EFFECTS OF STRAIN, STOCKING DENSITY AND LIMITED-TIME FEEDING ON GRQWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF BROILER CHICKENS

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A mini-dissertation submitted in partial fulfillment of the requirements for

the degree of Masters of Science in Agriculture

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SOUTH **AFRICA**

April 2015

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DECLARATION

1, LIGARABA TSHILILO JOYCE, hereby deciare that this dissertation is submitted tor the partial fulfillment of the requirements of Masters of Science in Agriculture degree at the University of Venda and also that this research has not been previously submitted for any degree at this or any ether university, and that it is my work in design and execution and that all reference materials contained herein have been duly acknowledged_

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DEDICATION

1 dedicate this work to my uncles, Sigebe Bethuel and Sigebe Lazarus, mother Ligaraba Lizzy, children Pfano, Paul, Luvhani and the triplets Khangwelo, Mukhethwa and Shirly. To them I say "Perseverance is the key to success". 1 wouldn't have done it without them for they encouraged me and have been my pillar of strength to face every obstacle that I carne across.

ACKNOWLEDGMENT

I'm so thankful to the University of Venda for funding this study and providing its facilities for me to conduct the experiment. 1 would also like to express my sincere gratitude to my supervisors Dr. K. Benyi and Dr. J.J. Baloyi for their assistance in making preparations and throughout the gestation of this dissertation, patience and sharing their valuable knowledge and experience with me.

1 would also like to thank my son Paul Ligaraba, Machebele Hlamalani, Mulaudzi Mpfariseni and Tsanwani Tshililo for their assistance in data collection. Not forgetting my uncles, Mr Sigebe Bethuel and Sigebe Lazarus, my mother Mrs Ligaraba Lizzy tor their parental love, motivational words and support which always gave me strength and restored my courage each day. To my family I wish to say "Two are better than one" and to everyone else who made this work possible however not mentioned, 1'11 forever be thankful tor the good job you have done. May our HEAVENLY FATHER bless you.

1 thank you!

ABSTRACT

The effects of strain, stocking density and limited- time feeding on the growth performance and carcass characteristics of broiler chickens were investigated over a 49-day study period. Ross 308 and Cobb Avian48 birds were raised at the stocking densities of 30 and 40 kg body weight per meter squares (BW/ m^2) and assigned to ad *libitum,* 10 h and 12 h daily feed withdrawal programs with three replicates each. Overall, Ross 308 was superior to Cobb Avian48 in body weight gain, market weight and percent drumstick weight ($P<0.01$) and consumed more feed ($P<0.05$), but did not differ in percent carcass, back, breast, wing, gizzard, neck, liver and heart weights as well as abdominal fat ($P>0.05$). Ross 308 also had insignificant lower mortality rate than Cobb Avian48. The birds raised at the lower stocking density (30 kg BW/m^2) performed better in weight gain and final body weight ($P<0.05$) than those raised at the higher (40 kg BW/ m^2) stocking density and consumed similar quantities of feed ($P>0.05$), but did not show any influence on carcass traits ($P>0.05$). Neither strain nor stocking density had influence on feed conversion ratio and mortality rate, but there were significant strain x stocking density interaction effects on feed consumption during grower and on mortality rate during starter and entire study periods ($P<0.05$). The ad *libitum-fed* birds outperformed the feed-restricted ones in weight gain, final body weight, percent breast weight ($P<0.01$), neck and heart weights ($P<0.05$) and consumed more feed ($P<0.05$). Feed restriction also had significant effect on mortality rate ($P<0.05$), but feed conversion ratio and other carcass traits (percent carcass, breast, back, drumstick, neck, wing, gizzard, heart and liver weights as well as abdominal fat) were not statistically affected ($P>0.05$). The 10 h daily feed-restricted birds were insignificantly heavier (69 grams) than those on 12 h daily feed withdrawal regime, but consumed less (7 grams) feed. It is suggested that for profitable production in the subtropics, Ross 308 be reared at the stocking density of 30 kg BW/m^2 and feed restricted tor 10 hours daily.

Key words: Broiler chickens. Strain. Feed restriction. Stocking density. Growth performance. Carcass characteristics.

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CHAPTER 1: INTRODUCTION

1.1 Background

The dramatic genetic improvements in the growth rate and feed efficiency of broiler chickens over the past several years are the result of improved nutrition and genetic selection. However, along with these improvements ha\le come unintended detrimental changes such as increase in appetite. Broiler chickens tend to overeat when given free access to feed (Richards *et al.,* 2003) and the energy intake in excess of the requirements tor maintenance and production is converted into fat (Summers and Spratt, 2000; Cuddington, 2004). Fat is an unwanted product in human diet which can lead to obesity and higher incidence of metabolic disorders such as skeletal deformities, as:ites and sudden death syndrome in broilers (Havenstein *et al.,* 2003). These can lead to economie losses because of reduced animal performance, high mortality, and carcass condemnation at slaughter houses (Cuddington, 2004).

As broiler chickens get older, the carcass becomes progressively composed of less protein and more fat. Excessive fat also causes reduction in feed efficiency, difficulties in meat processing (Gamer *et al.,* 2002; Scott, 2002) and rejection of meat by consumers due to its adverse effects on human health (Kersler *et al.,* 2000; Urdaneta-Rincon and Leeson, 2002). Studies have shown that feed restriction coJld decrease the fat content in carcasses, thus resulting in improved carcass composition (Jones and Farrell, 1992; Nielsen *et al.,* 2003). However, some researchers have failed to rec:iuce carcass fat with feed restriction (Zubair and Leeson, 1996; Lippens *et al.,* 2000).

Intensive genetic selection of birds led to increased growth rate and feed conversion which made them highly sensitive to adverse environmental conditions (Al- Murrani *et al.,* 2006 and Sosnowka - Czajka *et al.,* 2006). Sabar *et al.* (2008) indicated that environmental factors such as temperature and humidity exert some influence on feed intake, heat prostration (Mahmood *et al.,* 2008, Butcher *et al.,* 2009) and subsequent fat deposition and late mortality. Factors like age, sex, strain, rearing season and intensity of restriction can influence fatness, feed efficiency and effects of restricted feeding on growth (Czirjak *et al.,* 2009).

Feed is the most expensive item in broiler production. It is believed that 70 to 75% of the cost of broiler production is incurred on feed (Mahmood *et al.,* 2005). Therefore, the need for efficient use of feed cannot be overemphasized. One way of reducing this cost is to restrict feed intake in the early life of chickens (Plavnik and Hurwitz, 1985, 1989; Lee and Leeson, 2001). Feed restriction in broilers can reduce early growth rate and feed intake, improve feed efficiency, reduce carcass and abdominal fat and result in the production of quality meat at a cheaper price (Navidshad *et al.,* 2006 and Mahmud *et al.,* 2008). It can also decrease the chances of metabolic diseases such as ascites and sudden death syndrome and leg disorders which otherwise may lead to high mortality and make the broiler enterprise unprofitable (Lippens *et al.,* 2000; Tumova *et al.,* 2002).

A desirable feeding strategy includes reducing the growth rate in early stages of growth and at the same time achieving little negative effects on the final broiler weight (Benyi *et al.,* 2010). Various feed restriction methods including quantitative feed restriction (Mahmud *et al.,* 2008; Czirjak *et al.,* 2009; Mohebodini *et al.,* 2009), skip a day feed removal (Khajali *et al.,* 2007; Benyi *et al.,* 2009; Ghazanfari *et al.,* 2010;), appetite suppression using glycolic acid and saponins (Al-Batsham *et al.,* 2008), limiting the time of daily access to feed (Onbasilar *et al.,* 2009; Benyi *et al.,* 2010) and diet dilution (Rezaei *et al.,* 2006; Azizi *et al.,* 2011) have been evaluated but the results have been conflicting. Such inconsistencies may relate to the different feeding strategies applied which may affect the bird's response (Czirjak *et al.,* 2009).

Dozier *et al.* (2002) and Dozier *et al.* (2003) reported that broiler chickens are able to compensate for loss of weight resulting trom short periods of feed restriction at an early age but complete growth compensation becomes unlikely as the period of under-nutrition increases.

