

**RESTRICTED FEEDING IN BROILER CHICKENS:
EFFECT OF AGE AT INITIATION AND SEVERITY
ON PERFORMANCE.**

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**A THESIS SUBMITTED IN PARTIAL FULFILMENT FOR THE
DEGREE OF MASTER OF SCIENCE IN ANIMAL PRODUCTION
(ANIMAL NUTRITION OPTION),
DEPARTMENT OF ANIMAL SCIENCE,
EGERTON UNIVERSITY.**

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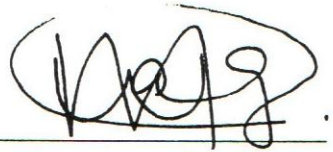
This thesis has been submitted with our approval as University supervisors.



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ABSTRACT

A completely randomized experimental design with a 4 x 3 factorial arrangement of treatments was conducted in order to investigate the effect of age and level of feed restriction on the performance and carcass quality of broiler chickens. The two main effects investigated were age of initiation of feed restriction at 4 levels (7, 14, 28 and 35 days) and the level of restriction at 3 levels (10%, 20% and 30%). One positive control (no restriction at any age or level) was used to compare with the other experimental treatments. A total of 468 day old broiler chicks were equally and randomly distributed among 39 pens, each measuring 1m² and 1m high. Quantitative feed restriction commenced at 7, 14, 28 and 35 days and lasted 2 wk after which birds resumed full feeding upto the end of the study period (56 days).

The performance of the broiler chickens was evaluated during the 2 wk restriction period, 2 wk recovery period and finally at 56 days. The variables evaluated were feed intake, feed efficiency, body weight, average gain, carcass quality and mortality rate.

All broiler chickens subjected to feed restriction had significantly ($P < .05$) lower mean body weights than the controls, with those restricted at 7 days having the lowest

final body weight at 56 days. During the 2 wk restriction period feed efficiency was higher ($P < .05$) for the restricted birds in all the groups but there were no significant differences ($P > .05$) between the controls and the restricted groups at the end of the experiment (56 days).

Restricted birds had significantly ($P < .05$) higher rates of gain than control groups during the recovery period but compensatory growth was only partial since all restricted birds had lower final body weight than the control birds. Interaction between age of restriction and level of restriction was not significant ($P > .05$) for all variables measured except for feed intake where broiler chickens restricted during the finisher period and at 30% had significantly ($P < .05$) lower intakes compared with the other feeding regimens. Restriction had no effect on overall mortality at the end of the study (56 days). Feed restriction significantly ($P < .05$) depressed carcass weight and abdominal fat regardless of age or level. There were no significant differences ($P > .05$) among restricted groups for all carcass variables measured.

From this study, it was evident that feed restriction reduced abdominal fat in broiler chickens, and saved on feeding costs.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to my supervisors, Dr. H.K. Muiruri of Animal Science Department and Prof. Mwangi Wathuta of Faculty of Science, for the tireless guidance and advice they accorded me in this study. I am deeply grateful to Dr. Muiruri for his enthusiastic supervision, and constructive criticism which motivated me to continue with the work. I am grateful to Egerton University for awarding me this scholarship.

Sincere thanks to the Deputy Vice-Chancellor, Prof. Rop who kindly intervened when I could not proceed with the study due to insufficiency of research funds and provided means by which this work could go on. I am sincerely grateful to Dr. Nassiuma for kindly assisting with data analysis and for allowing me to use his computer to type this thesis. I am indebted to Messrs. Akulla and Isiaho for their uncomplaining commitment in taking care of the birds. Without their assistance the work would have been too much for me.

Thanks to my daughter Cynthia and niece Sheila for their prayers, moral support, and the encouragement they accorded me, all of which inspired me to continue with the study. And to all of you who contributed in one way or another to make this work possible I say thank you and God bless you.

DEDICATION

In loving memory of my Father who first walked with me to school, and to my brother Francis who has played a key role in my education, this thesis is affectionately dedicated.

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LIST OF ABBREVIATIONS

The following abbreviations are used in the text:

ANOVA	Analysis of variance
BW	Body weight
C	Degrees Celsius
Carc	Carcass
FE	Feed efficiency
FI	Feed intake
g	gram
GIT	Gastro - intestinal tract
h	hour
ICU	International chick units
IU	International units
kcal	kilocalorie
kg	kilogram
ME	Metabolizable energy
mg	milligram
NPDP	National Poultry Development Programme
Rc	Recovery
Rs	Restriction
SDS	Sudden Death Syndrome
SE	standard error
wk	week
yr	year

1. INTRODUCTION

Kenya's poultry industry comprises of 3 major sectors, namely: rearing of local chickens, Franchise hatcheries, and commercial production of chicken meat and eggs (National Poultry Development Project, 1989).

