CHAPTER 1

INTRODUCTION

1.1 Background

Chickens are kept in most areas of the world and play a vital role in many rural households (Alders *et al.,* 2001). In the Limpopo province and South Africa as a whole, broiler chicken production is an important source of income and employment. Meat from broiler chickens has become an important dietary component of most people in South Africa. Chicken meat is an important source of high quality protein, is easily digested and contains all essential amino acids. It is also an excellent source of vitamin A, thiamin, riboflavin and niacin (Robert, 1992). Poultry manure is also very important as a ruminant feed (Lyle *et al.,* 1975) and fertilizer used in crop production.

1.2 Motivation

Poultry production can play an important role in poverty alleviation and in the supply of quality protein to rural people (Pedersen, 1998). The high demand for chicken meat, low capital input required, early market age, rapid return over invested capital and the small space required for poultry production have increased awareness that chicken farming is a profitable venture in the Limpopo province. However, high fat deposition in broiler chickens does affect the industry (Zubair and Leeson, 1996). Allowing birds an unlimited supply of food results in consumption in excess of the bird's requirements for maintenance and production and the excess energy is converted into fat (Scott *et al.,* 1969; Fontana *et al.,* 1992; Cuddington, 2004). Excessive fat is one of the main problems faced by the broiler industry these days, since it not only reduces carcass yield and feed efficiency but also causes rejection of the meat by consumers (Kessler *et al.,* 2000) and causes difficulties in processing (Chambers, 1990). Recent reports on food restriction during the growing period in broiler chickens indicate that restricting food intake lowers body weight and carcass fat and improves food efficiency with compensatory growth during refeeding (Plavnik *et al.,* 1986; Fontana *et al.,* 1992 Al-Taleb, 2003). However, contrary results have also been reported elsewhere (Summers *et al*., 1990; Leeson *et al*., 1991; Robinson *et al.,* 1992). Broiler chickens undergoing compensatory growth, also, exhibit greater than normal feed intake relative to body weight, and may exhibit some associated digestive adaptations (Zubair and Leeson, 1994b). The use of this concept to address problems of high carcass fat requires more studies on the nutrition of the broiler chicken during the period of growth compensation.

1.3 Aim and objectives

1.3.1 Aim

The aim of this study was to improve productivity of Ross 308 broiler chickens through manipulation of compensatory growth.

1.3.2 Objectives

The objectives of the study were to determine:

1. The effects of sex, period and level of feed restriction at the starter stage and their interactions on subsequent diet intake, digestibility, growth, mortality and carcass characteristics of Ross 308 broiler chickens.

2. The effects of sex, feed restriction at the starter stage and level of lysine supplementation during realimentation and their interactions on diet intake, digestibility, growth, mortality and carcass characteristics of Ross 308 broiler chickens.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Broiler chickens are raised on concentrated energy diets to maximize growth rates and reduce the total number of days needed to reach market weight. Plavnik *et al.* (1986) reported that the increase in growth rate of modern broiler chickens has been associated with increased fat deposition. This problem most commonly occurs in broiler chickens that are fed *ad libitum* (Pasternak and Shalev, 1983). The high growth rate which results causes stress on the birds and can result in metabolic diseases and skeletal disorders that lead to economic losses due to reduced animal performance, high mortality rates and carcass condemnation at slaughter houses (Cuddington, 2004). The phenomenon of compensatory growth has long been recognized as having the potential to have profound effects on the rate of growth and body composition of most animals. An animal whose growth has been slowed down by nutritional deprivation may exhibit an enhanced rate of growth when realimented. If this exceeds the maximal rate of gain when adequate nutrition has been provided, the animal is said to have undergone compensatory or "catch-up" growth (McMurtry *et al.*, 1988). Wilson and Osbourne (1960) referred to compensatory growth as being the period of rapid growth, relative to age, exhibited by mammals and birds after a period of nutritional restriction. It is a complex phenomenon because it involves genetic, physiological, nutritional, metabolic, endocrinal and behavioral relationships (Nir *et al.*, 1996). Plavnik and Hurwitz (1985), Calvert *et al.* (1989) and Jones and Farrell (1992) reported that during the period of feed restriction, growth rate is slower than that of birds given free access to food, but when access to food is again unrestricted, the previously-restricted birds exhibit an accelerated rate of weight gain. However, when feed restriction is severe, compensatory growth is not sufficient to ‘catch - up’ to market weight (Onderka and Hanson, 2003). On the other hand, the previously restricted birds apparently utilise food more efficiently following the period of restricted feeding because their overall feed intake and feed conversion ratio are lower than those of full fed birds (Al-Taleb, 2003), or could be because food restriction induces reduced energy requirement (Mac Leod *et al.*, 1979).

2.2 Methods of feed restriction

Various methods of undernutrition have been used to retard or even stop growth during the restriction period. These methods include: physical feed restriction, limiting the level of consumption of food in time (skip-a-day feeding) or reducing the hours of illumination of feeding (Religious *et al.,* 2001), diet dilution, chemical methods of feed restriction and use of low protein or low energy diets (Zubair and Lesson, 1996)

2.2.1Physical feed restriction

Physical feed restriction provides a calculated quantity of feed per bird, which is often just enough to meet maintenance requirements (Plavnik and Hurwitz, 1989). However, it has a constraint due to the need to weigh feed on a daily basis. In addition to this, it is necessary to provide sufficient feeder space to avoid competition among the restricted birds and to prevent unequal growth of birds within a flock. Quantitative feed restriction has been observed to reduce mortality and culling (Fontana *at al.,* 1992; Robinson *et al.,* 1992), improve feed conversion ratio (Fontana *et al.,* 1992; Deaton, 1995; Plavnik and Hurwitz, 1988b; Lee and Lesson 2001) and allow a complete recovery of body weight if the degree of restriction was not too severe and slaughter ages were extended beyond 6 weeks (Deaton, 1995; Plavnik and Hurtwiz, 1988b). Dozier *et al.* (2002), referred to feed restriction programs of yielding inconsistent results in the literature and that variation maybe partially attributed to differences in bird management, lighting, strain and ventilation. Plavnick and Hurwitz (1988a) reported complete compensatory gain with males but not females after early feed restriction. From their findings, it can be deduced that with females feed restriction should be initiated from 5 to 7 days of age and the duration should not exceed 5 days to achieve complete recovery of final body weight and optimum feed efficiency. Although the level of early feed restriction is an important factor influencing the broiler chicken response, early feed restriction at 30% of *ad libitum* intake was not able to influence broiler chicken performance parameters at market age of 49 days (Giachetto *et al.,* 2003). In the same study, broiler chicken carcass protein, total fat and abdominal fat pad were not affected by the treatment. Benyi and Habi (1998), with a 30% food restriction, reported less abdominal fat deposition than when there was a 15% food reduction, reduction of feeding time by 2 days per week or *ad libitum* feeding. Tumova *et al.* (2002) reported an accelerated growth rate on the previously restricted birds at the age of 21 days resulting in a similar daily weight gain with full-fed cockerel, and from the age of 35 days daily weight gain of the previously restricted birds was higher at about 15% than full-fed broiler chickens. Lippens *et al.* (2000) working with Ross and Hybro broiler chickens, indicated that moderate early-life feed restriction programmes did not always guarantee sufficient 'catch-up' growth to obtain a similar slaughter weight at the same age as their *ad libitum* birds. No significant differences were observed with regard to feed conversion ratio and total carcass fat, although the restricted birds showed a tendency towards a higher abdominal fat content. Rosebrough and MacMurty (1993) suggested that even feed-restricted broiler chickens are still overeating and that the level of feed intake may control de novo lipogenesis. A controversial aspect of feed restriction programs has been the inconsistent carcass fat deposition. Summers et al. (1990) and Jones and Farrell (1992) did not find changes in carcass composition of birds after feed restriction conditions; however, Plavnick and Hurwitz (1985, 1989) and Plavnick *et al.* (1986) reported a decrease in fat pad on broiler chickens restricted from 6 to 12 days of age, without adverse effects on growth. Lee and Leeson (2001), Leeson *et al*. (1991), Saleh *et al.* (2004, 2005) and Urdaneta-Rincon and Leeson (2002) were not able to show a clear effect.

2.2.2 Skip-a-day feeding

Skip-a-day feed removal is a technique for limiting early growth and has not been extensively examined for broiler chickens (Dozier *et al.,* 2002). Skip-a-day feeding programs providing limited allotments are widely used in broiler breeder's growth restriction programs. Removing feed for 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 and reduce the incident of ascites without affecting final body weight (Arce *et al.,* 1992; Ballay *et al.,* 1992). Oyedeji and Atteh (2005) and Oyedeji *et al*. (2003), reported reduction in feed intake after subjecting the birds to fasting on every other day. Oyedeji and Atteh (2005) concluded that skip-a-day feeding for 3 weeks starting at day-old would improve carcass quality and reduce sudden death syndrome which is often associated with birds that are on *ad libitum* feeding.

2.2.3 Lighting

Lighting is a powerful exogenous factor in control of many physiological and behavioural processes (Manser, 1996). Birds are very sensitive to light. Light allows the birds to establish rhythmcity and synchronize many essential functions, including body temperature and various metabolic steps that facilitate feeding and digestion (Olanrenwaju *et al.,* 2006). Light intensity, color, and the photoperiodic regime can affect the physical activity of broiler chickens (Lewis and Morris, 1998). Broiler chickens normally do not eat during darkness, as long as this period does not extend for more than 12 hours (Sartory, 1979). As a normal practice, modern broiler chickens are grown under 23 hours of light per day. It is known that by altering lighting schedules by either reducing the hours of light or developing intermittent schedules, feed utilization is improved (Blair et al., 1993; Wilson et al., 1984; Alpedoorn *et al.,* 1999). Light manipulation is used in broiler chicken production to control growth, improve feed efficiency, minimize mortality and reduce electricity costs. Broiler chickens under different reduced lighting programs, therefore, will reduce their feed intake. However, broiler chickens do learn to eat during darkness when hours of light are low (Morris, 1986). It is hypothesized that short photoperiods early in life will reduce feed intake and limit growth (Olanrewaju *et al.,* 2006). Classen (2004), comparing 12 light-hours versus 12 dark-hours, 16 light-hours versus 8 dark-hours and 20 light-hours versus 4 dark-hours demonstrated clearly that longer periods of darkness prevent regular access to feed and consequently reduce feed intake and limit growth. Chickens can learn to eat in the dark (Perry, 1981), but their feed intake in the dark is much reduced (Buyse and Decuypere, 1988). They can also learn to increase feed intake during the light period in anticipation of the dark period but are limited by their crop size (Perry, 1981).

2.2.4 Diet dilution

Many workers have used diet dilution as an alternative method of nutrient restriction because of the advantage of attaining a more consistent growth pattern within a flock. Leeson *et al.* (1991) and Jones and Farrell (1992), using 50 to 65 % diet dilution with rice hulls in order to retard early growth, reported that even though the birds ate more feed, the adjustment was insufficient to normalize nutrient intake and so growth rate was reduced. Griffiths *et al.* (1977) lowered the energy of a broiler chicken diet to 2233 kcal ME/kg DM from 3087 kcal ME/kg DM of feed by substituting ground yellow corn with oat meal as the main ingredient. Chickens fed the low energy diet consumed significantly more feed than those fed the high energy diet. When fed the low energy diet from 0 to 3 weeks of age, the chicks were not significantly different in body weight or in abdominal fat pad development from the *ad libitum* birds at 4 weeks of age. Leeson *et al.* (1992) offered broiler chickens a conventional finisher diet diluted up to 50% with a 50:50 mixture of sand: oat hulls from 35 to 49 days of age, and showed no significant difference in body weight at 49 days or breast weight at 42 or 49 days of age. Cabel and Waldroup (1990) observed that diluting the starter diet with sand from 5 to 11 days of age moderately restricted growth, which was completely recovered by 49 days of age.

2.2.5 Chemical methods

The use of chemicals is another means of achieving reduced growth rate. It has an advantage of evenly distributing the feed among birds and so reducing the variations in growth than can occur with physical feed restriction. Restriction of feed intake of broiler chickens by chemical means was suggested by Fancher and Jensen (1988). Pinchasov and Jensen (1989), supplemented broiler chickens and fed them for 7 to 14 days and reported that diets with 1.5 and 3.0% glycolic acid intake was depressed by 17 and 45%, respectively, resulting in growth retardation during the undernutrition period of about 71 and 41%, relative to the growth of control birds. Body weight of the chemically restricted male broiler chickens was similar to those fed *ad libitum* at 49 days of age. Oyawoye and Krueger (1990) showed that 400 and 300 mg of phenylpropanolamine hydrochloride or monensin sodium per kg diet, respectively, significantly depressed body weight of the broiler chickens at 4 weeks of age. Pinchasov and Elmaliah (1994) included 1 or 3% of acetic and propionic acids in the diet and found that weight gains of chemically restricted birds were close to those obtaining under a recommended program of quantitative feed restriction for female broiler breeders between 2 to 6 weeks of age.