Summers and Spratt (2000) and Doyle and Leeson (2003) suggested that the response of broiler chickens toa period of under-nutrition depends on the nature, severity and duration of restriction, state of development of the bird relative to maturity during restriction, level of feeding during re-alimentation, period of re-feeding, direct nutrient content during re-feeding, sex and genotype of the population used tor the experiment. Some reports suggest that different strains of broiler chickens respond differently to different feeding regimes because, according to Gous *et al.* (1999), genetic potential influences the broilers' growth response and their nutritional requirements. Bruggmann *et al.* (2005), Benyi *et al.* (2009) and Benyi *et al.* (2010) reported significant strain and strain x diet or strain x feeding regime interaction effects on body weight, weight gain and feed intake. Dozier *et al.* (2003) however, did not find any differences among strains in their reactions to different restricted-feeding regimes.

Modern broilers have lower resistance to environmental factors and therefore are more susceptible to stress which has an adverse impact on their productivity (Sosnowka - Czajka et *al,* 2006). Sensitivity to environmental factors and susceptibility to stress may be genetically determined (Sosnowka-Czajka *et al.,* 2005; Campo *et al.,* 2008).

Limited-time feed restriction has been reported to decrease early growth without affecting final body weight or market weight (Khethani, 2008i, abdominal fat pad, feed efficiency, mortality rate (Achiempong-Boateng *et al.,* 2012) liver, heart weight (Turkyilmaz 2008) and carcass weight and yield (Dozier 111 *et al.,* 2002). Mazucco et al. (2000) and Benyi *et al.* (2010) also showed that there is no effect of limited time feeding on market weight. However, Dozier 111 *et al.* (2003) subjected broilers to 5-day feed removal in a skip-a-day feed restriction program and reported that the reduction of early growth rate of broilers does not allow tor complete recovery of final body weight and carcass parts. Achiempong-Boateng *et al.* (2012) reported reduced feed intake, weight gain and market weight of birds subjected to limited-time feeding (1 or 2 days per week). According to the results of Turkyilmaz (2008), gizzard weight decreased with increasing feed removal period. Results obtained by Oyedeji (2003) showed that live weight, weight gain and feed consumption were significantly reduced while feed conversion ratio, dressing percentage, weights of carcass parts and giblet weights were not significantly affected by feed restriction.

High stocking densities increase ammonia production, footpad lesions, litter moisture, heat stress, preening and decrease locomotion (Bennet *et al.,* 2003 and Ritz *et al.,* 2005) as well as higher mortality, lower meat production , greater incidence of leg disorders and cannibalism (Turkylmaz, 2008). According to Spring (2005), litter quality tends to deteriorate quickly at high stocking densities and consequently affects broiler performance and carcass quality and creates health hazards in the poultry shed. However, high stocking densities also reduce fixed casts of production (Hassanein, 2011) and increase profitability up to a critica! point (Puren *et al.,* 1995). Because of this, producers increase stocking densities and sacrifice some performance in the birds in order to obtain maximum return per square meter of floer area (Fairchild, 2005; Skrbic *et al.,* 2009). This situation is however changing; lower stocking densities are used in the tropics compared with temperate areas because of stress caused by environmental conditions. Feddes *et al.* (2002) reported that increasing placement density (of broiler chickens approximately 2.4 to 2.7 kg) adversely affects growth performance, carcass yield and skin scratches. Benyi *et al.* (2011) studied the effects of stocking densities 30, 35, 40 and 45 kg BW/m^2 on growth performance of two strains of broiler chickens (Ross 308 and Hubbard). The author suggested that for profitable broiler production in the tropics and subtropics, Ross 308 could be reared at a stocking density of 40kg BW/m^2. There is little information concerning the joint influence of stocking density, limited-time feeding and genotype on performance and characteristics of broiler chickens.

1.2. Problem Statement

Broiler breeders have selected birds for taster growth rate resulting in birds which reach market weight at an early age. However, this progress has been associated with undesirable correlated responses such as increased appetite and higher feed intake, high fat deposition and obesity, which lead to incidence of metabolic disorders such as ascites, sudden death syndrome, leg abnormalities and high rate á mortality. Increased appetite and higher feed intake also lead to high feeding casts and subsequently lower profitability.

1.3. Justification of the study

Different traits such as feed intake, feed efficiency, growth rate and carcass characteristics are affected by both genetic and environmental factors such as feeding, rearing season, temperature, light intensity and humidity (Campo *et al.,* 2008; Rack *et al.,* 2009; Benyi *et al.,* 2010; Acheampong-Boateng *et al.,* 2012). Different feed restriction methods have therefore been used in attempts to solve these problems but results have been conflicting. Researchers have shown great interest in feeding, since it represents the highest cost in poultry production. However, there is little information on the effects of genotype, stocking density and limited time feeding and their interactions on the performance and carcass characteristics of broiler chickens. This study therefore investigated the effects, singly and jointly of strain, stocking density and limited time feeding on growth and carcass traits in two strains of broiler chickens.

1.4. Objectives of the study

1.4.1. Overall objective

The main objective of this study is to investigate the effects of strain, stocking density and limited time feeding and their interactions on growth performance and carcass characteristics of broiler chickens.

1.4.2. Specific objectives

The specific objectives are to:

(i) measure the effects of strain, stocking density and limited-time feeding on growth parameters (body weight, weight gain, feed intake, feed conversion ratio and mortality rate) and on carcass characteristics (abdominal fat content, breast, back, wing, thigh, drumstick, neck and giblets weights) of broiler chickens

(ii) determine if there are significant interadion effects on growth and carcass parameters of broiler chickens

1.4.3. Expected outcome of the objectives

The results will be presented in seminars and conferences and there will be publications in peer-reviewed journals.

1.5. Hypotheses

(i) there are no strain, stocking density and limited-time feeding effects on growth and carcass traits.

(ii) there are no strain, stocking density and limited-time feeding interaction effects on growth and carcass traits.

CHAPTER 2: LITERATURE REVIEW

2.1 Effects of feed restriction on growth performance and carcass characteristics

Feed restriction has been reported to reduce early growth, but observations on compensatory growth are conflicting. According to Doyle and Leeson (2003) and Zubair and Leeson (1994), compensatory growth following under-nutrition is influenced by the nature, severity, timing and duration of under-nutrition, age at the commencement of under-nutrition, and the degree and pattern of realimentation. It seems that as the period of under-nutrition increases, complete growth correction becomes more unlikely (Plavnik *et al.,* 1986; Yu and Robinson, 1992).

Researchers however, seem to differ with regard to the effect of period of restriction on compensatory growth and market weight. Lee and Leeson (2001), Tumova *et al.* (2002) and Demir *et al.* (2004) reported that broiler chickens are able to compensate for loss of weight when feed is restricted for a short period at the early stages of growth but there is no evidence of compensatory growth resulting from long periods of feed restriction. Zubair and Leeson, (1994) also stated that because feed restriction temporarily reduces growth rate, normal weight is realized at market age. This situation relates to reduced maintenance energy needs rather than any real improvement in digestibility. Plavnik and Hurwitz (1985, 1989) and Mazzuco *et al.* (2000) reported that the period of restriction did not affect market body weight. Feed restriction for suitable periods of time may prove an effective method for realizing the benefits of compensatory growth when feed-restricted birds are returned to normal feeding. Unfortunately, the optimum period of feed restriction has received little attention. Petek (2000) and Ozkan *et al.* (2003) reported that daily feed removal for 3, 4 and 6 hours significantly reduced final body weight. Onbasilar *et al.* (2009) however, observed that 4-hour daily feed removal had no significant effects on final body weight.

Dozier *et al.* (2002) and Dozier *et al.* (2003) evaluated the responses of male broiler chickens to 24 hour feed removals for 2, 3, 4, 5 and 6 days during the starter period and reported that final body weight of birds subjected to 2, 3 and 4 days of feed removal were similar to that of the *ad libitum* fed birds. However those that were subjected to 5 and 6 days of feed removal did not recover final body weight compared with birds fed *ad libitum.* Cumulative feed conversion, mortality, carcass yield, carcass weight and abdominal fat pad were also not affected by feed removal. Dozier *et al.* (2002) subjected broiler chickens to skip-a-day feed removal for 2, 4 and 6 days starting from the 8th day of age followed by *ad libitum* consumption to 54 days of age. Feed removal for 2 and 4 days did not decrease final body weight, feed consumption or carcass weight. However, feed removal for a total of 6 days decreased these variables. On the contrary, according to Dozier *et al.* (2002), subjecting broilers to 4 days of feed removal significantly reduced early growth without compromising final weight or meat recovery. The probable explanation for the lower body weight of the feed-restricted birds was decrease in feed intake compared to ad *libitum* fed birds.