Indigenous chickens composed of old cocks, hens, and roasters form over 70% of the total chicken population in the country. They are found in virtually every homestead where they are raised by backyard rearing system with little or no improvement in terms of better housing, feeding, selection or disease control (Ministry of Agric., 1990).

Indigenous chickens supply the bulk of chicken meat and eggs consumed in the rural areas. However, this supply is not regular since sales are usually based on old culls and surplus eggs that were not given to the hens for incubation (Min. of Agric., 1990).

Franchise hatcheries are agents of overseas breeding companies and import the parental stock for production of commercial day-old chicks both broilers and layers for the local farmers and at times for export to the neighbouring countries like Uganda and Tanzania.

The Franchise hatcheries rely on overseas companies for supply of parental breeding stock, and often times supply of day-old chicks is erratic especially during peak periods like Christmas and Easter. Chicks are usually expensive and their quality is not always guaranteed.

Commercial broiler and egg producers include both the small and large scale farmers and are concentrated around the major urban centres. They supply most of the chicken meat and eggs consumed in the urban areas, institutions, and tourist and other hotels. Small scale broiler farmers keep on average 200 to 500 birds per batch while the large scale farmers keep on average 500 to 10,000 birds per batch using intensive systems either deep litter or battery cage system (NPDP, 1989).

Commercial broiler farmers rely on the provender feed millers for supply of feeds. Most of the feed millers import some of the raw ingredients used in the formulation of the feeds especially soybean and the broiler premixes. In addition there is a high competition for cereal grains between livestock and humans. As a consequence there is a greater use of by-products of the milling industries in poultry feed formulation, while grains go for human consumption. As a result supply of poultry feeds is often unreliable and the quality of the feeds is not always certain. There are no enforced poultry feed standards and usually the quality varies from one feed miller to another and between batches. Further, marketing channels are not well co-ordinated and the producer is left on his own to look for market for his products.

Many of the broiler farmers have entered into direct contracts with hotels, institutions, or with one of the leading hatcheries like Kenchic Ltd., where they sell their broilers after rearing them to market weight.

The above situation differs from the situation in those countries where poultry industries are well developed. In these countries, broiler production takes a specialized, integrated approach where some producers hatch and rear the day-old chicks to market weight using own formulated feeds, then process the broilers for sale (Gyles, 1989). Usually the number of birds involved is large (over 10,000 per batch) raised in specialized houses at different stages of growth. Production is continuous since chicks are available on demand, feed ingredients are abundant and most of the operations are computerized or automated and the marketing channels are well co-ordinated (Carmen and Mountney, 1988).

The high increase in Kenya's human population calls for an urgent need to increase production of protein sources to feed the nation (Min. of Agric., 1990). Broiler production would be a good choice since compared to the large livestock, broilers have a short cycle (6 to 7 wk) and occupy a relatively small space on the farm. There is therefore a high potential for broiler production especially if the birds can be produced more cheaply. This would involve improvement in poultry housing, supply of high

quality chicks and feeds, and well co-ordinated marketing channels. To achieve this initial investments are high but long - term benefits are worthy the effort. Among all these, feeding is probably one of the most important strategies.

The conventional method world over of feeding broiler is ad libitum in order to maximize intakes and hence growth. However, under this strategy, birds tend to over eat and there is alot of feed wastage (Nir et al., 1978).

There is a high variation in the quality of broiler meat produced by local broiler farmers and generally broilers produced in the country do not attain to the technical standards of those produced in the western countries in terms of feed intake, feed efficiency, average gain, and carcass quality (NPDP., 1989).

Any extra dietary energy not used for growth is usually deposited as fat (Cherry et al., 1984). Cartwright et al.(1986) showed that ad libitum fed birds from 0 to 49 days of age had a higher amount of abdominal fat content compared to restricted-fed birds. Excess abdominal fat in broiler chickens presents problems to the poultry industry such as product composition, consumer acceptance and represents wasted dietary energy (Hulan et al., 1980).