2.2.6 Use of low protein or low energy diets

Energy in broiler chickens is needed for maintenance and growth of body tissues, vital metabolic activities and maintenance of normal body temperature (Scott *et al*., 1982). Energy concentration of the diet is also of primary importance in determining the amount of feed ingested by the broiler chicken. Broiler chickens eat primarily to satisfy their energy requirements (Reddy, 2000; Scott *et al*., 1982). When this requirement is satisfied, the chicken stops eating. Therefore, diets with higher energy concentration will have lower intake and those with lower energy concentration will have higher feed intake (Macleod, 1991; Leeson, 1996). Holsheimer and Veerkamp (1992) and Yolcin *et al*. (1990) reported that high energy diets significantly increased absolute carcass weight and yield of abdominal fat, however, carcass part weights were not influenced by dietary energy. Also, relative abdominal fat weight increased linearly with increments in dietary energy. The use of low protein or low energy diets has an advantage in that it does not require any additional labor to weigh feed. Broiler chickens require 220, 200 and 180 g/kg dietary crude protein during the starting, growing and finishing periods, respectively, for optimal growth (NRC, 1994). Fisher (1984) reported that broiler chickens tend to increase their feed intake to make up for deficiencies when fed diets that are marginally deficient in crude protein. Leeson *et al.* (1996) reported that diluting commercial broiler chicken diets from 35 to 49 days of age with oat hulls and sand, which led to the diets deficient in energy content, caused a significant reduction in body weight at 42 days of age, although the growth was compensated thereafter. Birds seemed to maintain energy intake, therefore there was increased feed intake with energy deficient diet. Coon *et al*. (1981) comparing the performance of male and female broiler chickens fed low or high energy rations for 56 days, found a significant improvement in the feed conversion ratio using a diet with high energy level. Zorrila *et al.* (1993), observed a linear increase in body weight gain when diet energy levels were increased. On the other hand, a linear decrease in carcass weight and breast meat yield was observed with birds fed both protein and energy deficient diets. These results suggested that birds can grow quite well on low energy diet but a period of 7 days is necessary to adjust their feed intake (Leeson *et al.*, 1996). Babu *et al.* (1986) reported comparable feed intake, weight gain and feed: gain ratio for broiler chickens subjected to low crude protein diets compared with those on higher crude protein diets. In contrast, Plavnick and Hurwitz (1990) reported that broiler chickens fed low crude protein diets gained the least body weight and did not recover the body weight as measured at 56 days of age. Morris (1971) also reported 25% growth retardation by feeding low crude protein diets. Sizemore and Siegel (1993), tested the effects of early energy restriction, while keeping protein and other nutrients constant, on different female broiler chicken crosses. They observed significant differences in the response of female broiler chickens to energy restriction. They concluded that the reason the results on early feed restriction are often contradictory is that the genetic makeup of the broiler chicken may interact with its response to the nutritive content of the diet and change the final result.

2.2.7 Feed textures

Feed particle size influences broiler chicken growth and development (Jones et al., 1995). Broiler chickens fed on mash spend more time consuming their feed compared to birds fed pellets; as a result they spend more energy in the process (Jensen *et al*. 1962; Savory, 1974). Andrew (1991) suggested that the improvement in growth rate due to eating pellets is attributed to some extent to the increase in bulk density of pullets which in some situations increases nutrient intake.

2.3 Mechanisms in compensatory growth

The mechanisms governing compensatory growth have been studied by a number of workers (Wilson and Osbourn, 1960; Winick and Nobel, 1966; Mosier, 1986; Pitts, 1986). Two hypotheses have been put forward to explain the mechanisms that govern compensatory growth, the central control hypothesis and the peripheral control hypothesis (Zubair and Leeson, 1996). The central control hypothesis suggests that the body has a set point for body size appropriate for a particular age and that this control resides in the central nervous system (Wilson and Osbourn, 1960; Mosier, 1986). This stimulates a signal to be sent to the hypothalamus to increase the production of growth hormone by the anterior pituitary gland, which in turn is modulated by the environmental photoperiod. However, this theory holds an obvious weakness in that sufficient evidence exists to dismiss the action of growth hormone alone on compensatory growth (Mosier, 1986; Hornick *et al.,* 1998; Yambayamba *et al.,* 1996). Although much of this theory still remains hypothetical in that the sensors and signals have not been identified, the underlying thought that there is some central control mechanism that defines the end body size of the animal still remains plausible.

The peripheral control hypothesis suggests that control of body size is determined by the tissues where cell number or, more accurately DNA, determines the extent of growth following a period of undernutrition or illness (Winick and Noble, 1966; Pitts, 1986). Therefore, only upon severe restriction pre-natally or very early post-natally would one expect that total DNA might be decreased so that total mature size would be decreased. Nutritional deprivation has been shown to impact on DNA size, not number, so that theoretically upon realimentation the animal should be able to attain its appropriate size for age (Pitts, 1986).

Benschop (2000) indicated that the key mechanisms in compensatory growth are decreased maintenance costs, increased feed intake, increased efficiency of growth and in some instances increased digesta load. The reduction in maintenance costs would then allow for comparatively more energy for growth upon realimentation, thus contributing to the compensatory growth responses (Ryan, 1990).

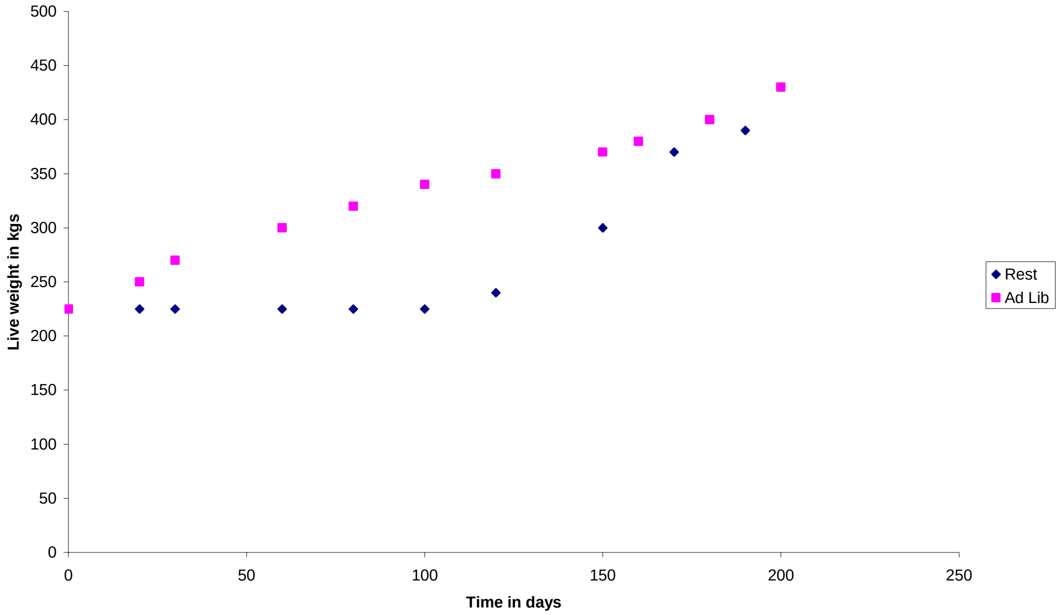
Increased feed intake has been demonstrated by many researchers as the main mechanism that drives compensatory growth. Zubair and Leeson (1994a) reported that restricted-refed broiler chickens have shown higher feed intake relative to body weight when compared to the *ad libitum* control. Hence, higher feed intake as related to body weight, and its associated digestive adaptations seem to be important contributing factors to any growth compensation. Birds with retarded growth due to undernutrition can achieve a growth rate higher than normal for chronological age after removal of the feed restriction (Plavnik and Hurwitz, 1985). Owing to the increased efficiency of protein deposition because of the concomitant water deposition that results in more gain per gram protein deposited than lipid deposited, higher rates of protein deposition during realimentation would have a significant impact on the overall growth rates (Benschop, 2000). However, the mechanisms responsible for this capacity have not yet been fully clarified (Giachetto, 1998).

Zubair and Leeson (1994b) reported that another adaptation exhibited by the restricted-refed broiler chickens is the relative enlargement of digestive organs, especially the gizzard, crop, pancreas and liver which enhance feed intake and help support compensatory growth. However, this theory is not supported by the findings of Subsilla *et al.* (1994), who applied food restriction of 75% and 50% of *ad libitum* intake to unsexed broiler chickens from day 5 to 11 days of age and could not find any differences in proportional liver weight during the experiment. Palo *et al.* (1995) suggested that the supply organs of previously restricted birds need to 'catch-up' first when realimented and eventually exceed in absolute weight those of the controls before compensatory growth can occur. In their trial, the restricted broiler chickens exhibited a higher proportional gizzard weight on days 14 and 21 but not on day 42, while the proportional weight of the proventriculus was significantly higher only on day 42 as compared with the *ad libitum* fed broiler chickens.

2.4 Types of compensatory responses

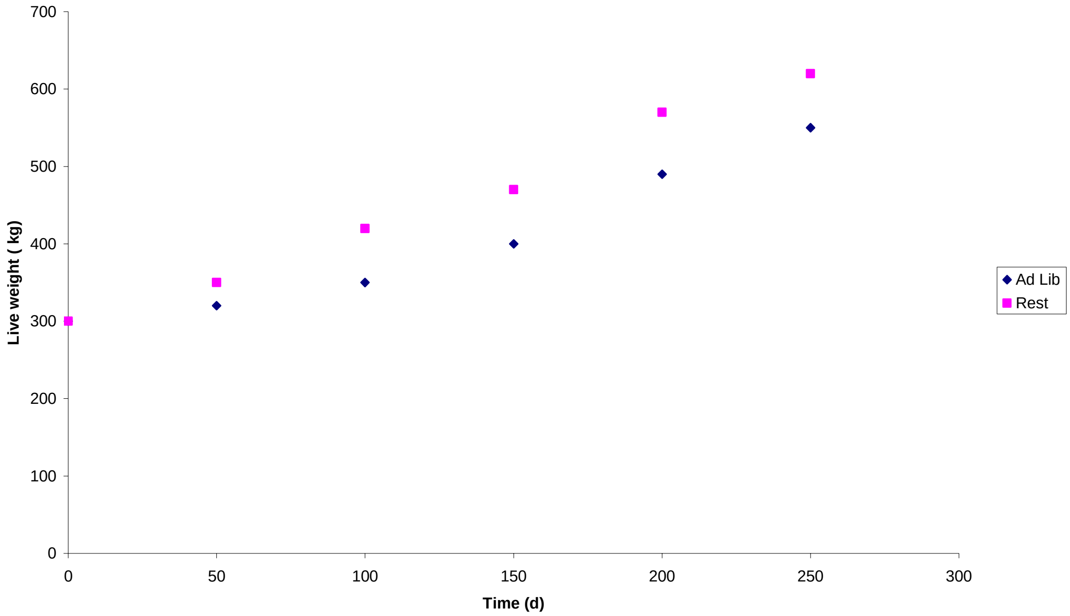
There are four possible responses that an animal can exhibit when realimented after a period of nutritional compensation. These include complete compensation, partial compensation, no compensation or a reduction in mature size. Complete compensation occurs when the animal is able to attain the same weight for age as unrestricted counterparts (Figure 2.1). This has been reported numerous times in sheep (Plavnik and Hurwitz, 1985, 1989, 1991), pigs (Ryan et al., 1993), and chickens (Plavnik and Hurwitz, 1990; Santoso *et al*. 1993; Zubair and Leeson, 1994; Deaton 1995; Zubair and Leeson, 1996).

Figure 2.1 Schematic representation of growth curves of *ad libitum* (Ad Lib) and feed restricted-refed (Rest) heifers showing complete compensation (adapted from Yambayamba *et al.,* 1996)



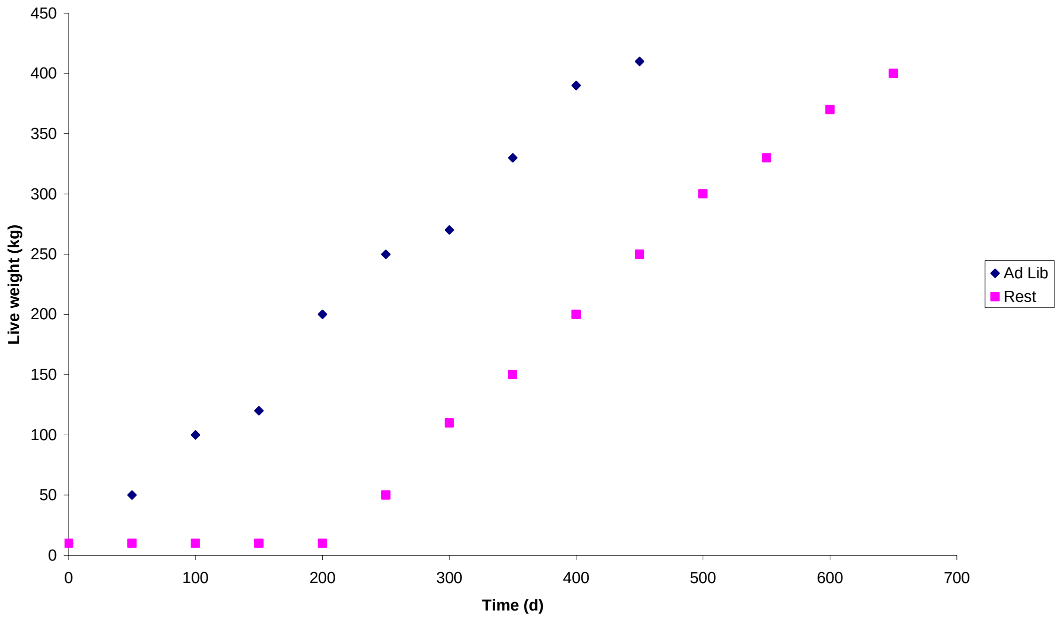
Partial compensation occurs when animals increase their rate of gain upon realimentation, but are unable to attain the same weight for age as unrestricted animals. Thus, in these situations the initial period of increased rates of growth only persists for a short while and then diminishes back to the level of unrestricted animals so that the growth curves of the unrestricted and restricted animals become parallel (Figure 2.2). However, some researchers claim that certain trials ended while growth rates were still different so it might have been possible to attain complete compensation even though it was reported that the animals had only partial compensation (Kamalzadeh *et al.*, 1998; Ryan, 1990).

Figure 2.2 Schematic representation of growth curves of *ad libitum* (Ad Lib) and restricted-refed (rest) steers showing partial compensation (adapted from Hornick *et al.,* 1998)



A less common response to nutritional restriction followed by realimentation is for an animal to grow at the same rate as unrestricted animals, thereby showing no compensation (Figure 2.3). This has been observed in various species and is usually seen when nutrient restriction has occurred at a very young age (Morgan, 1972; Tudor and O'Rourke, 1980). In most cases when nutrient restriction has been imposed at a level that is very severe, a reduction in mature size or permanent stunting has been observed (Taylor *et al.*, 1981).

Figure 2.3 Schematic representation of growth curves of *ad libitum* (Ad Lib) and restricted-refed (Rest) cattle showing no compensation (adapted from Tudor and O'Rurke, 1980)



2.5 Factors that influence compensatory growth in the broiler chicken.

The factors that influence compensatory growth include severity and duration of undernutrition, quality of the realimentation diet, sex of the bird, genetics and age of the bird (Zubair and Leeson, 1996). In addition to these, factors such as season of the year and temperature also exert some influence on feed intake and subsequent fat deposition in broiler chickens (Kubena *et al.*, 1972).