Khethani *et al.* (2008) studied the effect of limited-time feeding on growth performance of broiler chickens. They imposed three treatments, *ad libitum* feeding, one-week feed restriction, (22-29 days) and two-week feed restriction (22-36 days) followed by *ad libitum* feeding to 42 days of age. During feed restriction birds were denied feed daily from 19H00 to 7H00. There were no treatment effects on body weight, average daily feed intake and feed conversion ratio at the end of the experiment (42 days) and there was also no evidence of compensatory growth in the restricted birds. Demir *et al.* (2004) studied the effects of early and late feed restriction on broilers. Birds were assigned to five treatments: *ad libitum,* 25% and 50% quantitative restriction or 8 hand 16 h feed withdrawal regimes, respectively. These feeding regimes did not affect weight gain, feed intake, feed efficiency, abdominal fat and heart weights.

Mamood *et* al. (2005) studied the influence of feed withdrawal for different durations on the performance of broilers in summer. Birds were allotted to tour treatments: *ad libitum* (control), 6 hour, 8 hour and 10 hour daily feed withdrawal *tor* four weeks (2-6 weeks of age). Keeping birds off feed for 10 h daily significantly affected feed intake, weight gain and feed efficiency. Benyi *et al.* (2010) studied the effects of limited-time feeding on growth performance of two strains of broiler chickens (Ross 308 and Hubbard). The birds were denied feed for 6 h, 8 h and 10 h during the day *trom* 8-28 days of age followed by *ad libitum* feeding to market age at 49 days. Overall, daily feed removal reduced feed intake and improved feed efficiency in all feed-restricted birds, but had no significant effect on weight gain and market weight. A daily 10 h feed removal program was suggested for profitable broiler production.

Mahmood *et al.* (2007) investigated the effects of daily feed removal periods for different durations *(ad libitum;* 1 hour feeding, 3 hours off; 1 hour feeding, 5 hours off and 1 hour feeding, 7 hours off) from 8-28 days of age followed by *ad libitum* feeding to 42 days of age. The authors reported that the birds fed *ad libitum* consumed more feed and gained more weight than birds on the restricted feeding regimes but feed-restricted birds utilized feed more efficiently than the control birds. Dressing percentage and relative organ weights were not affected by treatment.

Acheampong-Boateng *et al.* (2012) studied the effects of limited-time feeding on growth performance of Hybro broiler chickens. The birds on treatment 1 were fed *ad libitum,* those on treatment 2 were fed *ad libitum* but denied feed on the fourth day (6 days/ week), those on treatment 3 were fed *ad libitum,* but denied feed on the third and fifth days of the week (5 days/ week) and those on treatment 4 were fed every other day. The treatments were imposed trom 7 to 35 days of age followed by *ad libitum* feeding to 49 days of age. The birds whose feeding periods were reduced by 1 and 2 days per week had similar performances but outperformed birds on the every other day feeding regime. Feed restriction did not influence feed conversion ratio. Overall, feed remova for 1 or 2 days a week or every other day reduced feed intake, weight gain and market weight without influencing feed efficiency, mortality rate and abdominal fat deposition.

Turkyilmaz *et al.* (2008) studied the effects of limited time feeding on carcass characteristics of broiler chickens to 37 days of age. Feeo withdrawal regimes were applied as follows: zero hours (group 1), 4 hours (group 2), 8 hours (group 3), 12 hours (group 4) and 14 hours (group 5). The treatments had no effect on liver, heart and abdominal fat weights as well as carcass yield (%). However, body weight and gizzard weight decreased with increasing feed removal period.

Mohebodini *et al.* (2009), compared the effect of severity of feed restriction and meal feeding on performance and carcass composition of broiler chickens trom 7-14 or 7-21days of age. Meal-fed birds had free access to feed for tour 2h periods during the day (6:00-8:00, 12:00-14:00, 18:00-20:00 and 0:00-2:00). Limited-time feeding reduced weight gain compared to *ad libitum* or meal feeding at the end of the experiment at 42 days of age. However, no significant differences between *ad libitum* and meal-fed groups for weight gain were observed. Carcass weight of the control group was significantly higher than those of the feed-restricted groups but was not significantly different trom the meal fed groups. The probable explanation for the differences in weight gain may be differences in feed restriction schedules used in the different studies.

2.2 Effects of strain on growth performance and carcass characteristics

Researchers such as Yakubu *et al.* (2010) and Skomorucha *et al.* (2007) reported that broiler chickens of different genotypes differ in growth rate, final body weight, feed intake and feed efficiency, while Skomorucha *et al.* (2009) and Dozier *et al.* (2006) reported insignificant differences in body weight, weight gain and feed conversion efficiency among several strains. According to Smith *et al.* (1998) broiler chickens trom different genetic groups differ in growth rate, final body weight, feed consumption and feed conversion ratio (kg feed / kg gain). The results of Skomorucha *et al.* (2009) showed that genetic differences had no effect on body weight. Rosa *et al.* (2007) studied the effect of energy intake on performance and carcass composition of male broiler chickens trom two different genetic groups. The broilers were fed diets with different metabolizable energy levels (2950, 3200 and 3450 kcal/ g). Ross 308 had better performance and carcass yield and deposited less abdominal fat than PCLC (an Embrapa non-improved line).

Dozier *et al.* (2003) fed birds of two strains ad *libitum* to 54 days of age or subjected them to 24h feed removal periods at 9, 11, 13, 15 and 17 days of age. At the end of the feed removal period, 5 day feed removal suppressed body weight by 44% and reduction of early growth did not allow tor complete recovery of final body weight and carcass weight. The results showed that strain had no effect on feed restriction. Benyi *et al.* (2010) compared two strains of broiler chickens over the period of 49 days and reported significant effects of strain on weight gain, final body weight, feed consumption and abdominal fat, but did not influence feed efficiency and mortality rate.

Olawumi and Fagbuaro (2011) studied the productive performance of three commercial broiler genotypes tor 8 weeks and reported significant effects of strain on live body weight, and percent carcass weight, breast, back, thigh muscle weights drumstick and heart weights. However, strain did not influence dressing percentage, liver and gizzard weights as well as abdominal fat weight. Chukwuka *et al.* (2010) also studied the effects of strain on growth and carcass characteristics of broilers tor 12 weeks and reported significant strain effects on dressing percentage and abdominal fat weight.

2.3 Effects of strain and feed restriction on body weight, weight gain, feed intake and abdominal fat content in broilers

Reports indicated that different strains of broiler chickens respond differently to different feed restriction regimes because strain affects compensatory growth of broilers subjected to feed restriction (Yu *et al.,* 1990; Gous *et al.,* 1999). Harvenstein *et al.* (2003), Ozkan *et al.* (2003), Zhao *et al.* (2004), Rosa *et al.* (2007) and Benyi *et al.* (2009) reported significant strain effects on body weight, weight gain and feed intake. Havenstein *et al.* (2003), Ozkan *et al.* (2003), Zhao *et al.* (2004), Rosa *et al.* (2007) and Benyi *et al.* (2009) reported significant strain x diet interaction effects on the same traits. Other researchers such as Dozier *et al.* (2003) and Jones and Farrel (1992), did not find any differences among strains in their abilities to compensate for body weight reduction and reduce fat deposition.

Bruggman *et al.* (2005), restricted broilers of different strains to 55% of *ad libitum* feed intake (intermediate restriction) from 6-15 weeks of age or restricted birds with diluted mash feed and reported a significant strain x feeding regime interaction effect on body weight. Benyi *et al.* (2009) studied the effects of skip a day feeding for 14 days during the starter or grower period followed by *ad libitum* feeding to market age (7 weeks) on the growth performance of two strains of broiler chickens, Ross 308 and Hybro over 7 weeks. Strain significantly affected body weight, weight gain, feed intake ard feed conversion. Strain x treatment interaction affected only feed intake.