In view of this, there is need to investigate other feeding strategies that will minimize excessive feed intake

and reduce abdominal fat. One of such strategies is feed restriction either quantitatively or qualitatively.

Studies comparing broilers reared under some form of feed restriction with broilers reared under ad libitum feeding generally show that feed restriction reduces abdominal fat and improves feed efficiency (Plavnik and Hurwitz, 1985, 1988a).

Both quantitative and qualitative methods of feed restriction have been used. Some researchers have suggested that decreasing the amount of energy would reduce fat deposition and that increasing the level of energy would have the opposite effect (Griffiths et al., 1977; Summers and Leeson, 1979; Mabray and Waldroup, 1981; Jackson et al., 1982). The observed reduction in fat deposition with low energy feeds has been attributed to depressed lipogenesis (Yeh and Leveille, 1969), and to an increased synthesis of uric acid (Buttery and Boorman, 1976). Other methods of feed restriction that have been attempted include diet dilution using non-nutritive materials such as sand, cellulose (alpha floc), rice or oat hulls at varying ratios e.g 10, 20, or even 50% of the conventional diet (Leeson et al., 1992). Other workers have suggested reducing feed intake by use of anorectic compounds e.g glycolic acid or tryptophan (Pinchasov et al., 1985; Mollison et al., 1984), or by reducing feeding time by means of intermittent lighting

(Beane et al., 1979) or use of alternate feeding e.g skip-a-day or skip-two days (Bartov et al., 1989).

Quantitative feed restriction may be applicable under Kenyan conditions as it does not involve alot of scientific knowledge in working out the different restriction programmes (personal observation). When using this method, restriction can be imposed for the whole period (0 to 56 days), or during specific periods of the production cycle such as the brooding stage (0 to 28 days) or the finisher stage (29 to 56 days). Restriction can vary in severity such that less than 10% feed intake of full-feed would be considered mild and over 50% of full-feed would be considered severe (Plavnik and Hurwitz, 1985). The length of restriction period can also vary for example from 3 to 14 days depending on ones choice and circumstances (Ballay et al., 1992).

From the preceding discussion, it can be inferred that conventional feeding of broilers is associated with certain specific problems as increased deposition of abdominal fat, skeletal abnormalities, sudden death syndrome and increased feeding costs. This research is therefore designed to try and investigate an alternative feeding strategy for broiler chickens and ellucidate some of these problems. In so doing it is herewith hypothesized that performance and carcass

quality of restricted-fed broilers is similar to that of ad libitum-fed broilers.

Although there is some information concerning the effects of feed restriction (imposed either early or late) on the performance and carcass quality of broilers, information on the effects of the level of restriction on performance of broilers is scanty.

This study was therefore designed with the overall objective to investigate the effects of feed restriction initiated at different ages (7, 14, 28, and 35 days) and at different levels (10%, 20%, and 30% of full feed) on the performance and carcass quality of broiler chickens. Specific objectives of the study were:-

- i) To determine the effect of age at initiation of feed restriction and severity of restriction on the performance and carcass quality of broiler chickens.
- ii) To examine the effect of restricted feeding on the phenomenon of compensatory growth in broiler chickens.

2. LITERATURE REVIEW

2.1.0 Growth and carcass characteristics of broiler chickens

2.1.1. Growth

Growth expressed as body weight gain over unit time, consists of development and differentiation of the four major components of the body namely the nervous, bone, muscle and fat tissues (Washburn and Bondari, 1978). In addition it involves increases in the water, protein, fat, ash and vitamin content of the body (Nestor, 1980). The relative and proportional increase in these components can vary depending on a number of factors such as age, sex, and genetic make-up (Marks, 1980) and the dietary regimen involved (Kubena et al., 1972; Mabray and Waldroup, 1981).

The present day broiler has been selected and bred for a fast rate of growth (Summers and Leeson, 1986; Leeson et al., 1992; Ballay et al., 1992). For example, in 1950, broilers attained 1.8 kg live weight in 84 days while in 1990 they averaged the same weight at 44 days (Gyles, 1989). Improved housing, feeding and disease control have all contributed to the fast rate of growth of broiler chickens (Gleaves, 1989).

Previously the kind of meat chickens kept were the pure heavy breeds like Plymouth Rock or New Hampshire Red other

than hybrid broiler chickens such as the Cobb broiler. The former breeds have a slower growth rate compared to the latter. Selection and breeding between different lines has produced the present day hybrid broiler that combines a high rate of gain, increased feed conversion ratio and high feed consumption. Increased feed consumption often results in excess nutrient intake (Nir et al., 1978).

