate of 4°C/minute to 230°C. Finally an isothermic period of 230°C for 10 minutes followed. FAMES n-hexane (1 l) were injected into the column using a Varian CP 8400 Autosampler. The injection port and detector were both maintained at 250°C. Hydrogen, at 45 psi, functioned as the carrier gas, while nitrogen was employed as the makeup gas. Galaxy Chromatography Software recorded the chromatograms.

Fatty acid methyl ester samples were identified by comparing the retention times of FAME peaks from samples with those of standards obtained from Supelco (Supelco 37 Component Fame Mix 47885-U, Sigma-Aldrich Aston Manor, Pretoria, South Africa). All other reagents and solvents were of analytical grade and obtained from Merck Chemicals (Pty Ltd, Halfway House, Johannesburg, South Africa).

Fatty acids were expressed as the proportion of each individual fatty acid to the total of all fatty acids present in the sample. The following fatty acid combinations were calculated: omega-3 (n-3) fatty acids, omega-6 (n-6) fatty acids, total saturated fatty acids (SFA), total monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), PUFA/SFA ratio (P/S), n-6/n-3 ratio, atherogenicity index and desaturase index.

### 5.2.3 Indices of lipid quality

From the data of fatty acid composition, the index of atherogenicity (AI) and the desaturase index (DI) were calculated. The AI is an indication of the relationship between the pro-atherogenic SFAs and the main classes of anti-atherogenic PUFAs and the DI estimates the activity of stearoyl-coenzyme-A desaturase (SCD)-desaturase by comparing product-to-precursor fatty acid ratios and is also important for production of CLA and MUFA (Souyert *et al.*, 2006)

of the tendency of clot formation in blood vessels based on the relationship between pro-thrombogenic SFAs and anti-thrombogenic MUFAs and PUFAs (Garaffo *et al.*, 2011). The indices were calculated using the formulae proposed by Ulbricht and Southgate (1991):

$$AI = 12:0 + (4 \times 14:0) + 16:0 / (n-6 \text{ PUFA} + n-3 \text{ PUFA} + \text{MUFA})$$

$$DI = C14:1 / C14:0$$

### 5.3 Statistical analysis

Data for fatty acid composition and lipid health indices were analysed using the Proc GLM, procedure of SAS (2003) and pair-wise comparisons of LS Means was done. The following statistical model was used:

$$Y_{ij} = \mu + \alpha_i + E_{ij}. \text{ Where,}$$

- $Y_{ij}$  = dependent variables (fatty acid profiles and health lipid index variables)

- $\mu$  = overall mean
- $\mu_i$  = effect of treatments (Control, birds restricted for one week, birds restricted for two weeks)
- $E_{ij}$  = random error

#### 5.4. Results and discussion

Table 5.1 presents the effect of feed restriction on fatty acids profiles of broiler chicken meat. The treatments had a significant effect ( $P < 0.05$ ) on C20:4c5, 8, 11, 14 (n-6), and C18:3 c 6, 9, 12 (n-6). The (C18:3 c 6, 9, 12 (n-6) was found to be highest in T1 (0.18) and lowest in TRT3 (0.13), which is an essential fatty acid (National Research Council, 1994). There was no significant difference on SFA, but SFA had highest values in T 2 (32.7) and T3 (33.8) which were under feed restriction. The treatments had no effect ( $P > 0.05$ ) on n-6/n-3 ratio, and in all the treatments the n-6/n-3 values were higher than the recommended value of  $< 5$  (Rondelly *et al.*, 2004). The n-6/n-3 ratio plays an important role in reducing the risk of coronary heart disease (American Heart Association, 2008). Treatments had an effect on PUFA/SFA ratio with meat from T1 having the highest values ( $0.57 \pm 0.01$ ) and in all the treatments the ratio were relatively had favourable balance ( $0.5 \pm 0.01$ ) which is close to the recommended ratio of 0.4 (Wood *et al.*, 2003). No significant treatment effect was observed on the PUFA/MUFA, although it was highest in T 3 ( $0.38 \pm 0.01$ ) and lowest in T 1 ( $0.36 \pm 0.01$ ).