Rack *et al.* (2009) studied the effects of genotype, choice feeding and season on organically reared broilers. The results revealed that fast-growing genotypes were superior in performance and carcass characteristics compared with slow-growing genotypes. Benyi *et al.* (2010) revealed that different strains of broilers respond differently to feed restriction. Ross 308 was superior to Hubbard in weights (initial and final body weights), weight gain, and feed utilization but consumed more feed.

2.4 Effects of stocking density on growth performance and carcass characteristics of broilers

The effects of stocking density on productive performance have been investigated by several researchers but the results have been contradictory. Different researchers have reported that in broilers high stocking densities decrease body weight, feed consumption and increase mortality related to heat stress (Feddes *et al.,* 2002; Dozier *et al.,* 2006; Estevez *et al.,* 2007 and Skomorucha *et al.,* 2009). Beg *et al.* (2011) reported that birds raised at lower stocking densities consumed significant more feed. Many authors such as Thomas *et al.* (2004), Petek *et al.* (2010), Ventura *et al.* (2010), Uzum and Oral Toplu (2013) reported that feed conversion ratio was not affected by stocking density whereas other authors such as Ravindran *et al.* (2006), Skomorucha *et al.* (2009) reported increased feed conversion ratio with increase in stocking density.

Some researchers reported that stocking density had no significant effects on mortality (Skrbic, 2007; Beg *et al.,* 2011; Benyi *et al.,* 2015), although it should not be overlooked that percentage mortality increases with increasing of stocking density (Skrbic, 2007), especially in stocking densities above 10 birds/m^2 (Thomas *et al.,* 2004). In contrast Turkylmaz (2008) reported high mortality rate at high stocking density. Benyi *et al.* (2015) investigated the effect of genotype (Ross 308 and Avian Cobb 48) and stocking density on broiler performance during two subtropical seasons. The results have shown that stocking density significantly affects weight, weight gain and feed consumption but had no influence on feed conversion ratio and mortality rate. Birds raised at low stocking density (30 kg BW/m^2) had the highest feed intake and gained the most weight.

Uzum and Oral Toplu, (2013) investigated the effect of stocking density and feeding regime on performance, carcass and meat quality characteristics and some stress parameters in broilers under heat stress. The chicks (Ross 308) were assigned to 4 treatment groups based on stocking density (12 broilers/m^2 or 18 broilers/m^2) and feeding program *(ad libitum* or 8 hour feed removal) to 42 days of age. Final body weight, weight gain and cumulative feed consumption of broilers reared at 12 broilers / m^2 were higher than those reared at 18 broilers / m^2. Body weight, weight gain and feed consumption trom 21-42 days, were significantly affected by stocking density. The authors reported insignificant effects of stocking density and feed restriction on meat quality characteristics. They concluded that stocking density lower than 18 broilers / m^2 could be more suitable for broilers under heat stress in environmentally uncontrollable broiler houses.

Skrbic *et al.* (2011) investigated the effects of three stocking densities (20, 15 and 10 birds/m^2) on Hubbard at the ages of 3 and 6 weeks. At the age of 6 weeks, stocking density of 20 birds/ m^2 resulted in significantly lower growth of broilers, higher mortality and higher incidence of leg lesions and problems with body feathering, compared to stocking densities of 5 and 10 birds / m^2. Hassanein (2011) studied the effects of stocking densities and feed additive on broiler performance and carcass traits. Birds on the low densities showed higher body weight and body weight gain and improved carcass yield than birds raised at high densities.

The effects of stocking density on carcass traits have been studied by several researchers but the results have been contradictory. Several reports indicate that stocking density has no significant effects on breast weight percentage drumstick weight and back weight (Thomas *et al.,* 2004; Beg *et al.,* 2011); giblet weight percentage (Yakubu *et al.,* 2010; Beg *et al.,* 2011) and abdominal fat percentage (Uzum and Oral Toplu, 2013). Thomas *et al.,* (2004), Ravindran and Thomas (2004), Turkyilmaz (2008) and Beg *et al.* (2011) also observed insignificant effects of different stocking densities on carcass weight, dressing percentage, thigh, breast, wing, neck and adipose tissue weight. However, other researchers reported that high stocking densities decreased breast tender weight (Dozier *et al.,* 2006), and length, width and depth of breast (Garcia *et al.,* 2002). Hassanein (2011) showed improved carcass yield at low stocking densities and Beg *et al.,* (2011) observed that high stocking densities resulted in more abdominal fat deposition. Feddes *et al.* (2002), Dozier *et al.* (2005), Dozier et *al.* (2006) and Beg *et al.* (2011) reported that carcass, shank, wing, breast tender weights and dressing percentage decreased as stocking density increased. Yakubu *et al.* (2010) reported insignificant influence of genotype and housing density on relative visceral organs. Similarly, Garcia *et al.* (2002) reported negative effects of increased stocking density on length, width and depth of breast.

Beg *et al.* (2011) showed that the dressing percentage were significantly higher in birds raised at low stocking densities (8 bird/ m^2 and 10 bird/m^2) than those raised at high stocking densities (12 bird/m^2). Also, no significant difference was observed in different carcass parts for stocking densities and feeding regimes. The author also reported significantly higher abdominal fat depositions at higher stocking densities. Yakubu *et al.* (2010) reported significant strain x stocking density interaction on some carcass traits whilst Benyi *et al.* (2011)

reported a significant interaction effects on feed conversion ratio. Uzum and Oral Toplu (2013) reported that stocking density had significant effects on breast and heart weights, but there was no significant influence on percent wing, back, thigh, gizzard and abdominal fat weights.

CHAPTER 3: MATERIALS AND METHODS

3.1 Site description

The investigation was conducted from October to December 2014 at the poultry facility of the School of Agriculture, University of Venda, Thohoyandou (22°57'58"S and 30°29'05"E) in South Africa. The climate of the area is subtropical with cold dry winters and hot rainy summers.

3.2 Experimental procedure

Five hundred and forty-nine day-old male Ross 308 broiler chicks and six hundred and seventy-five day-old male Cobb Avian48 chicks henceforth called Ross and Cobb respectively were raised on a commercial broiler starter diet from day 1 to 21, grower diet trom day 22 to 35 and finisher diet trom 36 to 49 days of age (Table 3.1). The investigation lasted for 7 weeks.

All birds were fed ad *libitum* for the first 6 days (acclimatization period). On day 7, the birds of each strain were leg-banded, individually weighed and randomly assigned to the two stocking densitiesx three feed restriction combinations. The feed restriction treatments were either *ad libitum* or 1 O hour or 12 hour daily feed removal till 35 days of age. The stocking densities were 30 and 40 kg BW/ m^2. The calculated stocking densities of 30 and 40 kg BW/ m^2 corresponded to 26 and 35, and 32 and 43 chicks per pen for Ross and Cobb respectively. Each strainx stocking density x feed restriction combination was each represented by three replicate pens each measuring 322 cm x 92.7 cm (2.98 m2). Stocking densities were calculated based on estimated 49-day body weights of 3.38 and 2.78 kg for Ross and Cobb respectively. The equation used to calculate the number of birds per pen needed for the projected stocking densities was:

Birds/pen= [final treatment density (kg/m^2) x pen area (m^2)] / projected final BW (kg) (Dozier *et al.,* 2005; Dozier *et al.,* 2006).