Excess nutrient intake has been shown to result in both metabolic and physiological disorders and other problems. Such disorders include leg abnormalities (Hester et al., 1990), sudden death syndrome (Hulan et al., 1980), excess deposition of abdominal fat (Cherry et al., 1984; Plavnik and Hurwitz, 1985), obesity and poor reproductive performance of breeders (McDaniel et al., 1981), and finally increased feeding costs (Rosebrough et al., 1986). Consequently there has been increased interest in restricting nutrient intake for broiler chickens with the view to minimize some of these problems and reduce feeding costs (Plavnik and Hurwitz, 1985).

The use of various feed restriction programs and a shift from marketing whole broilers to cut up and further processed products has renewed interest in growth patterns of individual organs and muscle masses of chickens (Dror et al., 1977; Prescott et al., 1985; Pinchasov et al., 1985; Lilburn et al., 1986; Nixey, 1986; Cherry et al., 1985;

Katanbaf et al., 1989a). The rate at which posthatch growth proceeds is determined partly by the distribution of growth among organs during early development (Lilja et al., 1985; Katanbaf et al., 1989a).

- There are both genetic and non-genetic factors that influence organ growth patterns. Studies with quail and chickens subjected to artificial selection for final body weight have confirmed within-species variation for these traits and supported the theory that patterns of growth during posthatch development have a considerable influence on total body weight (Lilja et al., 1985; Katanbaf et al., 1989a). In an experiment to determine the effect of restricted feeding on organ size and carcass composition of commercial broilers, Katanbaf et al. (1989a) found that restricted feed intake increased relative weights and lengths of various segments of the gastro-intestinal tract and pancreas. This in turn caused a reduction in relative abdominal fat pad weights and lipid content of the liver and total carcass. Lower body fat contents of restricted fed birds resulted from limiting feed intake since ad libitum fed birds ate to near gut capacity with resulting obesity (Nir et al., 1978; Siegel and Dunnington, 1987). Leeson et al. (1992) found that a 10% restriction in feed intake from 35 to 42 days of age resulted in a 25% reduction in weight gain, whereas a 50% restriction over the same period gave

almost an 80% reduction in weight gain. In another experiment where the diet was diluted with sand:oat hulls in the ratio of 50:50 and was substituted in the finisher diet at 10%, 20%, 30%, 40% or 50% at the age of 35 to 42 days then 42 to 49 days the viscera was not significantly ($P>.05$) larger at evisceration.

Of all the non-genetic factors that influence growth of broiler chickens, feeding is probably one of the most important, and any adverse variation either in quality or quantity of the feed reduces the rate of growth of broiler chickens.

2.1.2. Carcass Composition

Carcass composition refers to the chemical constituents of the broiler tissues such as moisture, ash, protein, and lipid (Rasmussen and Mast, 1989). To assess carcass composition of broiler chickens, sampled birds are weighed and fasted overnight, then killed by cervical dislocation. The carcasses including the feathers but excluding the giblets are autoclaved for 6 to 8 hours then ground to a homogenous consistency. The homogenized samples are stirred and subsamples are taken and freeze-dried for 6 days. A 2g sample in duplicate is taken from each subsample and dried overnight in a heated oven at 110 C. Total dry matter, crude protein, ether extract, and ash are determined by proximate

analysis (Association of Analytical Chemists, 1980). Carcass composition is affected by both genetic and non-genetic factors. Nir et al. (1978) reported lower body fat content for restricted fed birds compared to the controls. Siegel and Dunnington (1987) showed that although crude protein content was not affected, carcass ash was greater for restricted-fed than ad libitum fed birds, suggesting relatively greater skeletal bone development for restricted fed birds.

Feeding influences the composition of broiler tissues, by influencing the content of moisture, protein, ether extract, and ash in the tissues usually in a proportional manner.

2.1.3 Carcass Quality

This refers to the eating quality or market desirability of the broiler carcass (Carmen and Mountney, 1988). Carcass quality is normally assessed at the end of the rearing period, 49 or 56 days, but can be done at any age depending on the purpose. Carcass quality may be done by visual, and physical measurements, organoleptic and microbiological measurements (Carmen and Mountney, 1988). Rasmussen and Mast (1989) outlined the following procedure that may be used to assess carcass quality. Prior to the assessment the broiler chickens are starved for 8 to 12 h to empty the gut and minimize chances of faecal contamination.