The level of PUFA in the current study was highest in T 3 ( $18.3 \pm 0.531$ ) and lowest in TRT 1 ( $18.1 \pm 0.531$ ), the PUFA values were increasing with the increase of feed restriction period. The values for the other fatty acids did not differ significantly ( $P > 0.05$ ) across the dietary treatments. The most abundant fatty acid class in all the samples was MUFAs, making up  $50.0 \pm 0.973$ ,  $48.9 \pm 0.973$ , and  $47.7 \pm 0.973$  of the total fatty acid composition in meat samples from T 1, T 2, and T 3, respectively. The second most abundant class of fatty acids was SFAs, with  $31.8 \pm 0.754$ ,  $32.7 \pm 0.754$ , and  $33.8 \pm 0.754$  in T 1, T 2 and T 3 samples, respectively. The PUFA content for T1, T2 and T3 samples was  $18.1 \pm 0.531$ ,  $18.2 \pm 0.532$ , and  $18.3 \pm 0.531$ , respectively.

There was no significant difference observed on %Fat, fat free dry matter and moisture among treatment groups. The moisture content for the treatments in this study were within the same range 71.6 ó 77.8%, whereas fat content were higher than the recommended levels of 1.35 to 3.90 % observed by (Suchy *et al.*, 2002) on prolonged feeding.

**Table 5. 1:** The effect of feed restriction duration on fatty acids profiles of broiler chicken meat.

Fatty Acids	Treatments			Significant Difference
	T1	T2	T3	
	( <i>ad libitum</i> )	(One week)	(Two weeks)	
C12:0	0.22 0.014	0.20 0.014	0.24 0.014	NS
C14:0	0.58±8 0.030	0.58± 0.030	0.62± 0.030	NS
C14:1c9	0.15± 0.012	0.13± 0.012	0.14± 0.012	NS
C16:0	25.0 ±0.580	25.4 ±0.580	26.2 ±0.580	NS
C16:1c9	ND	ND	ND	
C17:0	0.05± 0.006	0.05± 0.006	0.06± 0.006	NS
C17:1c10	0.08 <sup>a</sup> ±0.021	0.05 <sup>a</sup> ± 0.021	0.19 <sup>b</sup> ± 0.021	NS
C18:0	5.85 ±0.368	6.33 ±0.368	6.69 ±0.368	NS
C18:1c7	3.42± 0.180	3.29± 0.180	3.16± 0.180	NS
C18:1t9	0.08 <sup>b</sup> ± 0.015	0.04 <sup>a</sup> ± 0.018	0.04 <sup>a</sup> ± 0.018	NS
C18:1c9	39.0± 0.800	38.3± 0.800	37.3± 0.800	NS
C18:2c9,12 (n-6)	16.0± 0.317	16.2 ±0.317	16.3± 0.317	NS
C20:0	0.04 ±0.005	0.04± 0.005	0.05± 0.005	NS
C18:3c6,9,12 (n-6)	0.18 <sup>b</sup> ± 0.009	0.13 <sup>a</sup> ± 0.009	0.12 <sup>a</sup> ± 0.009	*
C20:1c11	0.16± 0.018	0.15± 0.018	0.14± 0.018	NS
C18:3c9,12,15 (n-3)	0.53± 0.017	0.53± 0.017	0.52± 0.017	NS
C20:2c11,14 (n-6)	0.05± 0.009	0.05± 0.009	0.04± 0.009	NS
C20:3c8,11,14 (n-6)	0.18± 0.035	0.20 0.035	0.18± 0.039	NS
C20:4c5,8,11,14 (n-6)	1.11 <sup>b</sup> ±0.129	1.13 <sup>b</sup> 0.129	0.48 <sup>a</sup> ±0.129	*

SFA	31.8± 0.754	32.7 ±0.754	33.8± 0.754	NS
MUFA	50.0± 0.973	48.9 ±0.973	47.7 ±0.973	NS
PUFA	18.1± 0.531	18.2± 0.532	18.3± 0.531	NS
(n-6)	17.6± 0.532	17.7± 0.532	17.8 ±0.532	NS
(n-3)	0.53± 0.017	0.53 ±0.017	0.52 ±0.017	NS
PUFA:SFA	0.57± 0.019	0.55± 0.019	0.54 ±0.019	NS
PUFA/MUFA	0.36± 0.016	0.37± 0.016	0.38± 0.016	NS
n-6/n-3	33.3± 1596	33.1 ±1.1596	34.1± 1.596	NS
% Fat	5.49 <sup>a</sup> ±1.332	5.15 <sup>a</sup> ±1.332	7.27 <sup>b</sup> ±1.332	*
% Fat Free Dry Matter	21.7± 0.381	21.8± 0.381	21.3 ±0.381	NS
% Moisture	72.7 ±1.166	72.9 ±1.166	71.3 ±1.166	NS