2.5.1 Severity and duration of undernutrition

Studies have shown that the longer the period of undernutrition, the more difficult it is for broiler chickens to compensate for the reduction in weight gain (Yu and Robinson, 1992). It is not clear whether milder restriction programs of shortened duration would have much effect on reduction of body fat deposition, which is one of the primary objectives of feed restriction (Zubair and Leeson, 1996). Allowing birds an unlimited supply of food can result in consumption in excess of the bird's requirements for maintenance and production and in the excess energy being converted into fat

(Scott *et al*., 1969; Ross Breeders, 1978). As suggested by Wilson and Osbourne (1960), the more severe the restriction, the greater the initial gains would be immediately after realimentation. Plavnik and Hurwitz (1985, 1988b) suggested a calculated value of 1.5 kcal ME/day/g $BW^{2/3}$ to sustain maintenance energy requirements for male broiler chickens; with this energy value, birds gained some weight, suggesting that birds under feed restriction program may have slightly lower maintenance requirement. Contrary to these results, Calvert *et al*. (1987), Robinson *et al.* (1992) and Pinchasov and Jensen (1989) were unable to demonstrate complete recovery of broiler chickens subjected to similar levels of feed restriction. Deaton (1995) reported that male broiler chickens had reduced growth by 8% by restricting feed intake 10% between 7 and 14 days of age. However, 25 to 40% feed intake restriction resulted in about 18% or greater reduction in body weight at 14 days, and these birds did not fully compensate by 41 days of age.

2.5.2 Quality of the realimentation diet

Numerous studies have pointed out the importance of the quality of the realimentation diet and the effect it can have on the type of response that is seen. Plavnik and Hurwitz (1989) concluded that broiler chickens require higher amounts of methionine and lysine during realimentation for improved compensatory growth. This was further supported by the work of Jones and Farrell (1992) who observed higher growth rates and leaner carcasses in previously restricted birds supplemented with lysine in comparison to the non-restricted birds. They also found that diets supplemented with lysine or methionine reduced the weight of the abdominal fat pad and produced a leaner carcass. On the other hand, Jones and Farrell (1992) reported that dietary supplementation with lysine or methionine during the re-feeding period resulted in inconsistent responses for final body weight and carcass composition. Dietary lysine has been shown to impact on the performance of broiler chickens, particular with respect to breast meat accretion and yield (Corzo and Kidd, 2004). According to Acar *et al*. (1991), lysine concentrations of 7.5 to 11.5 g/kg diet had no effect on performance or carcass yield of broiler chickens aged between six and eight weeks. Fontana *et al.* (1992) reported that following restriction, protein maybe a limiting nutrient in the realimentation diet. Insufficient levels of proteins in the realimentation diets may also be the reason why complete compensation has not always been reported after nutritional restriction (Benschop, 2000). Acar *et al.* (2001) reported a significant interaction between feeding regimen and lysine level, which has shown that chilled carcass yield of broiler chickens fed *ad libitum* was increased with increasing lysine, whereas yield was decreased in feed restricted broiler chickens by increasing the lysine in the diets. Other reports suggest that increased lysine in diets improved feed efficiency and breast meat yield and decreased the percentage of carcass fat in high meat yielding broiler chickens (Moran and Bilgili 1990; Acar *et. al.*, 1991), whereas live body weights remain unaffected. Jones and Farrell (1992) found no conclusive results at 49 days of age when the early feed-restricted broiler chickens received supplemental lysine and methionine. Acar *et al.* (2001) concluded that increased lysine in the broiler chicken diets following feed restriction did not have any beneficial effect on the final body weight, percentage carcass yield, or any of the carcass characteristics, with the exception of pectoralis minor muscle yield, which was increased when birds were fed diets with high lysine content. Lott *et al.* (1997) found that increased lysine levels in the diets did not contribute to ascites mortality, however, in contrast to their findings, Kerr *et al.* (1999) and Acar *et al*. (2001) indicated that increased dietary lysine increased the overall mortality.

2.5.3 Sex of the bird

There have been differing compensatory responses between the sexes of various species of animals, but the findings have not always been consistent. The difference in responses between the sexes is likely the result of the higher innate rate of growth of males in comparison to females (Zubair and Leeson, 1996). Plavnik and Hurwitz (1991) found that although both sexes were capable of complete compensation under similar conditions, male broiler chickens were able to compensate more quickly than females. An interesting observation in pigs was also made by Kyriazakis *et al*. (1991) who noted that during the restriction period the male pigs gained at a faster rate than the females, but at the end of the restriction there was no significant difference in body composition between the sexes. Upon realimentation there was also no difference in daily weight gain or final body composition between the sexes.

2.5.4 Genetics

Gous *et al*. (1999) suggested that genetic potential influences the broiler chicken's growth response because it affects its nutritional requirements. Differences in compensatory responses between genotypes within a species appear to be more pronounced than differences between sexes. As well, it is not only the growth rates that are known to differ, but the final body composition can also be influenced (Carstens *et al.*, 1991; De Greef *et al.* 1992; Hogberg and Zimmerman, 1978; Plavnik and Hurwitz, 1985, 1991). In broiler chickens, fast-growing strains showed much less compensatory growth than slower-growing ones, suggesting that nutrient requirements after restriction might vary with genetic differences (Cherry *et al.*, 1978). In contrast, Plavnik *et al.* (1986) obtained complete compensatory growth in body weight of fast growing broiler chickens.

2.5.5 Age of the bird

Feed restriction may have the effect of delaying physiological aging in animals (Wilson and Osbourn, 1960). The most sensitive period in life during which restriction could have a detrimental effect on future growth is in the pre and post-natal period (Tudor and O'Rourke, 1980). In broiler chickens which had been maintained at minimal growth for one week, growth resumed upon refeeding with a curve similar to that of controls (Yu *et al.*, 1990). Due to the short span of time to market age in broiler chickens, a very precise schedule is required to ensure adequate time for complete compensation (Benschop, 2000). Benyi and Habi (1998) feed-restricted broiler chickens from 4 to 8 weeks of age and showed that feed-restricted treatment birds were not able to achieve normal final body weight at 56 days of age. When the time allowed for refeeding extended beyond the period of fast growth in control birds, delayed fast growth enabled the restricted birds to compensate. Cristofori *et al*. (1997) restricted broiler chickens from 7 to 21 or 21 to 35 days, to a level that only supported their maintenance requirements, resulting in lower body weights at both 42 and 49 days, as compared to the *ad libitum* birds. The lower body weights of the restricted birds as compared to the control, may be related to the duration or the age at initiation of the restriction period. Working with turkeys, Auckland (1972) observed that compensatory growth often occurred late in the growth phase when the rate of weight gain normally declined.

2.6 Conclusion

Chickens with retarded growth due to undernutrition can achieve a growth rate higher than normal for chronological age after removal of feed restriction. The compensatory growth exhibited by restricted birds allows the recovery of body weight at slaughter age and sometimes a higher body weight than that of birds fed *ad libitum*. Compensatory responses are affected by a number of factors such as age at which the restriction is applied, sex and genotype of the animal, the length of refeeding period and the quality and quantity of the realimentation diet. The mechanisms controlling compensatory growth are related to reduced overall maintenance requirement and an improved feed efficiency for growth. However, the mechanisms responsible for this capacity have not yet been fully clarified. Similarly, compensatory responses have been variable. It is, therefore, important to ascertain some factors responsible for compensatory responses.

CHAPTER 3

MATERIAL AND METHODS

3.1 Study area

This study was conducted at the University of Limpopo Experimental Farm at Syferkuil. The experimental farm is situated about 9 km northwest of the Turfloop campus. The ambient temperature around the study area is around 32 ºC during summer and 25 ºC or lower during winter seasons. The mean annual rainfall is between 446.8 and 468.4 mm.

3.2 Preparation of the house

The experimental house was thoroughly cleaned with water, disinfected with Jeyes fluid and then left to dry for seven days. The house was left open for one week after cleaning so as to break the life cycle of any disease causing organisms that were not killed by the disinfectant. The experimental house was divided into 54 floor pens each with an area of approximately 2 m^2. Fresh saw-dust was spread to a thickness of 7 cm. All the equipment such as drinkers, feeders and wire separators were thoroughly cleaned and disinfected. The footbath was thoroughly cleaned and a new disinfectant was added.

3.3 Acquisition of materials and birds

All the required materials for the experiment were purchased prior to the commencement of the study. A total of 2500 Ross 308 day old chicks from SA Chicks Hatchery in Benoni, were used in an open-sided house with curtains. The experimental diets were purchased from Epol Pretoria - West Milling company, Pretoria.

3.3.1 Nutrient composition of experimental feeds

The nutrient composition of the starter and grower diets used in the first and second experiments are presented in Table 3.1 The nutrient composition of the diets met the requirements for broiler chickens as recommended by the NRC (1994).

Table 3.1 Nutrient composition of the starter and grower diets (the units are in g/kg for dry matter, g/kg DM for protein, lysine, fat, calcium and phosphorous, and MJ ME/kg DM for energy).

	Nutrient						
Diet	Dry matter	Energy	Protein	Lysine	Fat	Calcium	Phosphorous
Starter	880	16.4	233.0	11.0	25	12	6.0
Grower	880	15.5	198.8	11.5	25	10	5.5

3.4 Experimental procedure, treatments and design

3.4.1 Experiment 1: Effect of level and period of feed restriction on subsequent productivity of Ross 308 broiler chickens.

Ross 308 broiler chickens were raised for 12 days before the experiment commenced. A 2 x 3 x 3 Factorial arrangement in a Completely Randomised Design was used, involving 2 sexes of chickens, 3 feeding regimes: *ad libitum* feed as the control, 75 % *ad libitum* (75 % of amount of feed intake of *ad libitum* chickens of the previous day) and 50 % *ad libitum* and 3 restriction periods (5, 7 and 9 days, respectively). At 12 days of age, the birds were randomly assigned to the 18 treatment combinations each replicated three times, with 10 birds per pen. Re-alimentation period was from day 22 until day 42. The experiment was carried out between May and July 2005. The treatments were:

SMR_0P_5 : Male chickens without any starter feed restriction.

SMR_0P_7 : Male chickens without any starter feed restriction.

SMR_0P_9 : Male chickens without any starter feed restriction.

$SMR_{75}P_5$: Male chickens fed 75 % of the *ad libitum* starter intake for five days.

$SMR_{75}P_7$: Male chickens fed 75% of the *ad libitum* starter intake for seven days.

$SMR_{75}P_9$: Male chickens fed 75% of the *ad libitum* starter intake for nine days.

$SMR_{50}P_5$: Male chickens fed 50% of the *ad libitum* starter intake for five days.

$SMR_{50}P_7$: Male chickens fed 50% of the *ad libitum* starter intake for seven days.

$SMR_{50}P_9$: Male chickens fed 50% of the *ad libitum* starter intake for nine days.

SFR_0P_5 : Female chickens without any starter feed restriction.

SFR_0P_7 : Female chickens without any starter feed restriction.

SFR_0P_9 : Female chickens without any starter feed restriction.

$SFR_{75}P_5$:Female chickens fed 75% of the *ad libitum* starter intake for five days.

$SFR_{75}P_7$: Female chickens fed 75% of the *ad libitum* starter intake for seven days.

$SFR_{75}P_9$: Female chickens fed 75% of the *ad libitum* starter intake for nine days.

$SFR_{50}P_5$: Female chickens fed 50% of the *ad libitum* starter intake for five days.

$SFR_{50}P_7$:Female chickens fed 50% of the *ad libitum* starter intake for seven days.

$SFR_{50}P_9$: Female chickens fed 50% of the *ad libitum* starter intake for nine days.

All the birds were fed the broiler starter mash diet until 21 days old followed by the grower mash until 42 days old. Fresh water was given *ad libitum*. The vaccination schedule for the experiment followed the same procedures at the University of Limpopo Experimental farm (Appendix 8.1).

3.4.2 Experiment 2: Effect of feed restriction during the starter period and level of lysine supplementation during realimentation on productivity and carcass characteristics of male and female Ross 308 broiler chickens.

Ross 308 broiler chickens were raised for 14 days before the experiment commenced. A 2 x 3 x 3 Factorial arrangement in a Completely Randomised Design was used, involving two sexes of chickens, 3 feeding regimes: *ad libitum* (control), 75 % *ad libitum* (75 % of amount of feed intake of *ad libitum* chickens of the previous day) and 50 % *ad libitum*, and 3 levels of lysine supplementation (0, 2.5 and 5 g/kg feed, respectively). The lysine supplementation was done during the grower stage, that is, starting from the time the birds were 22 days old up until they were 42 days old. The birds were randomly assigned to 18 treatment combinations with 3 pens per treatment combination. There were 54 floor pens, each containing 10 birds. The experiment was carried out between August and September 2005. The experimental treatments were as follows:

ZMR_0L_0 : Male chickens without any feed restriction and lysine supplementation.

$ZMR_0L_{2.5}$: Male chickens without any feed restriction plus 2.5 g lysine per kg diet.

ZMR_0L_5 : Male chickens without any feed restriction plus 5 g lysine kg diet.

$ZMR_{75}L_0$: Male chickens fed 75% of the control intake for seven days without lysine supplementation.

$ZMR_{75}L_{2.5}$: Male chickens fed 75% of the control intake for seven days plus 2.5 g lysine per kg diet.

$ZMR_{75}L_5$: Male chickens fed 75% of the control intake for seven days plus 2.5 g lysine per kg diet.

$ZMR_{50}L_0$: Male chickens fed 50% of the control intake for seven days without lysine supplementation.

$ZMR_{50}L_{2.5}$:Male chickens fed 50% of the control intake for seven days plus 2.5 g lysine per kg diet.

$ZMR_{50}L_5$: Male chickens fed 50% of the control intake for seven days plus 5 g lysine per kg diet.

ZFR_0L_0 : Female chickens without any feed restriction and lysine supplementation.

$ZFR_0L_{2.5}$: Female chickens without any feed restriction plus 2.5 g lysine per kg diet

ZFR_0L_5 : Female chickens without any feed restriction plus 5g lysine per kg diet.