Weighing is repeated just before killing to obtain the live shrinkage due to fasting. Exsanguination is performed by severing the carotid artery with a knife, followed by bleeding for 3 minutes. Birds are scalded in hot water (at about 100 C) then defeathered either mechanically or manually. Carcasses are eviscerated by hand and all the organs and shell (empty body) weighed separately. The weights of the shanks, head, neck, blood and feathers are obtained by difference. The weight of the gastro-intestinal tract inclusive of the liver and spleen is also recorded separately. Abdominal fat (adhering to the skin, the viscera, the gizzard and proventriculus) is scrapped and weighed. The breast including the breast bone and the two muscles, Pectoralis major and Supracoracoideus and the skin on top is incised from the clavicle joint and from the rib cage and weighed. All the preceding weights are expressed as a proportion of carcass weight (body minus blood, feathers, head, shanks, and internal organs).

Visual assessment involves the general conformation of the breast bone, the back, the shanks, the wings, muscle, fat covering and presence or absence of protruding pin feathers (Carmen and Mountney, 1988). Organoleptic tests which includes tenderness, juiciness and flavour of the carcass are done by a taste panel. Here two or more carcass

samples are roasted or grilled in the oven then tasted by trained panelists (Carmen and Mountney, 1988).

Microbiological assessment involves bacteria and mould surface count which gives a measure of the sanitary conditions under which the birds were processed. In addition free ammonia determination gives a measure of protein tissue breakdown, while iodine number measures fat breakdown (Carmen and Mountney, 1988).

2.2.0. Feed intake regulation and control in chickens

Feed intake regulation and control in poultry is governed by factors such as the physiological factors of the bird, dietary factors, the type of bird and the environment (Denbow, 1989).

2.2.1. Physiological Factors

Feed intake regulation is a major concern of many poultry producers (Snapir and Robinson, 1989). When primary breeders select for increased growth rate of broilers and ducks, a correlated response has been increased feed intake (Denbow et al., 1981). Physiological control of feed intake in poultry is governed by three components: sensory control that is the physical senses of sight, taste, and smell (Kuenzel, 1989; Barbato et al., 1982), peripheral and central control (Savory, 1985; Shurlock and Forbes, 1984;

Skewes et al., 1986b; Denbow, 1989), and hormonal control (Snapir and Robinson, 1989). These three components all play a role in helping a bird to seek, find, and consume food. Some help the bird to grasp and mandibulate the food while others are concerned with the sensory qualities of the diet and the body's physiological response to them (Denbow et al., 1981).

Factors that interfere with the normal functioning of these physiological mechanisms ultimately interfere with feed intake.

2.2.2. Dietary Factors

Broiler chickens like all other animals eat for calories (Church and Pond, 1982). A high energy density diet depresses intake while a low calorie density diet increases intake. Broilers therefore adjust their feed intake in relation to dietary density. Such adjustments are closely related to the energy requirement of the bird (Hill and Dansky, 1954; Lytle and Messing, 1976).

The form and appearance of the diet also controls intake. Generally birds prefer grains or coarse material than finely ground mash, while feed in pellet form or crumb form enhances intake (Scott et al., 1982).

The National Research Council (NRC, 1984) recommends that the starter diet for broiler chicks 0 to 28 days should

contain 3,200 kcal ME /kg feed and 23% crude protein and for the finisher diet (29 to 56 days) energy should be 3,200 kcal ME/kg feed and 20% crude protein. Other NRC requirements are given in **Appendix III**.

2.2.3. The Bird Factors

Heavy birds have higher intakes due to high maintenance requirements and hence broilers having been selected and bred from the heavy breeds eat more than the light breeds. Nir et al. (1978) postulated that the high rate of growth of broilers has been accompanied by high feed intake (upto or exceeding 10% of body weight).

2.2.4 Environmental Factors

Hot ambient temperatures especially coupled with high humidity depress feed intake. For growing chicks, the thermal neutral zone is 25 C to 30 C, hence lower temperatures of less than the lower critical temperature (12 C) increase feed intake substantially while temperatures of above the upper critical temperature (35 C) decrease feed intake (Smith, 1979). Birds are not able to locate their feed in the dark, therefore, increasing the number of lighting hours increases feed intake. The converse is true (Beane et al., 1977). The health of the bird is another factor that controls feed intake. Most infectious diseases and infestations with parasites result in reduced feed

intake proportionately to the severity of the infection (Gleaves, 1989).