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<sup>abc</sup>Means in the same row with similar superscripts are not significantly different (P >0.05)

MUFA=Total mono-unsaturated fatty acids

PUFA=Total poly-unsaturated

SFA=Total saturated fatty acids

P: S=PUFA/SFA ratio

n- 6 / n-3=Total omega-6 and omega-3 fatty acids

#### **5.4 Atherogenic and desaturase index levels in broiler breast meat**

The effect of atherogenic and desaturase index levels in broiler breast meat is presented in Table 5.2. There were no significant treatment difference effects ( $P > 0.05$ ) observed in both the atherogenic index (AI) and desaturase index (DI) of breast meat in the current study. However, DI was highest in T1 ( $6.7 \pm 0.45$ ) and lowest in T 3 ( $5.7 \pm 0.45$ ).

**Table 5. 2:** Effect of feed restriction on health lipid indices of subcutaneous fat and intramuscular fat

Index	Treatments			Significance
	T1 <i>(ad libitum)</i>	T2 <b>(One week)</b>	T3 <b>(two weeks)</b>	
<b>AI</b>	0.4± 0.01	0.4 ±0.01	0.4 ±0.01	NS
<b>DI</b>	6.7 ±0.45	6.0± 0.45	5.7±0.45	NS

AI-Atherogenicity Index

DI-Desaturase Index

NS-not significant

## **5.6 Conclusion**

The treatments had an effect on C20:4C5, 8, 11, 14, (n-6) and C18:3 c 6, 9, 12 (n-6). There was no treatment effect on the SFA, MUFA, PUFA, (n-6), (n-3), PUFA/MUFA and n-6/n-3. The broilers that were restricted for two weeks had the highest proportions of PUFA. There were no significant difference ( $P>0.05$ ) in treatments observed in both the atherogenic index and desaturase index of breast meat in current study. The observation from this study showed that feed restriction had minor effect on the fatty acids profiles of breast muscle. Therefore feed restriction has no effect on the fatty acids of broiler chicken.

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## **6. Chapter 6: General discussion, conclusions and recommendations**

### **6.1 General discussion**

The broad objective of the study was to determine the effect of restricted feeding on growth performance, physico-chemical characteristics, shelf-life indicators and fatty acids profiles of broiler chicken meat. A total of 144 day-old broiler chicks were used, the chicks were randomly allocated to the following three treatments; the control (T1), one week of feed restriction (T2), and two weeks of feed restriction (T3).

In Chapter 3, feed intake, growth rate, feed conversion efficiency, slaughter weight, carcass weight, dressing percentage and organ weight of broiler chickens was determined. Feed restriction had an effect on growth performance of broiler chickens. The ADG of T 2 and T 3 were high after one week of their restriction period, T 2 being high at week 5 and T 3 high at week 6. The treatment 2 birds had high dressing percentage although there was no significant effect on slaughter weight between *ad libitum* and one week restriction birds. The treatments had minimal influence on organ weights of broiler chicken. The study showed that T 2 had similar results to T 1 with T 3 having lower results. The T 3 broilers had lower body weights due to longer period of restriction compared to other treatments. Other studies also observed the longer the period of under nutrition, the more difficult it is for broiler chickens to compensate for reduction in live weight (Yu and Robinson, 1992).

Results from Chapter 4, showed that T 2 had high values of Lightness (L\*) on day 8 compared to others. The birds that were restricted for one week had the highest values of pH at day 1, 7 and 10. This may be due to glycogen deficiency that usually occurs when animal survive stress, which is associated with fasting but are slaughtered before they have sufficient time to replenish their muscle glycogen stores (Ngoka and Froning, 1982; Papinaho *et al.*, 1995).

According to Chodová and Tmová, (2013), feed restriction affects muscle fibre characteristics, which change the percentage of oxidative fibres leading to higher pH value. Meat quality was not much affected by feed restriction especially on the physico-chemical shelf-life indicators. Lippens *et al.* (2000) also failed to find significant differences in meat quality when applying feed restriction programs in broilers.