$ZFR_{75}L_0$: Female chickens fed 75% of the control intake for seven days without lysine supplementation.

$ZFR_{75}L_{2.5}$ Female chickens fed 75% of the control intake for seven days plus 2.5 g lysine per kg diet.

$ZFR_{75}L_5$: Female chickens fed 75% of the control intake for seven days plus 5g lysine per kg diet.

$ZFR_{50}L_0$: Female chickens fed 50% of the control intake for seven days without lysine supplementation.

$ZFR_{50}L_{2.5}$: Female chickens fed 50% of the control intake foe seven days plus 2.5 g lysine per kg diet.

$ZFR_{50}L_5$: Female chickens fed 50% of the control intake for seven days plus 5 g lysine per kg diet.

3.5 Data collection

3.5.1 Feed intake

Feed intake was measured daily from day 12 to day 42 for Experiment 1 and from day 14 to day 42 for Experiment 2 by calculating the difference of weight between the feed offered and the leftover by the birds each day per pen. The difference was then divided by the number of birds-days (no of birds X no of days alive) to obtain feed consumption (g) per bird per day.

3.5.2 Live weight

The initial live weight was taken at 12 days old for Experiment 1 and at 14 days old for Experiment 2, and thereafter mean live weight per pen was measured daily, by weighing the chickens in each pen and dividing the weight by the total number of birds in the pen.

3.5.3 Feed conversion ratio

The feed conversion ratio (FCR) per pen was calculated as the amount of feed consumed divided by the total weight of live chickens plus that of dead or culled chickens minus initial weight of all chickens in the pen. Therefore, any chicken that died or was culled had its weight and intake included in the calculation of feed conversion ratio.

3.5.4 Mortality rate

The mortality rate per pen was calculated as the total number of deaths divided by the total number of chickens then multiplied by a hundred.

3.5.5 Apparent digestibility

Two chickens per each replicate were randomly selected and transferred to a metabolic cage. The cages were designed with separate watering and feeding troughs. A three-day adaptation period was allowed, followed by a three-day collection period. Feed offered and refusals were measured. After adaptation period excreta was collected from each replicate, dried and kept for chemical analysis. Feed and water was provided *ad libitum*. Apparent digestibility (AD) of nutrients was calculated according to McDonald *et al.* (1992) as follows:

$$\text{AD (\%)} = \frac{(\text{Amount of nutrient ingested} - \text{Amount of nutrient excreted}) \times 100}{\text{Amount of nutrient ingested}}$$

The apparent metabolisable energy (AME) of the diet was calculated as follows (AOAC, 1998):

AME = Energy in feed consumed – energy in excreta

3.5.6 Carcass characteristics

At 42 days old, four broiler chickens per pen were randomly selected and slaughtered. Prior to slaughter live weights were measured, and thereafter carcass weights of individual chickens were measured. Dressing percentage was calculated, that is, carcass weight divided by the live weight times a hundred. Breast, thigh, drumstick, liver, gizzard, fat pad weights and intestine length were measured. The lengths of the intestines were measured from the duodenum to the cloaca.

3.6 Chemical analysis

Dry matter of the feeds, refusals, feaces, and meat samples were measured by drying the samples in the oven for 24 hours at a temperature of 105 °C. The nitrogen content was determined using LECO FP 2000® Protein Analyser (University of Kwazulu-Natal laboratory, Durban). The bomb calorimeter was used to measure gross energy values for feeds and feaces (University of Kwazulu-Natal laboratory, Durban). Diets were analysed for lysine by Epol, Pretoria-West according to the method described by AOAC (1998). Calcium, phosphorus, fat and crude fibre were determined as described by AOAC (1998).

3.7 Statistical analysis

Statistical analyses were conducted using the general linear model (GLM) procedure of the Statistical Analysis System (SAS, 2000) package. In Experiment 1, analysis of variance was used to determine the effects of sex, level of food restriction and period of food restriction. In Experiment 2, analysis of variance was used to determine the effects of sex, level of food restriction and level of lysine supplementation. Data analysed included diet intake, feed conversion ratio, digestibility, growth rate, mortality, and carcass characteristics. The effects of interactions were not included in the model because earlier analyses including all the interactions showed that they were not important. Means were separated using Duncan's multiple-range test (Duncan, 1955).

CHAPTER 4

RESULTS

4.1 Experiment 1. Effect of level and period of feed restriction during the starter period on subsequent productivity of Ross 308 broiler chickens.

The effects of level and period of feed restriction on live weight at 21 days of age, feed conversion ratio and mortality of male and female Ross 308 broiler chickens between 12 and 21 days of age are presented in Table 4.1.1. Level of feed restriction had effect (P<0.05) on feed intake, live weight and feed conversion ratio. However, level of feed restriction had no effect (P>0.05) on mortality. Period of feed restriction had no effect (P>0.05) on feed conversion ratio. Broiler chickens on 9 days of feed restriction had lower (P>0.05) live weights and feed intakes than those on 5 days of feed restriction. However, broiler chickens on 5 days of feed restriction had live weights and feed intakes similar (P>0.05) to those on 7 days of feed restriction. Similarly, broiler chickens on 7 days of feed restriction had live weights and feed intakes similar (P>0.05) to those on 9 days of feed restriction. Broiler chickens on 7 days of feed restriction had higher (P<0.05) mortality rates than those on 5 and 9 days of feed restriction. However, broiler chickens on 5 and 9 days of feed restriction had similar (P>0.05) mortality rates. Male and female broiler chickens had similar (P>0.05) live weights and mortality rates. However, female chickens had lower (P<0.05) feed intakes and better feed conversion ratio than male chickens.

Results of the effect of level and period of feed restriction on dressing percentage and carcass characteristics of male and female broiler chickens at 21 days of age are presented in Table 4.1.2 Level of feed restriction had no effect (P>0.05) on dressing percentage, gizzard and liver weights of broiler chickens. Broiler chickens on 75 and 50% *ad libitum* feeding had similar (P>0.05) intestine lengths and fat pad weights. Broiler chickens on 50% *ad libitum* feeding had lower (P<0.05) fat pad weights than those on *ad libitum* feeding. However, chickens on 75% *ad libitum* feeding and those on *ad libitum* feeding had similar (P>0.05) fat pad weights at 21 days of age. Period of feed restriction had no effect (P>0.05) on dressing percentage, fat pad weight, gizzard weight, liver weight and intestine length of broiler chickens. Male and female chickens had similar (P>0.05) live weight, dressing percentage, fat pad weight, gizzard weight, liver weight, and intestine lengths at 21 days of age.

Table 4.1.1. Effect of level and period of feed restriction on live weight and intake at 21 days of age, feed conversion ratio (FCR) and mortality (%) of male and female Ross 308 broiler chickens between 12 and 21 days of age.

		Variable			
Treatment	No.	Live weight (g)	Intake (g/bird/day)	FCR (g feed/g lwt gain)	Mortality (%)
Restriction					
0 % *ad libitum*	180	692.50[a]	101.53[a]	2.29[a]	0.000[a]
75% *ad libitum*	180	640.83[b]	72.87[b]	1.81[b]	0.555[a]
50% *ad libitum*	180	531.11[c]	48.80[c]	1.74[b]	1.111[a]
SE		13.41	0.86	0.07	0.5237
Period					
5	180	640.00[a]	75.65[a]	1.89[a]	0.000[b]
7	180	625.83[ab]	74.70[ab]	1.96[a]	1.666[a]
9	180	598.61[b]	72.85[b]	2.00[a]	0.000[b]
SE		13.41	0.86	0.07	0.5237
Sex					
Male	270	628.33[a]	77.15[a]	2.07[a]	0.3704[a]
Female	270	614.63[a]	71.65[b]	1.83[b]	0.7407[a]
SE		10.95	0.70	0.06	0.4276

[a,b,c] : Means in the same column not sharing common superscript are significantly different (P<0.05)
SE : Standard error

Results of the effects of level and period of feed restriction at the starter stage on feed intake, intake as percentage of live weight, growth rate, feed conversion ratio and mortality of male and female broiler chickens between 22 and 42 days of age are presented in Table 4.1.3. Level of feed restriction had no effect (P>0.05) on feed intake, growth rate and mortality of broiler chickens between 22 and 42 days of age. Broiler chickens on *ad libitum* feeding and those on 50% *ad libitum* feeding had similar (P>0.05) feed conversion ratio between 22 and 42 days of age. However, broiler chickens on 75% *ad libitum* feeding had a poorer (P<0.05) feed conversion ratio than those on *ad libitum* feeding and those on 50% *ad libitum* feeding. Period of feed restriction had no effect (P>0.05) on feed intake, growth rate, feed conversion ratio and mortality of broiler chickens between 22 and 42 days of age. Male broiler chickens had higher (P<0.05) feed intake, growth rate and feed conversion ratio than female chickens. However, when intake was expressed as percentage of live weight, chickens on 75 and 50% *ad libitum* feeding had similar (P>0.05) feed intake. When intake was expressed as percentage of live weight, male chickens had lower (P<0.05) feed intake than females.

Table 4.1.2. Effect of level and period of feed restriction on dressing percentage and carcass characteristics of male and female Ross 308 broiler chickens at 21 days of age.

		Variable				
Treatment	No.	Dressing percentage (%)	Fat (g)	Gizzard (g)	Liver (g)	Intestine length (cm)
Restriction						
0 % *ad libitum*	180	87.154[a]	2.780[a]	17.983[a]	20.275[a]	167.11[a]
75% *ad libitum*	180	86.956[a]	2.252[ab]	17.311[a]	20.658[a]	154.44[b]
50% *ad libitum*	180	84.174[a]	1.852[b]	16.761[a]	18.944[a]	154.83[b]
SE		1.0225	0.2666	0.5889	1.5415	3.6173
Period						
5	180	86.415[a]	2.622[a]	18.136[a]	20.933[a]	161.38[a]
7	180	87.088[a]	2.080[a]	17.036[a]	20.422[a]	159.50[a]
9	180	84.781[a]	2.183[a]	16.883[a]	18.522[a]	155.50[a]
SE		1.0225	0.2666	0.5889	1.5415	3.6173
Sex						
Male	270	87.229[a]	2.192[a]	17.872[a]	19.765[a]	161.25[a]
Female	270	84.960[a]	2.398[a]	16.831[a]	20.154[a]	156.33[a]
SE		0.8349	0.2177	0.4808	1.2586	2.9535

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

SE : Standard error

Table 4.1.3 Effect of level and period of feed restriction on feed intake (g DM/bird/day), growth rate (g/bird/day), intake as percentage of live weight, feed conversion ratio (FCR) (g feed/g live weight gain) and mortality (%) of male and female Ross 308 broiler chickens between 22 and 42 days of age.

		Variable				
Treatment	No.	Feed intake (g)	Intake as % of live weight	Growth rate (g/bird)	FCR (g feed/g lwt gain)	Mortality (%)
Restriction						
0 % *ad libitum*	180	152.518^a	7.475^b	65.589^a	2.333^b	2.778^a
75% *ad libitum*	180	155.665^a	7.956^a	62.618^a	2.510^a	2.778^a
50% *ad libitum*	180	150.596^a	8.167^a	64.319^a	2.358^b	1.389^a
SE		1.989	0.1583	1.216	0.048	1.1859
Period						
5	180	153.203^a	7.648^a	65.257^a	2.361^a	1.389^a
7	180	155.324^a	7.953^a	63.562^a	2.468^a	2.778^a
9	180	150.252^a	7.997^a	63.708^a	2.372^a	2.778^a
SE		1.989	0.1583	1.216	0.048	1.1859
Sex						
Male	270	157.397^a	7.598^b	67.840^a	2.326^b	1.852^a
Female	270	148.456^b	8.134^a	60.511^b	2.474^a	2.778^a
SE		1.624	0.1292	0.993	0.039	0.9683

^{a,b,c} : Means in the same column not sharing common superscript are significantly different (P<0.05)
SE : Standard error

Dry matter digestibility, nitrogen digestibility and retention, and metabolisable energy of male and female broiler chickens between 40 and 42 days of age are shown in Table 4.1.4. Level of feed restriction had no effect (P>0.05) on dry matter digestibility. However, chickens on 75 and 50% *ad libitum* feeding had higher (P<0.05) nitrogen digestibility and nitrogen retention values than those on *ad libitum* feeding. Broiler chickens on 75 and 50% *ad libitum* feeding had similar (P>0.05) nitrogen digestibility and nitrogen retention values. Broiler chickens on 75% *ad libitum* feeding had higher (P<0.05) metabolisable energy values than those on *ad libitum* feeding. However, birds on *ad libitum* feeding and 50% *ad libitum* feeding had similar (P>0.05) metabolisable energy values, and birds on 75 and 50% *ad libitum* feeding were not different (P>0.05). The period of feed restriction at the starter stage and the sex of the broiler chickens had no effect (P>0.05) on dry matter and nitrogen digestibilities, nitrogen retention and metabolisable energy of the birds between 40 and 42 days of age.

Table 4.1.4 Effect of level and period of feed restriction on dry matter digestibility, nitrogen digestibility (decimal), nitrogen retention (g/bird/day) and metabolisable energy (MJ/kg DM) of male and female Ross 308 broiler chickens between 40 and 42 days of age.