Other stresses in management of the birds such as overcrowding, noises, and excessive handling tend to keep the birds excited and reduce feed consumption. Improper design of the house and general uncleanliness of the unit, dirty feed and water troughs all lead to a decrease in feed intake (Gleaves, 1989).

Environmental factors as seen above influence the quantity of feed eaten by broiler chickens. Favourable environmental conditions enhance voluntary feed intake while unfavourable conditions restrict feed intake.

2.3.0 Feed Restriction in Broiler Chickens

Early feed restriction in broilers has been associated with improved feed efficiency and reduced abdominal fat pad (Plavnik and Hurwitz, 1988a). Different workers have employed different methods in restricting feed intake for broilers.

2.3.1. Quantitative Restriction

Hurwitz et al. (1980) derived the following equation to predict the ME requirements per day of broiler chickens:

$$ME = 1.5 \times BW^{.67}$$

Where

ME = Metabolizable energy required in kcal per bird per day.

BW = body weight of the bird at start of the restriction period.

Based on this equation, Plavnik and Hurwitz (1985) restricted the energy intake of broiler chicks to the maintenance requirements (30, 35, and 40 kcal ME/day while the controls were allowed 75 kcal ME/day at 7 days of age for 14 days. Body weight lost during the 2 wk period was regained by 56 days of life on subsequent full feeding while restriction for longer periods (more than 14 days) permanently retarded growth. Overall (at end of 56 days), feed-restricted broilers had better feed efficiency and less abdominal fat compared to the controls. Other methods of quantitative feed restriction that have been used include fasting for 1 to 3 days starting at day 1. Fasting of the broiler chickens was shown to retard adipocyte hypertrophy hence the amount of abdominal fat was less for the fasted birds than for the controls (March and Hansen, 1977; Cabel and Waldroup, 1990).

Intermittent lighting has been used to limit feeding time where birds are provided light for a limited period to allow them to eat several times a day. Beane et al. (1977) using this method during the first 2 wk of life found that the birds on continuous lighting had higher amounts of

abdominal fat pads than those on intermittent lighting, probably due to increased feed intake.

Alternate feeding where feed is provided on one day for two or three days (skip-a-day or skip-2-days respectively) has been practised for broiler breeder pullets. This method of restriction has been shown to improve flock uniformity and saves on labour demand (Bartov et al., 1989).

Diet dilution using non-nutritive material such as sand, cellulose (Alpha floc), rice or oat hulls has been tried at varying ratios in the broiler finisher diets (Summers et al., 1990; Leeson et al., 1992). In each of these trials, results showed that diet dilution improved feed efficiency and reduced the size of abdominal fat pad.

Chemical feed restriction by means of anorectic compounds has also been tried. Pinchasov and Jensen (1989) used graded quantities of glycolic acid (1.0%, 1.2%, 1.4%, 1.6% added to the feed) in the starter and finisher diet of broilers at 7 to 49 days and found that feed intake was depressed proportionately depending on the amount of glycolic acid added to the feed.

2.3.2. Qualitative Restriction

Since quantitative feed restriction may require extra labour or mechanization, alternative methods of restricting feed intake have been examined. Qualitative feed restriction

involves provision of feed that is either deficient or imbalanced for a given nutrient (Leeson et al., 1991).

Ferket and Moran (1985), fed low-energy diets (2,400 kcal ME/kg and 16% CP) to breeder toms and found that body weights were depressed and birds had poor reproductive efficiency. Diets deficient (Singsen et al., 1965), or imbalanced with respect to various amino acids (Smith, 1968), or diets containing amino acid analogs (Fancher and Jensen, 1988) have been fed to broiler replacement pullets with the view to restrict growth and reduce abdominal fat. Plavnik and Hurwitz (1990) fed a low protein diet (9.4% CP) to broiler chickens at 5, 7, and 11 days and found that broilers did not recover the lost weight at 56 days of age although feed efficiency was improved significantly (Plavnik and Hurwitz, 1990).

Auckland and Morris (1971) fed low protein diets (12% CP) to growing turkeys (upto to 6 weeks) and obtained a 25% growth reduction during the restriction period.