Table 3.1 Chemica! composition (Label values) of commercial broiler starter, grower and finisher feeds were used in the study

Composition	Starter	Grower	Finisher
Crude protein (g/kg)	200.0	180.0	160.0
ME (MJ/kg)	12.76	13.00	13.20
ME:CP ratios (MJg^{-1})	0.06	0.07	0.08
Fat (g/kg)	25.0	25.0	25.0
Fibre (g/kg)	50.0	60.0	70.0
Moisture (g/kg)	120.0	120.0	120.0
Calcium (g/kg)	12.0	12.0	12.0
Phosphorus (g/kg)	6.0	5.5	5.0
Lysine (g/kg)	12.0	10.0	9.0

*Supplied by Meadow Feeds, Randfontein, South Africa

All birds were fed *ad libitum* trom 36 to 49 days of age. Heat was provided *tor* the first three weeks by two 175-watt infrared bulbs per pen and water was provided *ad libitum.* Continuous lighting was provided by 40-watt fluorescent tubes. The birds were individually weighed on day 7 and weekly until 49 days of age. The birds were fasted tor 12 hours prior to each weighing. Feed intake was recorded on pen basis when the birds were weighed. After the final weighing on day 49, tour birds were randomly sampled trom each pen and slaughtered. After desanguination and defeathering, the head and shanks were removed and the carcass was opened and entrails were also removed. Each carcass plus entrails was then placed in a polyethylene bag and chilled tor 48 hours, after which the carcasses were thawed and weighed. The following carcass parts were removed and weighed: breast, back, wing, drumstick, neck, liver, gizzard, heart and abdominal fat (the fat surrounding the gizzard, rectum and adjacent abdominal muscles). The weights of the carcass, carcass parts and giblets were expressed as percentages of live weight.

3.3. Statistical methods

Pen means were used for body weights, weight gains, feed intake and feed efficiency as well as carcass weight and the weights of the carcass parts. Pen means were used for all data (weights and relative weights) as well as feed intake and feed conversion ratio. All data were analyzed by analysis of variance for a 2 x 3 x 2 factorial in a completely randomized design using the Minitab 16 statistica! software (Minitab, 2014). Two strains, three feed restriction treatments and two stocking densities were tested.

The following statistica! model was used for the analysis of variance:

$$Y_{ijkl} = \mu + S_i + D_j + F_k + (SD)_{ij} + (SF)_{jk} + (DF)_{ik} + (SDF)_{ijk} + E_{ijkl}$$

Where

$Y_{,skt}$ = is the observation for ....

μ = overall mean

Si = effect of the i^{th} strain

Di = effect of the j^{th} stocking density

Fk = effect of the k^{th} feed restriction

(SD)iJ = interaction effect between i^{th} strain and r stocking density

$(SF)_{ik}$ = interaction effect between i^{th} strain and k^{th} feed restriction

$(DF)_{1k}$ = interaction effect between j^{th} stocking density and k^{th} feed restriction

(SDF)iJk = interaction effect between i^{th} strain, $_{/h}$ stocking density and k^{th} feed restriction

E_{iJkt} = random error

Statistica! significance of differences among means was determined by Tukey's procedure (Steel and Torrie, 1981).

CHAPTER 4 : RESULTS

4.1 Growth performance

During the starter period (Table 4.1) there were no interaction effects on all the traits except strain x stocking density interaction on mortality rate (P<0.05). Strain had significant effects on initia! body weight, body weight gain and 21-day body weight (both at P<0.01) as well as feed consumption (P< 0.05), but had insignificant effects on feed conversion ratio and mortality rate (both at P>0.05). Ross was initially heavier, consumed more feed, gained more body weight and was heavier on day 21 than Cobb. Feed restriction had significant effects on 21-day body weight, body weight gain and feed consumption (all at P<0.01), but did not significantly affect feed conversion ratio and mortality rate (both at P>0.05) . There were progressive reductions in body weight gain and 21-day body weight with increasing duration of feed withdrawal. Stocking density had insignificant effects on initia! body weight, body weight gain, feed consumption, feed conversion ratio and mortality rate (all at P>0.05).

There were no interaction effects on all the traits during the grower period with the exception of strain x stocking density interaction effect on feed consumption (P<0.05) (Table 4.2). Strain had significant effects on 35-day body weight, body weight gain and feed consumption (all at P<0.01) but did not affect feed conversion ratio and mortality rate (both at P>0.05). Ross consumed more feed, gained more body weight and was heavier at 35 days than Cobb. Feed restriction significantly affected 35-day body weight, body weight gain and feed consumption (all at P<0.01), but had insignificant effects on feed conversion ratio and mortality rate (bath at P>0.05). Birds that were fed *ad libitum* consumed more feed, gained more body weight and were heavier at 35 days of age than these whose feeding times were reduced by 10 and 12 hours daily, but the two latter groups did not differ in these traits. Stocking density had significant effects on 35-day body weight and body weight gain (both at P<0.01) but did not affect feed consumption, feed conversion ratio and mortality rate (all at P>0.05). Birds raised at the stocking density of 30 kg BW/m^2 gained more body weight, consumed more feed and were heavier than these raised at the stocking density of 40 kg BW/m^2.

Table 4.1: Effects of strain, feed restriction and stocking density on broiler performance till day 21 (starter period)

Source	N	IBW (g)	W21 (g)	BWG1-21 (g)	FC1-21 (g/b/d)	FCR1-21 (gf/gg)	M1-21 (%)
Strain							
Ross	18	143⁸	656⁸	520⁸	60⁸	28	1a
Cobb	18	137b	625b	482b	56b	2a	2a
SEM		1.3	7.2	72	1.3	0.0	0.5
Stocking density							
30kg BW/m"-	18	140⁸	643⁸	5)2⁸	60⁸	2a	1a
40kg BW/mi	18	140⁸	638⁸	499⁸	57⁸	2a	2a
SEM		1.3	7.2	72	1.3	0.0	0.5
Feed restriction							
Ad libtum	12	139⁸	778⁸	639⁸	74⁸	2a	1a
10 h	12	139⁸	591b	453b	52b	2a	2a
12 h	12	142⁸	553c	410c	49b	2a	1a
SEM		1.6	8.8	88	1.5	0.0	0.6
Significance							
Strain		**	**	*"	*	ns	ns
Feed restriction		ns	**	*"	**	ns	ns
Stocking density		ns	ns	ns	ns	ns	ns
SxF		ns	ns	ns	ns	ns	ns
SxD		ns	ns	ns	ns	ns	*
FxD		ns	ns	ns	ns	ns	ns
SxFxD		ns	ns	ns	ns	ns	ns

IBW = initia! body weight; W21 = body weight at 21 days of age; BWG = body weight gain; FC = feed consumption; FCR = feed conversion ratio; MR = mortality rate, S = strain, F = feed restriction, D = stocking density, g/b/d = grams per bird per day, gf/gg = gram feed per gram gain

P<0.01; *P<0.05; ns = not significant; N = number of observations

Table 4.2 Effects of strain, feed restriction and stocking density on broiler performance during the grower period (22 - 35 days of age).

Source	N	W3s	BWG22-3s	FC22-3s	FCR22-3s	MR22-3S
		(g)	(g)	**(g/b/d)**	(gf/gg)	(%)
Strain						
Ross	18	1668^{8}	1012^{8}	**135^{8}**	**28**	28
Cobb	18	**1510b**	**885b**	119b	28	58
SEM		17.1	16.6	2.8	0.1	1.0
Stocking density						
30kg BW/mi	18	1636^{8}	**993^{8}**	**130^{8}**	**28**	38
40kg BW/mi	18	**1542b**	**903b**	**124^{8}**	28	**48**
SEM		17.1	16.6	2.8	0.1	1.0
Feed restriction						
Ad libitum	12	1849^{8}	1072^{8}	**142^{8}**	**28**	**2a**
10 h	12	**1482b**	**891b**	**122b**	**2a**	**3a**
12 h	12	**1434b**	**882b**	**116b**	**28**	**4a**
SEM		20.9	20.3	3.4	0.1	1.3
Significance						
Strain (S)		**	**	**	ns	ns
Feed restriction (F)		**	**	**	ns	ns
Stocking density (D)		**	**	ns	ns	ns
SxF		ns	ns	ns	ns	ns
SxD		ns	ns	*	ns	ns
FxD		ns	ns	ns	ns	ns
SxFxD		ns	ns	ns	ns	ns

W_3=5 body weight at 35 days of age; BWG = body weight gain; FC = feed consumption; FCR = feed conversion ratio; MR = mortality rate, S = strain, F = feed restriction, D = stocking density g/b/d = grams per bird per day, gf/gg = gram feed per gram gain

**P<0.01; *P<0.05; ns = not significant; N = number of observations

During the finisher period there were no significant interaction effects on any of the traits (Table 4.3). Strain had a significant effect on 49-day body weight (P<0.01) as well as body weight gain and feed consumption (both at P<0.05) but did not influence feed conversion ratio and mortality rate (both at P>0.05). Ross consumed more feed, gained more weight and was heavier at 49 days of age than Cobb. Feed restriction had a significant effect only on body weight at 49 days of age (P<0.01). Birds which were fed *ad libitum* were significantly heavier than the 10- and 12-hour daily feed-withdrawal birds, but the difference between the 10- and 12- hour feed-restricted birds was not significant. Body weight at 49 days of age was significantly affected by stocking density (P<0.05). Birds raised at the stocking density of 30 kg BW/m^2 were significantly heavier than those raised at 40 kg BW/m^2.