		Variable			
Treatment	No.	DM digestibility	Nitrogen digestibility	Nitrogen retention	Metabolisable energy
Restriction					
0 % *ad libitum*	180	0.7386[a]	0.6142[b]	1.7310[b]	11.5644[b]
75% *ad libitum*	180	0.7642[a]	0.7051[a]	2.1986[a]	12.1521[a]
50% *ad libitum*	180	0.7568[a]	0.6996[a]	2.1167[a]	12.0765[ab]
SE		0.0121	0.033	0.1258	0.1815
Period					
5	180	0.7541[a]	0.6831[a]	2.0153[a]	11.9557[a]
7	180	0.7397[a]	0.6479[a]	1.9497[a]	11.7351[a]
9	180	0.7658[a]	0.6852[a]	2.0813[a]	12.1021[a]
SE		0.0121	0.033	0.1258	0.1815
Sex					
Male	270	0.7458[a]	0.6733[a]	1.9956[a]	11.7720[a]
Female	270	0.7607[a]	0.6707[a]	2.0352[a]	12.0899[a]
SE		0.0099	0.0188	0.1027	0.1482

[a,b,c] : Means in the same column not sharing common superscript are significantly different (P<0.05)
SE : Standard error

The effects of level and period of feed restriction at the starter stage on live weight and carcass characteristics of male and female Ross 308 broiler chickens at 42 days of age are presented in Table 4.1.5. The period of feed restriction had no effect (P>0.05) on dressing percentage, thigh, drumstick, wing, fat pad, gizzard and liver weights and intestine lengths of broiler chickens at 42 days of age. However, broiler chickens on 5 days of feed restriction had similar (P>0.05) live weights and breast weights as those on 7 days of feed restriction. Broiler chickens on 9 days of feed restriction had live weights and breast meat weights similar (P>0.05) to those on 7 days of feed restriction. Level of feed restriction had no effect (P>0.05) on fat pad, gizzard and liver weights and intestine lengths of broiler chickens at 42 days of age. However, level of feed restriction affected (P<0.05) live weight, dressing percentage, thigh, drumstick, wing and breast meat weights of broiler chickens. Broiler chickens on 50% *ad libitum* feeding had lower (P<0.05) live weight, dressing percentage, weights of thigh, drumstick, wings and breast meat than those on *ad libitum* feeding. However, chickens on 75% *ad libitum* feeding and those on 50% *ad libitum* feeding had similar (P>0.05) live weight, dressing percentage, weights of thigh and breast meat. Broiler chickens on 50% *ad libitum* feeding had lower (P<0.05) drumstick and wing weights than those fed *ad libitum* and 75% *ad libitum* feeding. Male and female broiler chickens had similar (P>0.05) dressing percentage, and fat pad weight. However, female chickens had lower (P<0.05) live weights, thigh, drumstick, wing, breast, gizzard and liver weights, and intestine lengths than male chickens.

Results of the effects of level and period of feed restriction on parts when expressed as percentage of carcass weight of male and female broiler chickens are shown in Table 4.1.6. Level and period of feed restriction at the starter stage and sex of the chickens had no effect (P>0.05) on breast meat, thigh, drumstick, wing, gizzard and liver weights when expressed as percentage of carcass weight of Ross 308 broiler chickens at 42 days of age. Similarly, level and period of feed restriction at the starter stage and sex of the chickens had no effect (P>0.05) on nitrogen content of breast meat samples of Ross 308 broiler chickens at 42 days of age (Table 4.1.7).

Table 4.1.6 Effect of level and period of feed restriction on parts when expressed as percentage of carcass weight of male and female Ross 308 broiler chickens at 42 days of age.

		Variable					
Treatment	No.	Breast	Thigh	Drumstick	Wing	Gizzard	Liver
Restriction							
0 % *ad libitum*	180	30.024[a]	7.839 [a]	6.729[a]	5.746[a]	2.564[a]	3.229[a]
75% *ad libitum*	180	30.006[a]	7.527[a]	7.020[a]	5.885[a]	2.685[a]	3.348[a]
50% *ad libitum*	180	31.033[a]	7.800[a]	6.988[a]	5.830[a]	2.651[a]	3.464[a]
SE		0.5978	0.1123	0.1577	0.1178	0.0862	0.0904
Period							
5	180	30.509[a]	7.777[a]	6.844[a]	5.740[a]	2.656[a]	3.262[a]
7	180	30.532[a]	7.743[a]	6.972[a]	5.859[a]	2.599[a]	3.350[a]
9	180	30.022[a]	7.648[a]	6.922[a]	5.863[a]	2.644[a]	3.429[a]
SE		0.5978	0.1123	0.1577	0.1178	0.0862	0.0904
Sex							
Male	270	30.005[a]	7.665[a]	7.033[a]	5.723[a]	2.634[a]	3.319[a]
Female	270	30.704[a]	7.779[a]	6.792[a]	5.917[a]	2.632[a]	3.375[a]
SE		0.488	0.095	0.128	0.096	0.0704	0.073

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

SE : Standard error

Table 4.1.7 Effect of level and period of feed restriction on nitrogen content (g/kg DM) of breast meat samples of male and female Ross 308 broiler chickens at 42 days of age.

Treatment	No.	Nitrogen
Restriction	180	140.895^{a}
0 % *ad libitum*		
75% *ad libitum*	180	141.432^{a}
50% *ad libitum*	180	140.298^{a}
SE		0.7970
Period		
5	180	140.862^{a}
7	180	140.730^{a}
9	180	141.033^{a}
SE		0.7970
Sex		
Male	270	140.381^{a}
Female	270	141.368^{a}
SE		0.650

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

SE : Standard error

4.2 Experiment 2. Effect of feed restriction during the starter period and level of lysine supplementation during realimentation on productivity and carcass characteristics of male and female Ross 308 broiler chickens.

Results of the effects of level of feed restriction on live weight, intake and mortality of male and female Ross 308 broiler chickens at 21 days of age are presented in Table 4.2.1. Level of feed restriction had effects (P<0.05) on live weight and feed intake of broiler chickens. Increasing the level of feed restriction reduced (P<0.05) live weights and food intakes of broiler chickens. Level of feed restriction did not have any effect (P>0.05) on mortality of chickens during the restriction period. Male and female broiler chickens had similar (P>0.05) feed intakes and mortality rates. However, male broiler chickens were heavier (P<0.05) than female chickens at 21 days of age.

Table 4.2.1 Effect of level of feed restriction on feed intake (g DM/bird/day), live weight (g/bird/day) and mortality (%) of male and female Ross 308 broiler chickens at 21 days of age.

		Variable		
Treatment	No	Live weight	Feed Intake	Mortality
Restriction				
0 % *ad libitum*	180	493.889^{a}	85.569^{a}	0.000^{a}
75% *ad libitum*	180	429.500^{b}	64.472^{b}	0.000^{a}
50% *ad libitum*	180	348.056^{c}	43.319^{c}	0.555^{a}
SE		5.6451	1.4443	0.3207
Sex				
Male	270	432.370^{a}	65.083^{a}	0.3704^{a}
Female	270	415.259^{b}	63.824^{a}	0.000^{a}
SE		4.6092	1.1792	0.2618

^{ab,c}: Means in the same column not sharing a common superscript are significantly different (P<0.05).
SE : Standard error

Results of the effects of level of feed restriction and lysine supplementation on feed intake, intake as percentage of live weight, growth rate, feed conversion ratio and mortality of male and female

Ross 308 broiler chickens between 21 and 42 days of age are presented in Table 4.2.2. Level of feed restriction and lysine supplementation had no effect ($P>0.05$) on feed intake, growth rate, feed conversion ratio and mortality of the broiler chickens. Sex of the chickens had no effect ($P>0.05$) on mortality. However, male broiler chickens had higher ($P<0.05$) feed intake and growth rate, and better feed conversion ratio than female broiler chickens**.** When intake was expressed as percentage of live weight, differences ($P<0.05$) in feed intake were observed between chickens on 75 and 50% *ad libitum* feeding and those on *ad libitum* feeding. When intake was expressed as percentage of live weight, male chickens had lower ($P<0.05$) feed intake than female chickens.

Results of the effects of level of feed restriction, lysine supplementation and sex of the chickens on diet dry matter and nitrogen digestibilities, nitrogen retention and metabolisable energy are presented in Table 4.2.3. Level of lysine supplementation and sex of the broiler chickens had no effect ($P>0.05$) on dry matter digestibility, nitrogen digestibility, nitrogen retention and metabolisable energy of the chickens. Similarly, feed restriction levels had no effect ($P>0.05$) on dry matter digestibility, nitrogen digestibility and nitrogen retention. However, chickens on 75% *ad libitum* feeding had lower ($P<0.05$) metabolisable energy values than those on *ad libitum* feeding and those on 50% *ad libitum* feeding. Broiler chickens on 50% *ad libitum* feeding and those on *ad libitum* feeding had similar ($P>0.05$) metabolisable energy values.

Table 4.2.2 Effect of level of feed restriction and lysine supplementation on feed intake (g DM/bird/day), intake as percentage of live weight, growth rate (g/bird/day), feed conversion ratio (FCR) (g feed/ g live weight gain) and mortality (%) of male and female Ross 308 broiler chickens between 21 and 42 days of age.

		Variable				
Treatment	No	Feed intake	Intake as % of live weight	Growth rate	FCR	Mortality
Lysine						
0	180	103.190^{a}	7.265^{a}	45.379^{a}	2.299^{a}	0.694^{a}
2.5	180	102.728^{a}	7.268^{a}	44.717^{a}	2.306^{a}	2.778^{a}
5	180	104.441^{a}	7.399^{a}	46.743^{a}	2.241^{a}	1.389^{a}
SE		1.2280	0.1505	0.9804	0.0451	1.4525
Restriction						
0 % *ad libitum*	180	103.065^{a}	6.943^{b}	45.919^{a}	2.250^{a}	2.083^{a}
75% *ad libitum*	180	104.740^{a}	7.420^{a}	45.633^{a}	2.316^{a}	0.694^{a}
50% *ad libitum*	180	102.554^{a}	7.570^{a}	45.287^{a}	2.281^{a}	2.083^{a}
SE		1.2280	0.1505	0.9804	0.0451	1.4525
Sex						
Male	270	105.520^{a}	7.051^{b}	47.173^{a}	2.251^{a}	1.852^{a}
Female	270	101.386^{b}	7.571^{a}	44.053^{b}	2.313^{b}	1.389^{a}
SE		1.0027	0.1229	0.8005	0.0368	1.1859

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

SE : Standard error

Results of the effects of feed restriction and lysine supplementation on prodactivity, carcass characteristics and dressing percentage of male and female Ross 308 broiler chickens at 42 days of age are presented in Table 4.2.4. Level of lysine supplementation had no effect ($P>0.05$) on live weight, dressing percentage, intestine lengths, and thigh, drumstick, wing, breast, fat pad, gizzard and liver weights of broiler chickens. Similarly, level of feed restriction had no effect ($P>0.05$) on dressing percentage and intestine lengths, as well as on weights of wing, fat pad, gizzard and liver. However, chickens on 50% *ad libitum* feeding had lower ($P<0.05$) live weights, drumstick and breast weights than those on *ad libitum* feeding. Male and female broiler chickens had similar (P>0.05) dressing percentages and fat pad weights. However, male broiler chickens had higher (P<0.05) intestine lengths, live weights and thigh, drumstick, wing, breast and liver weights than female chickens.

Table 4.2.3 Effect of level of feed restriction and lysine supplementation on diet dry matter and nitrogen digestibilities (decimal), nitrogen retention (g/bird/day) and metabolisable energy (MJ/kg DM) of male and female Ross 308 broiler chickens between 40 and 42 days of age.

		Variable			
Treatment	No	DM Digestibility	Nitrogen digestibility	Nitrogen retention	Metabolisable energy
Lysine					
0	180	0.8443^{a}	0.7506^{a}	1.9314^{a}	13.2700^{a}
2.5	180	0.8300^{a}	0.7614^{a}	1.9786^{a}	13.1192^{a}
5	180	0.8303^{a}	0.7403^{a}	1.8789^{a}	13.1166^{a}
SE		0.0052	0.0193	0.0574	0.0867
Restriction					
0 % *ad libitum*	180	0.8374^{a}	0.7402^{a}	1.8797^{a}	13.1678^{ab}
75% *ad libitum*	180	0.8264^{a}	0.7518^{a}	1.9109^{a}	13.0219^{b}
50% *ad libitum*	180	0.8407^{a}	0.7604^{a}	1.9983^{a}	13.3162^{a}
SE		0.0052	0.0193	0.0574	0.0867
Sex					
Male	270	0.8352^{a}	0.7414^{a}	1.9036^{a}	13.0944^{a}
Female	270	0.8345^{a}	0.7601^{a}	1.9556^{a}	13.2428^{a}
SE		0.0043	0.0089	0.0468	0.0708

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

SE : Standard error

Level of feed restriction, lysine supplementation and sex of the chickens had no effect (P>0.05) on breast, thigh, drumstick, wing, gizzard and liver weights when expressed as percentage of carcass weight of the chickens at 42 days of age (Table 4.2.5). Level of feed restriction, lysine supplementation and sex of the chickens had no effect (P>0.05) on nitrogen content of breast meat samples of Ross 308 broiler chickens at 42 days of age (Table 4.2.6).

Table 4.2.5 Effect of level of feed restriction and lysine supplementation on parts when expressed as percentage of carcass weight of male and female Ross 308 broiler chickens at 42 days of age.

		Variable					
Treatment	No	Thigh	Drumstick	Wing	Breast	Gizzard	Liver
Lysine							
0	180	6.343[a]	5.665[a]	5.102[a]	21.487[a]	1.423[a]	1.482[a]
2.5	180	6.379[a]	5.739[a]	5.158[a]	20.192[a]	1.383[a]	1.569[a]
5	180	6.526[a]	5.535[a]	5.172[a]	21.756[a]	1.466[a]	1.535[a]
SE		0.1627	0.2216	0.1584	0.6187	0.0732	0.0526
Restriction							
0 % *ad libitum*	180	6.455[a]	5.645[a]	5.050[a]	21.504[a]	1.333[a]	1.493[a]
75% *ad libitum*	180	6.516[a]	5.940[a]	5.353[a]	22.055[a]	1.491[a]	1.556[a]
50% *ad libitum*	180	6.277[a]	5.353[a]	5.029[a]	20.596[a]	1.449[a]	1.537[a]
SE		0.1627	0.2216	0.1584	0.6187	0.0732	0.0526
Sex							
Male	270	6.544[a]	5.813[a]	5.176[a]	21.331[a]	1.500[a]	1.575[a]
Female	270	6.288[a]	5.480[a]	5.112[a]	21.493[a]	1.349[a]	1.482[a]
SE		0.1328	0.1809	0.1293	0.5051	0.0598	0.0429

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

SE : Standard error

Table 4.2.6 Effect of level of feed restriction and lysine supplementation on nitrogen content (g/kg DM) of male and female Ross 308 broiler chickens breast meat samples at 42 days of age

Treatment	No.	Nitrogen
Lysine		
0	180	141.9458[a]
2.5	180	142.0107[a]
5	180	142.3164[a]
SE		0.5314
Restriction		
0 % *ad libitum*	180	142.0427[a]
75% *ad libitum*	180	142.0231[a]
50% *ad libitum*	180	142.2071[a]
SE		0.5314
Sex		
Male	270	141.6504[a]
Female	270	142.5316[a]
SE		0.4339

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

SE : Standard error

CHAPTER 5

DISCUSSIONS

5.1 Experiment 1. Effect of level and period of feed restriction during the starter period on subsequent productivity of Ross 308 broiler chickens.