In Chapter 5, the treatments had an effect at ( $P < 0.05$ ) on C20:4C5, 8, 11, 14, (N-6) and C18:3 c 6, 9, 12 (n-6). There was no treatment effect on the SFA, MUFA, PUFA, (n-6), (n-3), PUFA/MUFA and n-6/n-3. Broilers restricted for two weeks had the highest proportions of PUFA. There was no significant difference in treatments observed in both the atherogenic index (AI) and desaturase index (DI) of breast meat in current study. Furthermore, atherogenic index in this study was found to have low values. According to Usoro *et al.* (2006) low atherogenic indices are protective against coronary heart disease.

Fast growth rate in broiler chickens is accompanied by increased body fat deposition. This situation most commonly occurs with broiler chickens that consume feed *ad libitum*. Feed restriction programs are strategies that can be used to alter feeding management in order to decrease fat in broilers, but according to this study there was little different effect between feed *ad libitum* and those that were restricted for one week.

## **6.2 Conclusion**

The use of feed restriction on broilers had a significant effect on growth performance, even though it did not have much effect on the carcass characteristics of broiler chickens. Restricting broilers for one week had similar results as the unrestricted broilers. The birds that were restricted for two weeks, did not reach the slaughter weight according to this study. After feed restriction there was high feed conversion efficiency in one week and two weeks restricted broilers, which resulted in high average daily gain. Feed restriction did not have much different effect on physico-chemical shelf-life indicators of meat amongst the treatment although the meat was in an acceptable range. Feed restriction did not affect fatty acids profiles.

## **Recommendations**

Observation from this study showed that feed restriction have a potential to be used in broiler chicken production. Feed restriction for one week is recommended because it did not negatively affect body weights of the broilers

Further investigation using other means of quantitative restriction like skip a day restriction instead of long restriction period may be required.

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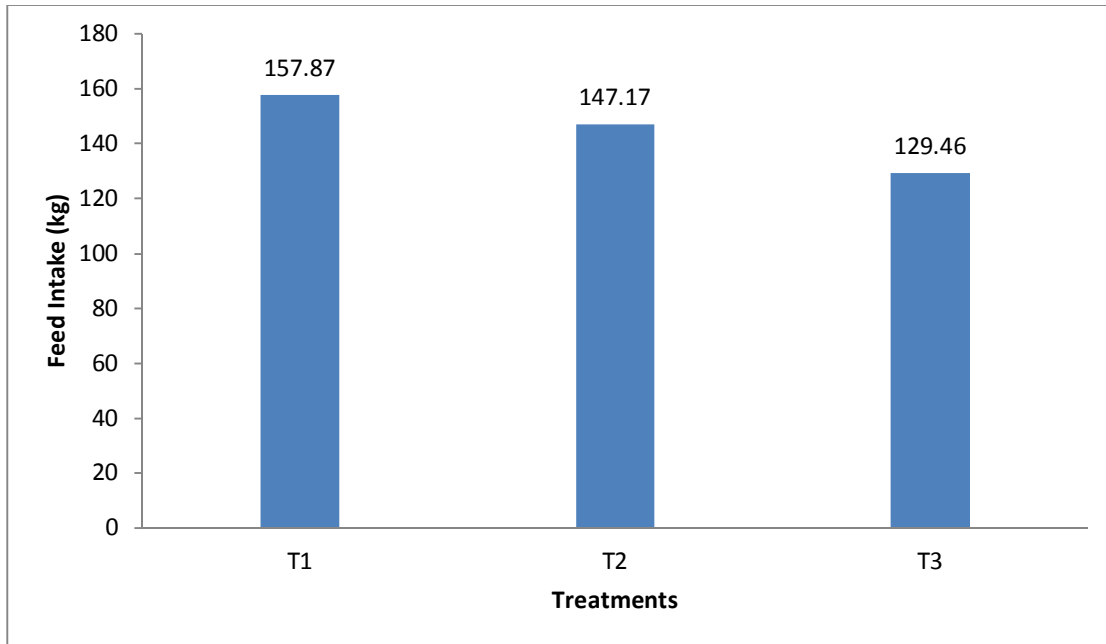
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## 7.1 Appendix



**Figure 7. 1: Accumulation of feed intake on T1-control, T2-on a week and, T3- two weeks restriction on broiler chickens.**