Over the entire study period there was a strain x stocking density interaction effect only on mortality rate (P<0.05). Strain had significant effects on body weight gain (P<0.01) and feed consumption (P<0.05), but had insignificant (P>0.05) effects on FCR and mortality rate. Ross consumed more feed, gained significantly more body weight and was heavier on day 49 than Cobb (Table **4.4).** Feed restriction had significant effects on body weight gain (P<0.01), feed consumption and mortality rate (both at P<0.05), but insignificantly affected FCR (P>0.05). Birds on *ad libitum* feeding gained significantly (P<0.01) more body weight and were heavier on day 49 than those on the 10- and 12- hour feed-withdrawal regimes, but consumed significantly (P<0.05) more feed. Stocking density had significant effects on body weight gain (P<0.05). Birds raised at 30 kg BW/m^2 stocking density performed better than those raised at the density of 40 kg BW /m^2.

Table 4.3 The effects of strain, feed restriction and stocking density on broiler performance during finisher period (36 - 49 days).

Source	N	w49	BWG3, -49	FC36-49	FCR36-49	M□6-49
		(g)	(g)	**(g/b/d)**	(gf/gg)	(%)
Strain						
Ross	18	**2772a**	**1104a**	**190a**	**3a**	**2a**
Cobb	18	2393°	**884°**	159°	3a	2a
SEM		71.9	69.5	9.8	0.2	0.1
Stocking density						
30kg BW/m'l.	18	2712a	1076a	180a	2a	2a
40kg BW/m'l.	18	2453°	911a	169a	3a	1a
SEM		71.9	69.5	9.8	0.2	0.1
Feed restriction						
Ad libitum	12	**2874a**	1023a	175a	3a	1a
10 h	12	2471°	**988a**	165a	2a	3a
12 h	12	2402°	**968a**	183a	3a	1a
SEM		88.1	85.1	12	0.2	0.7
Significance						
Strain		**	*	*	ns	ns
Feed restriction		**	ns	ns	ns	ns
Stocking density		*	ns	ns	ns	ns
SxF		ns	ns	ns	ns	ns
SxD		ns	ns	ns	ns	ns
FxD		ns	ns	ns	ns	ns
SxFxD		ns	ns	ns	ns	ns

W_{49}= body weight at 49 days of age; BWG = body weight gain; FC = feed consumption; FCR = feed conversion ratio; MR = mortality rate, S = strain, FR = feed restriction, D = stocking density g/b/d = grams per bird per day, gf/gg = gram feed per gram gain

* P<0.01; *P<0.05; ns = not significant; N = number of observations

Table 4.4 Effects of strain, feed restriction and stocking density on broiler performance during the entire study period (7 - 49 days).

Source	N	BWG1-49	FC1-49	FCR1-49	MR1-49
		(g)	(g/b/d)	(gf/gg)	(%)
Strain					
Ross	18	**2635a**	**126a**	oa	sa
Cobb	18	**2250b**	**110b**	oa	8a
SEM		72.5	4.6	0.0	1.2
Stocking density					
30kg BW/mi	18	**2572a**	**120a**	oa	**6a**
40kg BW/mi	18	**2313b**	**11Sa**	oa	6a
SEM		72.5	4.6	0.0	1.2
Feed restriction					
Ad libitum	12	2735[8]	**130a**	oa	**4b**
10 h	12	**2332b**	**108b**	oa	10ab
12 h	12	**2260b**	115[8]b	oa	**5a**
SEM		88.7	5.6	0.0	1.5
Significanee					
Strain (S)		**	*	ns	ns
Feed restriction (F)		**	*	ns	*
Stocking density (D)		*	ns	ns	ns
SxF		ns	ns	ns	ns
SxD		ns	ns	ns	*
FxD		ns	ns	ns	ns
SxFxD		ns	ns	ns	ns

BWG = body weight gain; FC = feed consumption; FCR = feed conversion ratio; MR = mortality rate, S = strain, F = feed restriction, D = stocking density, g/b/d = grams per bird per day, gf/gg = gram feed per gram gain

**P<0.01; *P<0.05; ns = not significant; N = number of observations

The results in Table 4.5 show that there were significant strain x stocking density interaction effects on feed consumption during the grower period and on mortality rate during the starter and the entire study periods (all at P<0.05).

Table 4.5 : Strain x stocking density means for feed consumption during the grower period and mortality rates during the starter and the entire study periods

Strain	Stocking density	N	MR1.21 (%)	MR1-49 (%)	FC22-3s (g/b/d)
Ross	30 kg BW/m²	9	2a	7a	134⁸
	40 kg BW/m²	9	1a	3a	136⁸
Cobb	30 kg BW/m²	9	oa	6a	126ab
	40 kg BW/m²	9	3a	ga	111b
SEM			0.7	1.7	3.9
Significanee					
SxD			*	*	*

FC = feed consumption; MR = mortality rate. S = strain, D = stocking density, g/b/d = grams per bird per day

P<0.01; *P<0.05; ns = not significant; **N = number of observations

4.2 Carcass characteristics

The results in Table 4.6 show that strain had a significant effect on drumstick weight (P<0.01) and feed restriction on breast (P<0.01), neck and heart weights (P<0.05). Drumstick weight for Ross was significantly higher than for Cobb. Breast weight of birds fed *ad libitum* was significantly higher than that of birds feed-restricted for 10 and 12 hours daily, but the neck and heart weights were higher in the 12 h feed-restricted birds. Stocking densities did not have significant effects on any of the carcass traits and no significant interaction effects were observed.

Table 4.6 Percentage weights of some carcass and giblets parts of two broiler strains raised at two stocking densities.

Source	N	CW	BKW	BRW	NW	GZW	HTW	WW	LVW	DRW	ABF
		%	%	%	%	%	%	%	%	%	%
Strain											
Ross	18	80.3a	15.4a	28.6a	4.8a	1.8a	0.53a	4.2a	2.9a	5.0a	2.1a
Cobb	18	79.6a	15.2a	29.0a	4.9a	1.9a	0.53a	4.3a	2.8a	4.8°	2.2a
SEM		0.664	0.227	0.391	0.086	0.047	0.011	0.079	0.071	0.058	0.087
Stocking density											
30 kg BW/m^2	18	79.6a	15.1a	29.1a	4.9a	1.8a	0.52a	4.1a	2.8a	4.9a	2.3a
40 kg BW/m^2	18	80.2a	15.5a	28.4a	4.8a	1.9a	0.54a	4.3a	2.9a	4.9a	2.0a
SEM		0.0664	0.227	0.391	0.086	0.047	0.011	0.079	0.071	0.058	0.087
Feed restriction											
Ad libitum	12	80.0a	14.9a	30.1a	4.5°	1.8a	0.50°	4.1a	2.8a	4.9a	2.0a
10 h	12	80.1a	15.8a	28.2°	4_9ao	1.9a	0.55a	4.4a	3.0a	4.9a	2.2a
12 h	12	79.6a	15.1a	28.0°	5.0a	1.9a	0.55a	4.3a	2.9a	4.9a	2.2a
SEM		0.814	0.278	0.479	0.105	0.057	0.014	0.097	0.087	0.071	0.107
Significance											
Strain		ns	ns	ns	ns	ns	ns	ns	ns	**	ns
Feed restriction		ns	ns	**	*	ns	*	ns	ns	ns	ns
Stocking density		ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
SxF		ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
SxD		ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
FxD		ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
SxFxD		ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

CW = carcass weight; BKW = back weight; BRW = breast weight; NW = neck weight; GI.W = gizzard weight; HTW = heart weight; *V'N.J* = wing weight; LVW = liver weight; DRW = drumstick weight; ABF = abdominal fat, S = strain, F = feed restriction, D = stocking density