Quantitative feed restriction during the starter period affected live weight of the broiler chickens at 21 days of age. The more severe the feed restriction the lower was the live weight attained at 21 days of age. This could be explained in terms of lower feed intake and hence, lower nutrient intake. The lower feed intake was attributed to smaller amounts of feed offered. These findings are in line with previous studies by Leu *et al.* (2002), Oyedeji and Atteh (2005) and Rezaei *et al.* (2006) which reported that feed restriction during the starter period had an effect on live weight of the broiler chickens at the commencement of the realimentation period. However, the present results are different from those of Plavnik and Hurwitz (1989) and Giachetto *et al*. (2003) who observed no differences when chickens were subjected to feed restriction. In the present study, the feed-restricted birds had better feed conversion ratio as compared to their ad *libitum* counterparts. This is similar to the findings of Plavnik and Hurwitz (1988b) and Oyediji *et al.* (2003, 2005). Even though quantitative feed restriction, in the present experiment, had effects on live weight, fat pad and intestine lengths of the broiler chickens at 21 days of age, it did not have any effects on dressing percentage and the weights of gizzard and liver. Saleh *et al*. (2004) reported that the cause of similar dressing percentage of the broiler chickens was due to a constant energy to protein ratio over the experimental period. This was the case in the present study where the ratio of energy to protein was maintained at a constant level for all treatments.

Period of feed restriction during the starter phase affected live weight of the chickens. Broiler chickens having more days of feed restriction tended to have lower live weights at 21 days of age. This could be explained in terms of lower feed intake over more days. These findings are similar to those of Arce *et al*. (1992).

Male and female broiler chickens had similar live weights at the end of feed restriction. Even though male chickens had better feed intake, female chickens had better feed conversion ratio.

In the present study, broiler chickens on 75% *ad libitum* feeding attained complete live weight compensation at the age of 42 days. This could be explained in terms of high intake expressed as a percentage of live weight. However, it could not be explained in terms of better feed conversion ratio, digestibility, nitrogen retention or metabolisable energy of the broiler chickens during the realimentation period. In fact, birds on *ad libitum* feeding had better feed conversion ratio. These results are similar to those of Zubair and Leeson (1994a, 1996). However, the present results are contrary to the findings of Fanguy *et al.* (1980).

Broiler chickens on 50% *ad libitum* feeding did not 'catch-up' with those on *ad libitum* feeding in terms of live weight. This could be explained in terms of similarities in feed intake, growth rate, feed conversion ratio and intestine length between birds on 50% *ad libitum* feeding and those on *ad libitum* feeding. However, these results could not be explained in terms of feed intake as a percentage of live weight. In fact, broiler chickens on 50% *ad libitum* feeding had higher feed intake expressed as a percentage of live weight. The present results are similar to those of Yu *et al*. (1992), Mazzuco *et al*.(1999), Sartori *at al*.(1999) and Mazzuco *et al.(*2000) who reported no significant growth 'catch-up' by the age of 42 days following feed restriction during the starter stage. Similarly, other authors (Leeson *et al.*, 1991; Ballay *et al.*, 1992; Santoso *et al.*, 1993; Deaton, 1995; Giachetto *et al.*, 2003) have reported no effects on live weight and carcass characteristics at the age of 42 days following feed restriction during the starter stage. However, the results of the present study are contrary to those of Gonzales et al. (1998) who found complete compensation in live weight of broiler chickens subjected to feed restriction during the starter stage.

The differences in live weight due to the period of feed restriction during the starter stage were maintained up to the age of 42 days. This means that there was no compensation in live weight during the realimentation period. This could be explained in terms of similar feed intake, growth rate, feed conversion ratio, dry matter and nitrogen digestibilities, nitrogen retention, metabolisable energy and intestine length. Other studies have also shown that the longer the period of undernutrition, the more difficult it is for broiler chickens to compensate for reduction in live weight (Yu and Robinson, 1992). Feed restriction for a period of one week starting from seven days of age allowed complete body weight recovery (Plavnik and Hurwtz, 1988a and b). However, recovery was not seen when restriction was imposed immediately after hatching (Funguy *et al*. 1980).

Male broiler chickens had higher live weights, thigh, drumstick, wing, gizzards and liver weights at 42 days of age. However, sex had no effect on fat pad weight. The better performance of male chickens in the present study could be explained in terms of higher feed intake and growth rate, a better feed conversion ratio and longer intestines. However, these findings could not be attributed to dry matter and nitrogen digestibilities, nitrogen retention or metabolisable energy during the realimentation period.

The abdominal fat pad weight was not affected by level and period of feed restriction and sex of the chickens. There is inconsistent information on fat deposition in broiler chickens following feed restriction. The present work is in agreement with the findings of Summers *et al.* (1990), Yu *et al* (1990), Santoso *et al.* (1993), Fontana *et al.* (1993), Sheiddeler and Bauzhman (1993), Deaton (1995) and Ramlah *et al.* (1996), but are in contrast to reports by Plavik and Hurwitz (1985, 1988a, 1991), Palo *et al.* (1995), Jones and Farrell (1992) and Santoso *et al.* (1995). Zubair and Leeson (1996) also reported that feed restricted birds had the same percentage of fat content as the control birds, suggesting that it is mainly due to the hypertrophy of the fat cells rather than hyperplasia. Rosebrough and McMurtry (1993) suggested that under-nutrition and re-feeding regimen produce an increase in total body fat. The activities of the enzymes associated with hepatic lipogenesis are depressed during the nutrient restriction periods, but after re-feeding their activity is increased (Rosebrough *et al.*, 1986; Mc Murtry *et al.*, 1988). The fact that there was no significant reduction in fat pad in the present work suggests that even feed-restricted broiler chickens were still eating and that the level of feed intake may control de novo lipogenesis (Rosebrough and McMurtry, 1993). At slaughter age (42 days), the level and period of feed restriction did not have an effect on gizzard, liver and intestine length of the previously restricted re-fed broiler chickens. This could be possible as pointed out by Zubair and Leeson (1994b) that another adaptation exhibited by the restricted-refed broiler chickens is the relative enlargement of digestive organs, especially the gizzard, crop, pancreas and liver which enhance feed intake and help support compensatory growth or could be due to the theory of repartitioning nutrients by the birds in favour of the supply organs when restricted (Govaerts *et al.*, 2000). Palo *et al*. (1995) suggested that the supply organs of previously restricted broiler chickens need to catch-up first when realimented and eventually exceed in absolute weight of the *ad libitum* birds before compensatory growth can occur.

5.2 Experiment 2. Effect of feed restriction during the starter period and level of lysine supplementation during realimentation on productivity and carcass characteristics of male and female Ross 308 broiler chickens.

Feed restriction during the starter period affected live weight of the broiler chickens at the age of 21 days. The more severe the feed restriction the lower was the live weight attained at 21 days of age in both male and female broiler chickens. This was expected since live weight gain depends on nutrient intake. Thus, those chickens offered lower amounts of feed attained lower live weights. These results are similar to the findings of Leu *et al*. (2002) and Oyedeji and Atteh (2005). The level of feed restriction which Plavnik and Hurwitz (1989) 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 feed intake. This maintenance energy level, however, must have been overestimated because the feed-restricted birds gained 2 to 4 g body weight each day during the restricted period. It is also possible, as suggested by some workers, that the birds in their study, even though in negative energy balance, were able to gain weight due to change in body composition: they used fat reserves and deposited more lean tissues (Leeson *et al*., 1991; Yu and Robinson, 1992). In the present study, level of feed had no effect on mortality of the chickens. This is similar to results reported by Oyedeji and Atteh (2005). However, the present results are contrary to the findings of Saleh *et al.* (2005) who reported that level of feed had effects on mortality of the broiler chickens.

Male broiler chickens were heavier than female chickens at the end of feed restriction. However, there were no significant differences in intake and mortality. Thus, differences in live weight could not be explained in terms of differences in feed intake. It is possible that differences in live weight may have been due to better feed conversion ratio in male chickens compared to female chickens.

These results are similar to those of Zubair and Leeson (1994b). However, the present results are contrary to those reported by Leeson *et al*. (1991).

The present results indicate that at 42 days of age broiler chickens on 75% *ad libitum* feeding attained similar live weights to those on *ad libitum* feeding. This means that there was complete compensation. This could only be explained in terms of higher intake expressed as percentage of live weight for those chickens on 75% *ad libitum* feeding. However, broiler chickens on 50% *ad libitum* feeding had lower live weights, drumstick and breast meat weights than those on *ad libitum* feeding. These results indicate that complete compensation did not occur in broiler chickens on 50% *ad libitum* feeding. Plavick and Hurwitz (1991) carried out a trial in which they offered broiler chicks or turkey poults varying levels of energy-restricted diets to determine the effect of compensatory growth on the fat content of the abdominal fat pad. While the turkey poults were able to fully compensate from all levels of restriction, the broiler chickens were only able to fully compensate from the mildest restrictions. Similarly, other workers were unable to demonstrate complete compensatory growth of broiler chickens which had been subjected to similar degrees of feed restriction (Pinchasov *et al.,* 1985; Plavnik *et al.,* 1986; Calvert *et al.,* 1987; Pinchasov and Jensen, 1989; Yu *et al.,* 1990). Leeson *et al*. (1991), reported complete body weight recovery by all treatment groups by 42 days of age with no change in overall efficiency. Carcass characteristics were also not affected by early life undernutrition. Jones and Farrell (1992) restricted broiler chickens to only 2.9 $KJ/kg^{0.67}$, a level much more severe than that recommended by Plavnik and Hurwitz (1989), and reported complete body weight recovery at 48 days of age. Plavnik and Hurwitz (1991) showed that milder feed restriction, which allowed 60 to 70% of normal growth, permits more realistic recovery.

Lysine supplementation during realimentation had no effect on live weight of the chickens at 42 days old. Similarly, lysine supplementation during realimentation did not have any effect on intake, digestibility, growth rate and feed conversion ratio of broiler chickens during the realimentation period. These results are similar to the findings of Jones and Farrell (1992) who observed little or no response to lysine and methionine supplementation when fed from 4 to 7 weeks of age. Santoso *et al*. (1995) and Leeson and Zubair (1997), indicated that dietary protein level following restriction has had no meaningful effect on growth rate or feed efficiency and that increasing the lysine levels during realimentation phase actually decreased growth rate in previously restricted birds. Similarly, Acar *et al.* (2001) reported no benefit in the final body weights and chilled carcass yields from increasing dietary lysine after early feed restriction. However, the present results are contrary to the findings of Plavnik and Hurwitz (1989) who concluded that broiler chickens require higher amounts of lysine and methionine during realimentation. Similarly, Hays *et al.* (1995) also observed that restricted steers realimeted on diets of increasing protein levels (9, 12 or 15% CP) showed a differential growth response to dietary protein in the first two weeks of realimentation. These authors suggested that the responsiveness to dietary protein in the realimentation diet was directly related to the severity of the restriction period. The present results show no existence of differential growth response to dietary lysine supplementation. They indicate that different levels of lysine supplementation had no significant effect on nitrogen retention, fat pad weight, breast meat yield and other carcass characteristics of broiler chickens. According to Acar *et al*. (1991), lysine concentrations of 7.5 to 11.5 g/kg diet have no effect on performance or carcass yield of broiler chickens aged between six and eight weeks. However, in other studies, dietary lysine has been shown to impact on the performance of broiler chickens, particularly with respect to breast meat accretion and yield (Corzo and Kidd, 2004).

Male broiler chickens attained higher live weights than female chickens at 42 days of age. This is similar to the findings of Plavnik and Hurwitz (1991). However, the present results are in contrast to the results of Lippens *et al.* (2000). The higher live weights observed in male chickens in the present study could be explained in terms of higher intake, growth rate and better feed conversion ratio. Additionally, male chickens had longer intestines. However, the present results could not be explained in terms of higher dry matter and nitrogen digestibilities, intake as a percentage of live weight, nitrogen retention or metabolisable energy during realimentation period. In fact, female chickens had higher intake values when intake was expressed as a percentage of live weight. These results are similar to those of Leu *et al.,* 2002.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

In the first experiment, level of feed restriction at the starter stage affected productivity, abdominal fat pad and intestinal length while period of restriction had no effect on any of the carcass traits of the broiler chickens at 21 days of age. Broiler chickens on 75% *ad libitum* feeding were able to attain complete live weight compensation by 42 days of age. This 'catch-up' could only be explained in terms of higher intake expressed as a percentage of live weight. However, chickens on 50% *ad libitum* feeding did not 'catch-up' with those on *ad libitum* feeding in terms of live weight. This could not be attributed to any of the factors studied.

In the second experiment, feed restriction at the starter stage affected the live weight of broiler chickens at 21 days of age. Chickens on 75% *ad libitum* feeding attained complete compensation in live weight while those on 50% *ad libitum* feeding did not. Thus, 75% *ad libitum* feeding was beneficial in terms of saving feed. It may, therefore, be a useful tool to reduce the cost of starter feed, without any adverse effect on the final body weight of the chickens. Lysine supplementation during realimentation had no effect on live weight and carcass characteristics of the chickens at 42 days of age. However, male chickens attained higher live weights than female chickens.

6.2 Recommendations

This study was run in one season of the year, there is, therefore, a need for a similar study to be done in a different season of the year. There is need for more research to be conducted to fully understand the mechanisms governing compensatory growth and the need or not of lysine supplementation during realimentation period.

CHAPTER 7

REFERENCES

Acar, N., Moran, E.T. Jr. and Bilgili, S.F., 1991. Live performance and carcass yield of male broilers from two commercial strain crosses receiving rations containing lysine below and above the established requirement between six and eight weeks of age. Poultry Science 70: 2315-2321.

Acar, N., Mullet, R.M., and Barbato, G.F., 2001. Effect of dietary lysine on yield losses Occurring during early feed restriction to reduce ascitis. J. Appl. Poult. Res. 10:211-220.