Plavnik and Hurwitz (1990) fed a low sodium diet (0.03%) to broiler chicks 6 to 12 days of age and reported that body weight gain lost during the period of sodium restriction was completely recovered at 56 days of age.

2.4.0. Response to Feed Restriction.

2.4.1. Age at Initiation of Feed Restriction

Plavnik and Hurwitz (1988a) restricted energy intake in male broiler chickens to their maintenance levels (33, 41, and 48 kcal ME/day) at 3, 5, and 7 days respectively for 7 days. Results showed overall weight gain at 56 days was not affected ($P > .05$) by early restriction, regardless of age (3, 5, or 7 days). However, feed intake was significantly ($P < .05$) reduced by restriction, without any difference due to age at restriction. Similarly, feed efficiency was improved significantly ($P < .05$) by feed restriction, again with no age effect.

In another experiment the two workers restricted energy intake to 52, 63, and 75 kcal ME/day in broiler chicks at 7, 9, and 11 days for 7 days followed by ad libitum feeding (105 kcal ME/day). They reported that abdominal fat pad was significantly ($P < .05$) reduced by early feed restriction without any interaction with age of initiation.

More recently, Ballay et al. (1992) provided cockerels either ad libitum or restricted to alternate day access starting at different ages between 1 to 18 days at a 6-day interval. At 34 days of age, there were no differences ($P > .05$) in body weights among the groups. Feed efficiency (0 to 39 days) was highest ($P < .05$) for the group on alternate

feeding throughout. Chicks that were restricted for the longest period had low relative breast weight at 34 days of age. There were some significant ($P < .05$) differences among feeding regimens for organs (GIT, liver, spleen and heart). Restriction at an early age of 5 days affected recovery since birds were not able to completely recover weight gain lost during the period of restriction (Plavnik and Hurwitz, 1988a).

Leeson et al. (1992) restricted feed intake for broilers by 10, 20, 30, 40, and 50% of the full-fed broilers at 35 to 49 days and found that as a percentage of the controls, weight gain was reduced less from 42 to 49 days (64%) than from 35 to 42 days (86%) for the 50% restricted group. Fontana et al (1992) found that weekly body weight gains of broilers subjected to early feed restriction were significantly lower than for the control groups which was also observed in the current study.

Restriction at an early age of less than 7 days appears to be detrimental to the future performance of broiler chickens since recovery was shown not to be complete on subsequent full-feeding.

2.4.2. Type and Level of Restriction.

Plavnik and Hurwitz (1985) investigated the effect of energy restriction on broiler performance by allowing an

energy level of 45, 40, 35, and 30 kcal ME/day between 1 and 3 wk of age while keeping the other nutrients at required levels. They reported that chicks continued to grow even under the most severe restriction (30 kcal ME/day) but growth rate was reduced stepwise with each reduction in energy fed.

Following full-feeding, final body weight (at 56 days) was depressed ($P < .05$) in all restricted groups in comparison with the controls (those on 105 kcal ME/day). In a later study Plavnik and Hurwitz (1990) fed a low sodium diet (0.03%) to broiler chicks 6 to 12 days of age and reported that the body weight gain lost during the restriction period was completely recovered at 56 days of age. However, birds that were fed a low protein diet (9.4% CP) did not recover the lost weight at 56 days although feed efficiency was improved significantly ($P < .05$). Recovery from energy restriction was shown to be faster than recovery from protein restriction.

2.4.3. The Sex Of The Bird.

In the study that examined the effect of age on response to feed restriction, Plavnik and Hurwitz (1988a) using the equation derived by Hurwitz et al. (1980) placed male and female broiler chicks at the ages of 7, 9 and 11 days on a 7-day restriction regimen, followed by ad libitum

feeding. During restriction the birds received 52, 63, and 75 kcal ME/day respectively. The diet used contained 2,900 kcal ME/day and 22.7% CP and control birds were allowed ad libitum feeding of 105 Kcal ME/day. Results showed that in female chicks, the severe 7-day feed restriction depressed overall weight gain progressively when applied at ages of 7, 9, and 11 days. In male chicks there was no difference ($P > .05$) in the overall response (growth, feed efficiency and abdominal fat) when the 7-day restriction was initiated at 7, 9, or 11 days. Further, a 3 to 5-day restriction period was sufficient to produce in females the full improvement in feed efficiency and the maximal reduction in abdominal fat. The two researchers inferred that females respond more either positively or negatively to feed restriction than do the males probably because of the hormonal differences between males and females.