**P<0.01; *P<0.05; ns = not significant; N = number of observations

CHAPTER 5 : DISCUSSION

5.1 Effects of strain on performance and carcass characteristics

The significant differences in initial body weight, body weight gain and body weight at 21 days obtained in this study supports earlier reports (Rosa *et al.,* 2007, Benyi *et al.,* 2009, Racket *al.* 2009 and Benyi *et al.* 2010) that genetic differences exist between strains in these traits. Since in addition to the heavier initia! body weight Ross also consumed more feed than Cobb, its superior weight gain and heavier body weight at 21 days of age could be attributed to genetic differences in bath weight gain and feed consumption capacity because of the positive genetic correlation that exists between these traits (Chambers 1990, Aggrey *et al.,* 2010). However, Dozier *et al.* (2006) and Skomorucha *et al.* (2009) did not find any significant differences among strains in body weight and body weight gain. The discrepancies in results are probably related to genetic differences among the strains used. The similar feed conversion ratios of two strains despite the *taster* weight gain and higher feed consumption of Ross shows that the strains utilized feed with the same degree of efficiency as observed earlier by Skomorucha *et al.* (2009). Contrary to the results Sosnowka-Czajka *et al.* (2005) and Skomorucha *et al.* (2007) reported significant differences in feed conversion ratio among different strains of broiler chickens.

According to the results in Table 4.6 percent drumstick weight of Ross was 0.2% higher than that of Cobb. These results are consistent with the results reported by Olawumi and Fagbuaro (2011) and Youssao *et al.* (2012) who observed significant strain effects on drumstick weight. Olawumi and Fagbuaro (2011) also reported insignificant effects of strain on liver, gizzard and abdominal fat whilst Youssao *et al.* (2012) observed insignificant effects on breast, wing, heart and liver weights. However Sandercock *et al.* (2009), Benyi *et al.* (2010) and Chukwuka *et al.* (2010) reported significant effects of strain on abdominal fat weight, Sandercock *et al.* (2009) also observed significant strain effects on heart and abdominal fat weights whilst Fotsa (2008) reported insignificant strain effects on drumstick weight as well as significant influence on breast weight.

5.2 Effects of stocking density on performance and carcass characteristics

The decrease in body weight and body weight gain with increasing stocking density observed in this study was also reported by Estevez *et al.* (2007), Skrbic *et al.* (2009), Skomorucha *et al.* (2009), Hassanein (2011) and Uzum and Toplu (2013). These negative effects could be the result of increased stress emanating trom increase in house temperature, high ammonia concentration and competition *tor* feed and water with increasing stocking density (EI-Deek and AI-Harthi, 2004). On the contrary, Turkyilmaz (2008) reported insignificant effects of stocking density on body weight whilst Dozier *et al.* (2005) and Dozier *et al.* (2006) reported better growth rate and feed efficiency with increasing s1ocking density during the starter period. The authors attributed this to increased metabolic heat production with increasing stocking density since the pens used in their study had no broeders and therefore the chicks benefited trom the increased non-evaporative heat production with increasing stocking densities. The insignificant effect of stocking density on feed conversion ratio was also reported by Thomas *et al.* (2004), Ventura *et al.* (2010) and Uzum and Toplu (2013), whereas Ravindran *et al.* (2006) and Skomorucha *et al.* (2009) reported increase in feed conversion ratio with increasing stocking density whilst Benyi *et al.* (2011) reported significant strain x stocking density interaction effects on feed conversion ratio.

The insignificant influence of stocking density on mortality rate during the different stages of growth observed in this study was confirmed by various researchers such as Thomas *et al.* (2004), Skrbic (2007), Melluzi *et al.* (2008) and Beg *et al.* (2011). In contrast, Imeada (2000) and Skrbic *et al.* (2011) found that mortality rate was markedly increased at high stocking densities. This probably resulted trom reduced dissipation á body heat to the air due to increased house temperature, poor air quality due to high ammonia production and reduced access to feed and water which resulted in reduced livability of broilers (Puron *et al.,* 1995; Feddes *et al.,* 2002; Bessei *et al.,* 2006).

The lack of significant effects of stocking density on carcass characteristics was previously reported by Ravindran and Thomas (2004), Thomas *et al.* (2004), Sreehari and Sharma (2010). Beg *et al.* (2011) also reported insignificant effects of stocking density on carcass characteristics except on abdominal fat weight percent and Uzum and Toplu (2013) reported insignificant influence of stocking density on back, wing, neck, gizzard, liver and abdominal fat weights. However, Dozier *et al.* (2005) and Hassanein (2011) observed significant reduction in carcass, breast, and thigh weights with increasing stocking density whilst Uzum and Toplu (2013) also reported significant effects on breast and heart weights.

5.3 Effects of feed restriction on performance and carcass characteristics

The significant reductions in body weight, body weight gain and feed consumption in the feed-restricted birds during feed restriction period observed in this study have been previously reported by other researchers (Benyi *et al.* 2011, Achiempong-Boateng *et al.* 2012). The *ad libitum-fed* birds performed significantly better in body weight and body weight gain than the feed-restricted birds but ate more feed. The feed-restricted birds failed to regain the weight lost during feed restriction despite the accelerated weight gains during re-alimentation as previously reported by Saleh *et al.* (2004). The inability of the feed-restricted birds to compensate tor the weight loss suggests that the duration of feed restriction was too long and the period of re-alimentation too short to allow complete recovery of body weight loss. Contrary to this, Navidshad *et al.* (2006), Onbasilar *et al.* (2009), Benyi *et al.* (2010) and Ghazanfari *et al.* (2010) reported similar final body weights and body weight gains in feed-restricted and full-fed birds, whilst Ozkan *et al.* (2003), Khethani *et al.* (2008) and Onbasilar *et al.* (2009) reported insignificant effects of feed restriction on feed consumption. These discrepancies on the effects of feed restriction could be due to timing, severity and duration of feed restriction.

The highest mortality rate was recorded in the 10 h feed-withdrawal birds tollowed by those on 12 h feed-restriction regime. The significantly higher mortality rate in the feed-restricted birds than their full-fed counterparts is in agreement with the results obtained by Doyle and Leeson (2003). However Dozier *et al.* (2002), Dozier *et al.* (2003), Benyi *et al.* (2010) and Acheampong-Boateng *et al.* (2012) reported insignificant effects of feed restriction on mortality rate. One would have expected a lower mortality rate in the feed-restricted birds as previously reported by Saleh *et al.* (2004) and Khajali *et al.* (2007) that feed restriction reduced mortality rate. The inconsistencies in the effects of feed restriction on mortality rate could be due to nature, duration and severity of feed restriction.

Full-fed birds showed higher percent breast weight than the feed-restricted ones. The probable explanation tor this could be that a high proportion of the feed consumed is used tor development of muscle tone. This suggests a positive correlation between breast weight and feed consumption. The lack of significant effects of feed restriction on percent carcass, back, gizzard, wing, liver, drumstick and abdominal fat weights in this study was also previously observed by Turkyilmaz (2008) who reported statistically insignificant differences in abdominal fat, carcass yield and liver weights, Beg et al. (2011) on back, drumstick, wing and abdominal fat weight percent and Demir et al. (2004), Benyi et al. (2010) and Acheampong-Boateng et al. (2012) on abdominal fat while Navel et al. (2008) also reported insignificant effect of feed restriction on carcass traits. Lipens et al. (2000) and Saleh et al. (2005) observed significantly lower carcass yield in feed-restricted birds. Contrary to our results, Beg et al. (2011) reported insignificant effect of feeding regime on breast weight percent. The finding on abdominal fat however, is contrary to that of Ghazanfari et al. (2010) who reported that feed restriction reduced abdominal fat deposition. One would have expected the full-fed birds on account of their heavier market weight to deposit more abdominal fat because of the positive genetic correlation ranging from 0.21 to 0.36 that exists between live weight and abdominal fat percent (Chambers, 1990).