Apeldoorn, E.J., Scharama, J.W., Machaly, M.M. and Parmentier, H.K., 1999. Effect of melatonin and lighting schedule on energy metabolism in broiler chickens. Poultry Science 78: 223-229.

Auckland, J.N., 1972. Compensatory growth in turkeys: practical implications and limitations. World's Poult. Sci. J. 28:291-300.

Arce, J., M. Berger, and C. L. Coello. 1992. Control of ascites syndrome by feed restriction techniques. J. Appl. Poult. Res. 1:1–5.

Andrews, J., 1991. Pelleting: review of why, how, value, and standards. Poultry Dig. 50: 64-71.

Alders, R.G., Spradbrow, P.B., Young, M.P., Mata, B.V., Meers, J., Lobo, Q.J.P. and Copland, J.W., 2001. Improving rural livelihoods through sustainable Newcastle disease control in village chickens. Livestock Community and Environment. Proceedings of the 10th

Conference of the Association of Institutions for Tropical Veterinary Medicine, Copenhagen, Denmark.

Al-Taleb, S.S., 2003. Effect of an early feed restriction productive performance and carcass quality. On Line Journal of Biological Sciences 3(6):607-611.

AOAC., 1998. Official Methods of Analysis. Association of Official Analytical Chemists, Washington, DC.

Ballay, M., Dunnington, E.A., Gross, B.W. and Siegel, P.B., 1992. Restricted feeding and broiler performance: age at initiation and length of restriction. Poultry Science 71: 440-447.

Blair, R., R. C. Newberry, and E. E. Gardiner. 1993. Effects of lighting pattern and dietary tryptophan supplementation on growth and mortality of broilers. Poult. Sci. 72:495–502.

Buyse J., and E Decuypere, 1988. The influence of intermittent light on broiler performance and on paterns of food intake. Pages 133-134 in: Leanness in mestic Birds. Genetics, Metabolic and Hormonal Aspects. B. Leclerc and C.C. Whitehead, ed. Buttenvorths, London, 8K.

Babu, M., Sandaranran , V., and Kothandaram, S., 1986. Studies on energy and protein requirements of broilers chickens. Indian Journal of Poultry Science. 26(2)275-279.

Banyi, k., and Habi, H., 1998. Effect of food restriction during the finishing period on the performance of broiler chickens. Br. Poult. Sci. 39:423-425.

Benschop, D., 2000. Compensatory growth in ruminants - an overview. Proceedings of the 2000 Course in Ruminant Digestion and Metabolism ANSC 6260. University of Gulph, Ontario, p. 1-16.

Calvert, C.C., MucMurtey, J.P., Brocht, D. and Miller, D.E., 1989. Effect of 6 and 12 day early feed restriction on rate and composition of gain in broilers. Poultry Science 68:23-28.

Cabel, M.C. and Waldroup, P.W., 1990. effect of different nutrient-restriction programs early in life on broiler performance and abdominal fat content. Poultry Science 69:652-660.

Carstens, G.E., Johnson, D.E., Ellenberg, M.A., and Tatum, J.D., 1991. Physical and chemical components of the empty body during compensatory growth in beef steers. J.Anim. Sci. 69:3251-3264.

Cherry, J.A., P.B. Siegel, and W.L Beane, 1978. Genetic-nutritional relationships in growth and carcass characteristics of broiler chickens. Poultry Sci. 571482-1487.

Calverl, C.C., J.P. McMurtry, R.W.Rosebrough, and RG. Campbell, 1987. Effect of energy level on the compensatory growth response of broilers following early feed restriction. Poultry Sci. 66(suppl.):75.

Classen, H.L., 2004. Day lengths effects performance, health and condemnations in broiler chickens. Proc. of the Australian Poult. Sci. Society, University of Sydney, Sydney, NSW.

Cristofori, C., Melluzi, A., Giordane, G., and Sirri, F., 1997. Early and late quantitative feed restriction of broilers: effects on productivity traits and carcass fatness. Arch. Geflugelkd. 61. 162-166.

Chambers, J.R., 1990. Genetics of growth and meat production in chickens. In: Poultry breeding and genetics (Crawford RD, ed.). Elsevier Science Publishers B.V., Amsterdam, Netherlands, pp. 599-643.

Coon, C.N., Becker, W.A. and Spencer, J.V., 1981. The effect of feeding high energy diets containing supplemental fat on broiler weight gain, feed efficiency, and carcass composition. Poultry Science 60, 1264-1271.

Corzo, A & Kidd, M.T., 2004. Starter dietary lysine level and strain cross effects on performance and carcass traits of broiler females. *Revista Brasileira Ciencia Avicola.* Vol.6, no.2, p.93-97. ISSN 1516-635X.

Cuddington, S., 2004. High energy diets affect broiler chicken welfare. http://www.facs.sk.ca/pdf/animal_care_award/articles_2004/cuddington_chickens.pdf.

Deaton, J.W., 1995. The effect of early feed restriction on broiler performance. Poultry Science 74: 1280-1286.

Dozier, W.A., R. J. Lien, J. B. Hess, S. F. Bilgili, R. W. Gordon, C. P. Laster, and S. L. Vieira.2002. Effects of Early Skip-a-Day Feed Removal on Broiler Live Performance and Carcass Yield. J. Appl. Poult. Res. 11:297–303

Duncan, D. B. 1955. Multiple range and multiple F tests. Biometrics 11:1–42.

De Greef, K.H., Kemp, B. and Verstegen, M.W.A., 1992. Performance and body composition of fattening pigs of two strains during protein deficiency and subsequent realimentation. Livestock Production Science. 30:141-153.

Fancher, B.I. and Jensen, L.S., 1988. Induction of voluntary feed intake restriction by dietary glycolic acid supplementation. Poultry Science 67: 1469 - 1482.

Fisher, C., 1984. Fat deposition in broilers pp. 437-470 in: Fats in animal nutrition. J. Wiseman, ed. Proc. Easter School in Agricultural Science, University of Nottingham (37th), Butterworth, London, U.K.

Fontana, E.A., Weaver, W.D., Watkins, Jr.B.A. and Denbow, D.M., 1992. Effect of early feed restriction on growth, feed conversion, and mortality in broiler chickens. Poultry Science 71:1296 – 1305.

Fontana, E.A., Weaver, W.D., Watkins, Jr.B.A. and Denbow, D.M., 1993. Early feed restriction of broilers. Effect of abdominal fat pad, liver and gizzard weights, fat deposition and carcass composition. Poultry Science 72:243 – 250.

Fanguy, R.C., Misera, L.K. Vo, K.C. Blohowiak, C.C. and Kreuger W.F., 1980. Effect of delayed placement on mortality and growth performance of commercial broilers. Poultry Science 59: 1215-1220.

Giachetto, P.F., 1998. Mecanismos hormonais do ganho compesatorio e composição de carcaça em frangos de corte submetidos a restrição alimentar com diferentes niveis energeticos. Dissertação (Mestrado em Zootecnia) - Faculdadde de Ciências Agrárias e Veterinarias, Universidade Estadual Paulista, Jaboticabal.

Giachetto, P.F., Guerreiro, E.N., Ferro, J.A., Ferro, M.I.T., Furlan, R.L. and Macari, M., 2003. Desempenho e perfil hormonal de frangos alimentados com diferentes niveis energeticos apos restrição alimentar. Pesquisa Agropecuaria Brasileira 38(6): 697-702.

Griffiths, L., Leeson, S. and Summers, J.D., 1977. Fat deposition in broilers: Effect of dietary energy to protein balance and early life caloric restriction on productive performance and abdominal fat pad size. Poultry Science 56: 638-646.

Gous, R.M., Moran, E.T.,Jr., Stilborn, H.R., Bradford, G.D., and Emmans, G.C., 1999. Evaluation of the parameters needed to describe the overall growth, the chemical growth, and the growth of feathers and breast muscles of broilers. Poultry Sci. 78:812-821.

Gonzales E., Buyse, J., Loddi, M.M., Takita, T.S., Buese N. and Decuypere, E., 1998. Performance, incidence of metabolic disturbances and endocrine variables of food-restricted male broiler chickens. British Poultry Science. 39:671-678.

Govaerts, T., Room, G., Buyse, J., Lippens, M., Groote, G. De., and Decuypere, E., 2000. Early and temporary quantitative food restriction of broiler chickens. 2. Effects on allometric growth and growth hormone secretion. British Poultry Science. 41: 355-362.

Hays, C.L., Davenpot, G.M., Osborn, T.G., and Mulvaney, D.R., 1995. Effect of dietary protein and estradiol-17B on growth and insulin-like growth factor I in cattle during realimentation. Journal Anim. Sci. 73: 589-597.

Hogberg, D.L., and Zimmeran, D.R, 1978. Compensatory responses to dietary protein, length of starter period and strain of pig. J. Anim. Sci. 47:893-899.

Holsheimer, J.P. and Veerkamp, C.H., 1992. Effect of dietary energy, protein and lysine content on performance and yield of two strains of male broiler chicks. Poultry Science 71:872-879.

Hornick, J.L., Eenaeme C. Van., Clinquart, A., Diex, M., and Istasse, L., 1998. Different periods of feed restriction before compensatory growth in Belgian Blue Bulls: 11. Plasma metabolites and hormones. Journal Animal Science. 76: 260-271

Jones, G.P.D. and Farrell, D.J., 1992. Early life food restriction of the chicken. I. Methods of application, amino acid supplementation and the age at which restriction should commence. British Poultry Science 33:579 - 587.

Jensen, L.S., Merril, L.H., Reddy, C.V., and McGinnis, J., 1962. observation on eating patterns and rate of food passage of birds fed pelleted and unpelleted diets. Poultry Sci. 41:1414-1419.

Jones, F.T., Anderson, K.E., and Ferket, P.R., 1995. Effect of extrusion on feed characteristics and broiler chicken performance. J. Appl. Poult. Res. 4:300-309.

Kessler, A.M., Snizek, Jr.P.N. and Brugalli, I., 2000. Manipulação da quantidade de gordura na carcaça de frangos. In: Anais da Conferência APINCO de Ciência e Tecnologia Avícolas. APINCO, Campinas, SP, Brazil, pp. 107-133.

Kubena, I.F., Loit, B.D., Deaton, J.N., Freece, F.N. and Amy, J.D., 1972. Body composition of chicks as influenced by environmental temperature and selected dietary factors. Poultry Science 51:517-522.

Kyriazakis, I., Stamataris, C., Emmans, G.C., and Whittemore, C.T. 1991. The effects of food protein content on the performance of pigs previously given foods with low or moderate protein contents. Anim. Prod. 52: 165-173

Kamalzadeh, A., Koops, W.J., Bruchem Van. J., and Bangma, G.a., 1998. Effect of duration of Feed quality restriction on body dimensions in lambs. Journal Animal. Science. 76: 735-742.

Kyriazakis, I., Stamataris, C., Emmans, G.C., and Whittemore, C.T. 1991. The effects of food protein content on the performance of pigs previously given foods with low or moderate protein contents. Anim. Prod. 52: 165-173

Kerr, B.J., M.T. Kidd, K.M. Halpin, G.W. McWard, and C.L. Quarles, 1999. Lysine level increase live performance and breast yield in male broilers. J. Appl. Poult. Res. 8:381–390.

Leeson, S., Summers, J.D. and Caston, L.J., 1991. Diet dilution and compensatory growth in broilers. Poultry Science 70:867-873.

Leeson, S., Caston, L. and Summers J.D. 1996. Broiler response to energy or energy and protein dilution in the finisher diet. Poultry Science 75: 522-528.

Leeson, S., and Zubair, K., 1997. Nutrition of the broiler chicken around the period of compensatory growth. Poultry Science 76: 992-999.

Leu, W.M.K., Cotta, J.T.B., Oliveira, A.I.G., and Rodrigue, P.B., 2002. Desempenho de frangos submetidos a restrição alimentar na fase inicial em diferentes sistemas de criação. Ciência Agrotecnica, Lavras 26(3): 610-617.

Lyle, A.D., Muller, J. and Dreyer, B., 1975. Over-wintering of oxen on rested veld using four different licks: winter 1975. Report, Kokstad Research station.

Leeson, S., Summers, D.J., and Caston, L.J., 1992. response of broilers to feed restriction or diet dilution in the finisher period. Poultry Sci. 70:867-873.

Leeson, S., 1996. Nutrition and Broiler Carcass Quality. Hubbard Farms Technical Report.

Lee, K. H., and S. Lesson. 2001. Performance of broilers fed limited quantities of feed or nutrients during seven to fourteen days of age. Poult. Sci. 80:446–454.

Lewis, P.D., and Morris, T.R., 1998. responses of domestic poultry to various light sources. Word's Poult. Sci. J. 54:72-75.

Lippens, M., Room, G., De Groote, G., and Decuypere, E., 2000. Early and temporary quantitative food restriction of broiler chickens. 1. Effects on performance characteristics, mortality and meat quality. British Poultry Science. 41: 343-354.

Lott, B.D., S.L. Branton, and J.D. May, 1997. Dietary lysine and ascites incidence. J. Appl. Poult. Res. 6:331–334.

MacLeod, M.G., Tullet, S.G., and Jewit, T.R. 1979. Effect of food intake regulation on the energy metabolism of hens and cockerels of a layer strain. British Poultry Science. 20: 521-531.

Manser, C.E., 1996. effect of lighting on the welfare of domestic poultry. A review. Ann. Welfare, 5:341-360.

Morgan, J.H.L., 1972. Effect of plane of nutrition in early life on subsequent live weight gain, carcass and muscle characteristics and eating quality of meat in cattle. J. Agric.

Sci.(Camb). 78: 417-423.

Morris, T.R., 1986. Light requirement of the fowl. In: environmental control in poultry production. Carter, T.C. (Ed), Edinburgh, Oliver and Boyod, pp. 15-39.

Morris, T.R., 1971. The effects of ahemeral light and dark cycles on eggs production in the fowl. Poult. Sci. 52(2) 423-445.

Moran Jr.,E.T., and Bilgili, S.F., 1990. Processing losses, carcass quality and meat yields for broiler chickens, receiving diets marginally deficient to adequate in lysine prior to marketing. Poult. Sci. 69: 702-710.