5.4 Effects of strain x stocking density interactions on performance and carcass characteristics

The strain x stocking density interaction effects observed in this study were caused by differential responses of the strains to the stocking densities. For mortality rates during the starter and entire study periods (Table 5) Ross birds raised at the lower stocking density (30 kg BW/m^2) had a higher mortality rate than these reared at the higher stocking density (40 kg BW/m^2) and vice versa for Cobb. For feed consumption Ross birds raised at the lower density consumed two grams less feed per day than their counterparts reared at the higher density. On the contrary, Cobb birds raised at the lower stocking density consumed 15 grams more feed per day than those reared at the higher density. Reports of significant strain x stocking density interaction effects on broiler performance are scarce. Tarrago and Puchal (1977) and Akinokun *et al.* (1986) reported significant interaction effects on feed conversion ratio, growth rate and mortality rate. More recently, Yakubu *et al.* (2010) reported significant interaction effects on carcass traits and Benyi *et al.* (2011) reported a significant interaction effect on feed conversion ratio.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

The overall results have shown that Ross 308 eutperfermed Cobb Avian48 in weight gain, market weight and percent drumstick weight and had insignificantly lewer mertality rate, but consumed more feed. The results alse revealed that feed-restricted birds consumed less feed than full-fed birds. Although the feed-restricted birds were statistically similar in market weight, the 10 h-daily feed-restricted birds consumed less feed but were heavier than these on 12 h daily feed withdrawal program. In addition, the birds raised at lewer stecking density (30kg BW/m^2) performed better in weight gain and final body weight than these reared at the higher stocking densities (40kg BW/m^2).

6.2 RECOMMENDATIONS

It is recommended to farmers that for profitable broiler production in the subtropics Ross 308 reared at the stocking density of 30 kg BW/m^2 and subjected to 10 h daily feed withdrawal program from 7 to 35 days of age fora 49-day production period may be considered.

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APPENDIX

Appendix 1. Mean squares of analyses of variance for initial body weight, 21-day body weight, body weight gain, feed consumption, feed conversion ratio and mortality rate during the starter period.

Source	df	IBW (g)	W21 (g)	BWG_{7_21} (g)	FC1-21 (g/b/d)	FCR_{7_21} (gf/gg)	MR1-21 (%)
Strain (S)	1	400.90**	8879**	13053**	158.65*	0.00385	0.563
Feed restriction (F)	2	51.95	173797**	177362**	2220.82**	0.02478	9.954
Stocking density (D)	1	**2.44**	167	129	91.12	0.03070	7.200
SxF	2	51.41	849	598	48.59	0.02312	3.828
SxD	1	21.99	202	357	4.18	0.02216	23.200*
DxF	2	**22.48**	750	1023	30.79	0.04335	5.564
SxDxF	2	5.21	758	810	13.94	0.00745	0.322
Error	**24**	32.25	929	931	27.90	0.01782	4.672

IBW = initial body weight; W21 = body weight at 21 days of age; BWG = body weight gain; FC = feed consumption; FCR = feed conversion ratio; MR = mortality rate, S = strain, F = feed restriction, D = stocking density, g = grams, g/b/d = grams per bird per day, gf/gg = gram feed per gram gain

**P<0.01; *P<0.05; ns = not significant; df = degrees of freedom

Appendix 2. Mean squares of analyses of variance for 35-day body weight, body weight gain, feed consumption, feed conversion ratio and mortality rate during the grower period.

Source	df	W35 (g)	BWG22-3s (g)	FC22-3s (g/b/d)	FCR22-3s (gf/gg)	MR22-3s (%)
Strain (S)	1	225566**	**144942****	2397.8**	0.00012	63.73
Feed restriction (F)	2	617568**	137154**	2249.0**	0.02723	18.26
Stocking density (D)	1	79481**	72362**	365.2	0.05681	2.20
SxF	2	1604	1300	71.4	0.04712	4.30
SxD	1	753	175	669.2*	0.15298	9.10
DxF	2	1102	3564	290.9	0.02062	19.95
SxDxF	2	19548	16681	242.6	0.00194	2.48
Error	**24**	5254	4963	136.2	0.03888	19.59

W3s = body weight at 35 days of age; BWG = body weight gain; FC = feed consumption; FCR = feed conversion ratio; MR = mortality rate, S = strain, F = feed restriction, D = stocking density, g = grams, g/b/d = grams per bird per day, gf/gg = gram feed per gram gain

**P<0.01; *P<0.05; ns = not significant; df = degrees of freedom

Appendix 3. Mean squares of analyses of variance for 49-day body weight, body weight gain, feed consumption, feed conversion ratio and mortality rate during the finisher period.

Source	df	W49 (g)	BWGa6-49 (g)	FC35-49 (g/b/d)	FCR35-49 (gf/gg)	MRa6-49 (%)
Strain (S)	1	1290056**	436747*	9127*	0.0922	0.538
Feed restriction (F)	2	778637**	9882	937	0.1754	15.235
Stocking density (D)	1	604788*	245776	1272	0.4098	18.778
SxF	2	66791	55783	1172	0.0356	17.319
SxD	1	168055	146304	220	0.0794	9.000
DxF	2	30300	22211	507	0.0817	3.305
SxDxF	2	92546	36146	757	0.2408	0.731
Error	24	93103	86895	1724	0.4139	5.375

W49 = body weight at 49 days of age; BWG = body weight gain; FC = feed consumption; FCR = feed conversion ratio; MR = mortality rate, S = strain, F = feed restriction, D = stocking density, g = grams, g/b/d = grams per bird per day, gf/gg = gram feed per gram gain

**P<0.01; *P<0.05; ns = not significant; df = degrees of freedom

Appendix 4. Mean squares of analyses of variance *tor* body weight gain, feed consumption, feed conversion ratio and mortality rate during the entire study period.

Source	df	BWG1-49 (g)	FC1-49 (g/b/d)	FCR1-49 (gf/gg)	MR1-49 (%)
Strain (S)	1	1335940**	2305.3*	0.0000157	58.52
Feed restriction (F)	2	785841**	1471.8*	0.0005000	102.08*
Stocking density (D)	1	602363*	220.9	0.0000526	0.03
SxF	2	64532	413.2	0.0001978	29.48
SxD	1	171922	145.3	0.0001169	107.81*
DxF	2	28930	401.6	0.0001471	55.50
SxDxF	2	93851	122.9	0.0001547	3.95
Error	24	94492	378.7	0.0001619	25.84

BWG = body weight gain; FC = feed consumption; FCR = feed conversion ratio; MR = mortality rate, S = strain, F = feed restriction, D = stocking density, g = grams, g/b/d = grams per bird per day, gf/gg = gram feed per gram gain

**P<0.01; *P<0.05; ns = not significant; df = degrees of freedom

Appendix 5. Mean squares of analyses of variance for percent carcass, back, breast, neck, gizzard, heart, liver, drumstick and abdominal fat weights of two broiler strains raised at two stocking densities.

Source	df	**CW** %	BKW %	BRW %	**NW** %	*Gz:i.N* %	HTW %	***WN*** %	LWv %	DRW %	ABF %
Strain (S)	1	4.455	0.4697	1.289	0.2056	0.12838	0.000142	0.0913	0.17334	0.63815**	0.1551
Feed restriction (F)	2	1.046	2.4664	16.467**	0.6224*	0.11120	0.010224*	0.3129	0.13459	0.01878	0.0949
Stocking density (D)	1	3.224	2.0949	4.85	0.0504	0.00792	0.002287	0.3517	0.09620	0.02622	0.3921
SxF	2	14.1801	0.2671	0.118	0.3474	0.01358	0.000931	0.0318	0.22382	0.14645	0.0902
SxD	1	0.055	0.6144	0.165	0.0562	0.00197	0.000901	0.0509	0.01664	0.04952	0.0018
DxF	2	6.350	0.4478	1.604	0.0466	0.00313	0.003603	0.0287	0.04256	0.08339	0.152
SxDxF	2	4.301	0.3889	1.241	0.0566	0.05774	0.001531	0.0363	0.23705	0.00123	0.2783
Error	24	7.943	0.9302	2.754	0.1326	0.03933	0.002256	0.1120	0.9119	0.06082	0.1374

CW = carcass weight; BKW = back weight; BRW = breast weight; NW = neck weight; *GZJN* = gizzard weight; HTW = heart weight; *WN* = wing weight; LWv = liver weight; DRW = drumstick weight; ABF = abdominal fat, S = strain, F = feed restriction, D = stocking density

**P<0.01; *P<0.05; ns = not significant; df = degrees of freedom