Macleod, M.G., 1991. Fat deposition and heat production as response to surplus dietary energy in fowls given a wide range of metabolisable energy:protein. British Poultry Science 32:1097-1108.

Mazzuco, H., Jaenisch, F.R. and Guidone, A.L., 1999. Efeito da restrição alimentar qualitativa no desempenho, na incidência de destúrbios metabólicos e no rendimento de carcaça em frangos de corte. Revista Brasileira de Zootecnia, Vicosa, MG v. 28 n. 6, p. 1333-1339.

Mazzuco, H., Guidone, A.L. and Jaenisch, F.R., 2000. Efeito da restrição alimentar qualitative sobre o ganho compensatório em frangos de corte. Pesquisa Agropecuaria Brasileira. Volume 35 (3) 543-549.

McDonald, P., Edwards, R.A. and Greenhalgh, J.F.D., 1992. Evaluation of foods (A)

Digestibility. In: Animal nutrition 4th edition. Pages 200-216.

McMurtry, J. P., Rosebrough, R.W., Plavnik, I. and Cartwright, A.I., 1988. Influence of early plane of nutrition on enzyme systems and subsequent tissue deposition. pp. 329-341 In: Biomechanisms Regulating Growth and Development (G. L. Steffens and T. S. Rumsey, ed). Betsville Symposia on Agricultural Research [12] Klumer Academic Publishers, Dordrecht, the Netherlands.

Mosier, H.D.Jr., 1986. The control of catch- up growth. Acta Endocrinology. 113:1- 7.

National Research Council, 1994. Nutrient Requirements of Poultry. 9th Revised edition, National Academy Press, Washington, DC.

Nir, I., Nitsan, Z., Dunnington, E.A. and Siegel, P.B.,1996. Aspects of food intake in young domestic fowl: Metabolic and genetic considerations. World Poultry Science Journal Vol. 52: 251-266.

Onderka, D.K., and Hanson, J.A., 2003. Growth performance of broiler chicks after severe early feed restriction. Poultry Section, Animal Health Laboratories, Alberta department of Agriculture.

Oyedeji, J.O., Atteh, J.O., and Adedeji, S.A., 2003. Response of broilers to skip a day (SAD) feeding. Nigerian Journal of Animal Production 30: 163-172.

Oyedeji, J.O. and Atteh, J.O., 2005. Response of broilers to feeding manipulations. International

Journal of Poultry Science 4(2): 91-95.

Oyawoye, E.O., and Krueger, W.F., 1990. Potential of chemical regulation of food intake and body weight of broiler breeder chick. Br. Poult. Sci. 31:735-742.

Olanrewaju, H.A., Thaxton, J.P., Dizier W.P., Pursuel, J., Roush, W.B., and Branton, S.L., 2006. A review of lighting programs for broiler production. International Journal of poultry Science 5(4): 301-308.

Palo, P.E., Sell, J.L., Piquer, F.J., Villaseca, L., and Soto-Salanova, M.F., 1995. Effect of early nutrient restriction on broiler chickens. Performance and development of the gastrointestinal tract. Poult. Sci. 74:88-101.

Plavnik, I., and Hurwitz, S., 1990. Performance of broiler chickens and turkeys poults subjected to feed restriction or to feeding of low-protein or low-sodium diets at an early age. Poult. Sci. 69:945-952.

Pinchasov, Y., and Elmaliah, S., 1994. Broiler chick responses to anorectic agents: 1. dietary acetic and propionic acids and the digestive system. Phar. Bioch. Behavior. 48: 371-376.

Pinchasov, Y., Nir, I., Nitsan, I., 1985. Metabolic and anatomical adaptations of heavy-bodied chicks to intermittent feeding. I Food intake, growth rate, organ weight, and body composition. Poult. Sci. 64:2098-2109.

Perry, *C.C.*, 1981. Growth and food intake of broilers under various lighting regimes.

Br. Poult. Sci. 22:219-225.

Pasternak, H. and Shalev, B.A., 1983. Genetic-economic evaluation of traits in broiler enterprise: reduction of food intake due to increased growth rate. British Poultry Science 24:531-536.

Pitts, G.C., 1986. Cellular aspects of growth and catch-up growth in rats: A reevaluation. Growth 50:419 – 436

Plavnik, I., and Hurwitz, S., 1985. The performance of broiler chicks during and following a severe feed restriction at an early age. Poultry Science 64:348 – 355.

Plavnik, I., and Hurwitz,S., 1988a. Early feed restriction in chicks: Effects of age, duration and Sex. Poultry Sc. 67: 1407-1413.

Plavnik, I., and Hurwitz, S., 1988b. Early feed restriction in male turkeys: Growth pattern, feed efficiency and body composition. Poultry Sci.67: 1407-1413.

Plavnik, I., McMurtry, J.P. and Rosebrough, R.W., 1986. Effect of early feed restriction in broilers. I. Growth performance and carcass composition. Growth 50:68 – 76.

Plavnik, I., and Hurwitz, S., 1989. Effect of dietary protein, energy and feed pelleting on the response of chicks to early feed restriction. Poultry Science 68:1118 – 1125.

Plavnik, I., and Hurwitz, S., 1990. Performance of broiler chickens and turkeys poults subjected to feed restriction or to feeding of low sodium diets at an early age. Pout. Sci. 69(4)945-952.

Plavnik, I., and Hurwitz, S., 1991. Response of broiler chickens and turkey poults to food restriction of varied severity during early life. British Poultry Science 32:343 – 352.

Pedersen, C.V., 1998. Fare driven research on the village chicken production in Zimbabwe. http://www.iaea.org.

Pinchasov, Y., and Jensen, L.S., 1989. Comparision of physiological and chemical means of feed restriction in broiler chicks. Poultry Science 68:61-69.

Ramlah ,A.H., Halim, A.S., and Siti-Sara,.R.A.,1996. Effects of early feed restriction on performance of broilers. Asin. Austr.J.Anim.Sci. 9:63-67.

Rezaei, M., Teimouri, A., Pourreza, J., Sayyahzadeh, H., and Waldropup, P.W., 2006. Effect of diet dilution in the starter period on performance and carcass characteristics of broiler chicks. Journal of Central European Agriculture. Volume 7(1) 63-70.

Robert, E.T., 1992. Poultry and egg products. In: Paul, C (ed) Scientific Farm Animal Production: An Introduction to Animal Science, fourth edition. Pages 111-125.

Robinson, F.E., Classen, H.L., Hanson,J.A. and Onderka, D.K., 1992. Growth performance, feed efficiency and the incident of skeletal and metabolic disease in full-fed and feed-restricted broiler and roster chickens. Journal of Applied. Poultry Research 1:33-41.

Ross Breeders, 1978. Producing Quality Broiler Meat and Management System of the Ross Broiler. PRM Marketing Livingstone, Scotland.

Ryan, W. J., Williams, I. H., and Moir, R.J., 1993b. Compensatory growth in sheep and cattle.1. Growth pattern and feed intake. Aust. J. Agric Res. 44: 1623-1633.

Reddy, C.V., 2000. Maintaining growth and production. Poultry International 39(2): 36-40.

Religious, K.B., Tesseraud. S., and Piccady, O. A., 2001. Food neonatale and early development of table fowl. 2001, INRA. Production. Animal., 14, 219-230.

Rosebrough, R.W., and McMurtry, J.P., 1993. Energy repletion and lipid metabolism during compensatory gain in broiler chickens. Growth Dev. and Aging. 57:73-83.

Rosebrough, R.W., Steele, N.C, McMurtry, J.P., and Plavnick, I.,186. Effect of early feed restriction in broilers. II. Lipid metabolism. Growth 50: 217-227.

Saleh, E.A., Watkins, S.E., Waldroup, A.L. and Waldroup, P.W., 2005. Effects of early quantitative feed restriction on live performance and carcass composition of male broiler grown for further processing. Journal of Applied Poultry Research. 14:87-93.

Saleh, E.A., Watkins, S.E., Waldroup, A.L. and Waldroup, P.W., 2004. Comparison of energy feeding programs and early feed restriction on live performance and carcass quality of large male broilers grown for further processing at 9 to 12 weeks of age.

Savory, C.J., 1974. Growth and behavior of chickens fed on pellets or mash. Br. Poult. Sci. 15:281-286.

Sartory, C.J., 1979. Feeding behavior. Pages 277-323. In: Food intake regulation in poultry. Boorman, K.N., and Freeman, B.M. ed Longman, Edinburgh, UK.

Scott, M.L., Nesheim, M.C., and Young, R.J., 1982. Nutrition of the chicken. Third edition, M.L. Scott and Associates, publishers Ithaca, New York. pp1-406

Sizemore, F. G., and H.S. Siegel, 1993. Growth, feed conversion, and carcass composition in females of four broiler crosses fed starter diets with different energy levels and energy to protein ratios. Poult. Sci. 72:2216–2228.

Scheideler, S.E. and Baughmam, G.R., 1993. Cumputarized early feed restriction programs for various strains of broilers. Poultry Sci 72: 236-242.

Susbilla, P.J., Frankel, T.L., Parkinson, G., and Gow, C.B., 1994. Weight of internal organs and carcass yield of early food restricted broilers. Br. Poult. Sci. 35:677-685.

Ryan, W.J., 1990. Compensatory growth in cattle and sheep. Nutrition Abstract Review

(B) 60: 653-664.

Santoso, U., Tanaka, k. and Ohtani, S., 1993. Effect of early feed restriction on growth performance and body composition in broilers. Asian Australian Journal of Animal Science. 6: 401-410.

Santoso, U., Tanaka, k. and Ohtani, S., 1995. Early skip-a-day feeding of female broiler chicks fed high-protein realimentation diets. Performance and body composition. Poultry Science 74:494-501.

SAS, 2000. Proprietary software release 8.1. Statistical Analysis Systems Institute, Inc., Cary, North Caroline, USA.

Sartori, J.C., Pezzato, A.C., Carrijo, A.S., Martins, C.L., Yokoi, C.H. and Farfan, J.R., 1999. Restrição alimentar e suplementação com concentrado de aminoácidos em frangos de corte. São Paulo: Facta, 1999.p.22.

Scott, M.L., Nesheim, M.C. and Young, R.J., 1969. Nutrition of the chicken, p. 49 M.L. Scott Ithaca, New York.

Summers, J.D., Spratt, D. and Atkinson, J.L., 1990. Restricted feeding and compensatory growth for broilers. Poultry Science 69:1855-1861.

Taylor, St. C. S., Turner, H.G., and Young, G. B., 1981. Genetic control of equilibrium maintenance efficiency in cattle. Anim. Prod. 33: 170-194.

Tudor, G.D., and O'Rourke., 1980. The effect of pre and post-natal nutrition on the growth of beef cattle. 11. The effect of severe restriction in early post-natal life on growth and feed efficiency during recovery. Aust. J. Agric. Res. 31: 179-189.

Tumova, E., Skrivan, M., Skrivanova, V. and Kacerovska, L., 2002. Effect of early feed restriction on growth in broiler chickens, turkeys and rabbits. Czech J. Anim. Sci., 47, 2002 (10): 418-428.

Wilson, L.J., Weaver, Jr, W.D., Beane, W.L., and Cherry, A., 1984. Effects of light and feeding space on leg abnormalities in broilers. Poult. Sci. 63:565-567.

Wilson, P.N. and Osbourn, D.F., 1960. Compensatory growth after undernutrition in mammals and birds. Biological Review. 35:325 - 3633.

Winick, M. and Nobel, A., 1966. Cellular response in rats during malnutrition at various ages. Journal of Nutrition. 89:300 – 306.

Underneta-Rincon, M., and Leeson, S., 2002. Quantitative and qualitative feed restriction on growth characteristics of male broiler chickens. Poult. Sci. 81:679-688.

Yambayamba, E.S.K., Price M.A. and Foxcroft, G.R., 1996. Hormonal status, metabolic changes, And resting metabolic rate in beef heifers undergoing compensatory growth. Journal Animal Science. 74: 57-69.

Yolcin, S., Ozokan, S., Acikgoz, Z., and Ozkan, K., 1990. Influence of dietary energy on performance carcass parts yield and nutrients composition of broilers reared at natural optimum and summer temperatures. British Poultry Science 39:633-638.

Yu, M.E., Robinson, F.E., Clandini, M.T. and Bodnar, L., 1990. Growth and body composition of broiler chickens in response to different regimes of feed restriction. Poultry Science, volume 69(12): 2074-2081.

Yu, M.E. and Robinson, F.E., 1992. The application of short-term feed restriction to broiler chicken production: A review. Journal of Applied Poultry Research 1:147 – 153.

Zorrila, F.F., Cuca, M.G. and Ávila, E.G., 1993. Efecto de niveis de energia, lisina y proteina en dietas para pollos de engorda en iniciacion. Veterinaria Mexico, Mexico. 24: 311-316.

Zubair, A.K. and Leeson, S., 1994a. Effect of varying period of early nutrient restriction on growth compensation and carcass characteristics of male broilers. Poultry Science 73:129 – 136.

Zubair, A.K., and Leeson, S., 1994b. Effect of early feed restriction and realimentation on metabolicheat production and changes in digestive organs in broiler chickens. Poultry Science 73: 529-538.

Zubair, A.K. and Leeson, S., 1996. Compensatory growth in the broiler chicken: a review. World's Poultry Science 52:189-201.

CHAPTER 8
APPENDIX

Appendix A: Vaccination programme

Day one on arrival:

1. Chicks will be vaccinated against Newcastle disease from the hatchery using Clone 30.
2. Vita stress will be added in the drinking water for the first two days to calm down the chicks due to stress they may experience through transportation and handling of the chicks on arrival.

Day three:

1. Tylo Tad will be added in the drinking water for prevention of *Escheria coli* bacteria and other disease causing microorganisms.

Day seven:

1. Chicks will be vaccinated against Infectious Bronchitis using “IBH 120”.

Day 12:

2. Chicks will be vaccinated against gumbora using D78 through drinking water.

Day 18:

1. Vaccinate against gumbora D78

Day 21:

1. Tylotad will be added in the drinking water. The withdrawal period will be 15 days.

Day 23:

1. Vaccinate against new castle disease using Clone 30.