2.5.0 Feed Restriction and Performance of Broilers

2.5.1 Feed Intake.

Newcombe et al. (1992) examined the interactive effect of feed restriction and Eimeria maxima infection with or without medication on growth and feed intake in broilers at 6 and 11 days of age and reported that feed intake for both restricted and ad libitum fed birds was similar immediately following ceasation of restriction. During the 14 to 35 days

of age however, feed intake was significantly ($P<.05$) reduced for restricted birds with concomitant reduction in weight gain from 14 to 28 days of age. Cabel and Waldroup (1990) found that feed consumption was lower in birds previously under feed restriction (more than one day of fasting). Yu et al. (1990) observed that chicks that had previously been on feed restriction consumed less food during the recovery period than those that had been on ad libitum feeding. Plavnik and Hurwitz (1988a) using an energy allowance of 33, 41, and 48 kcal ME/day at 3, 5, and 7 days respectively reported that feed intake was significantly ($P<.05$) reduced by feed restriction regardless of age (3, 5, or 7 days). From the preceding studies it can be inferred that feed restriction depresses feed intake and that compensatory intake does not always occur upon subsequent full-feeding.

2.5.2 Feed Conversion

Studies have shown that feed efficiency defined as $\text{gain, g} / \text{feed intake, g}$ expressed as a percentage or feed conversion defined as $\text{feed intake, g} : \text{gain, g}$ are affected by feed restriction (Scott et al., 1982). Early feed restriction improved feed efficiency without adversely affecting broiler market weight (Plavnik and Hurwitz, 1985, 1988b, 1989; Plavnik et al., 1986). Other workers (Summers et al., 1990;

Yu et al., 1990) observed similar feed efficiencies for restricted and unrestricted broilers at the end of their study (8 wk). Fontana et al. (1992) found that broilers that were subjected to feed restriction at an early age had significantly ($P < .05$) lower feed conversion than the controls. This was also reported by a number of other researchers (McMurtry et al., 1988; Pinchasov and Jensen, 1989) who observed a reduction in feed conversion in broilers subjected to early feed restriction.

There is therefore conflicting evidence regarding the effect of feed restriction on feed conversion where some workers found that restriction improved feed conversion, others found no effect, while some reported a reduction in feed conversion as a result of feed restriction.

2.5.3 Body Weight

Plavnik and Hurwitz (1985) applied feed restriction to broiler chicks at 7 days of age for 14 days where birds were allowed 40 kcal ME/day and found that although restriction was meant to arrest growth completely, a growth rate of about 4 g/day was obtained. On subsequent full-feeding growth rate of the treatment groups exceeded that of the controls (those on 75 kcal ME/day). They further noted that the weight gain lost during the period of restriction lasting upto 4 weeks could not be fully regained during the

period of full-feeding of upto 8 wk of age (Plavnik and Hurwitz, 1985). Feed restriction for 6 days hardly influenced the final body weight at 8 wk of age. These researchers noted that a full compensation for the weight retardation between 1 and 4 wk was not obtained within a growth period of 8 or 9 wk.

Fontana et al.(1992) subjected broiler chickens to early feed restriction (allowing 40 kcal ME/day starting at 4 days for 5 or 7 days) and found that weekly body weight gains of the restricted groups were significantly ($P<.05$) lower than for the controls (75 kcal ME/day), from 0 to 28 days of age. However, cumulative rates of gain for restricted broilers were significantly higher than for controls at 49 days of age. Ballay et al.(1992) provided cockerels either ad libitum access or restricted to alternate-day access to feed at different ages and lasting for different periods. Chicks restricted for only one 6-day period reached body weights equivalent to those fed ad libitum at 39 days of age. Body weights of chicks restricted for more than 6 days during the first 18 days posthatch were lower than those eating ad libitum at 39 days of age. Brody et al.(1980), found that feed restricted broilers when changed to ad libitum feeding gained weight rapidly but stabilized at a mean body weight of 500 to 700 g less than the controls.

From the above discussion, it is evident that feed restriction regardless of age or level depresses final body weight of the chickens.

2.5.4 Compensatory Growth.

This is defined as rate of growth exceeding that normally observed in the same breed of chickens of the same age following a period of undernutrition (Wilson and Osbourn, 1960). A number of factors influence compensatory gains after a period of feed restriction. Such factors include the nature, severity and duration of restriction, the pattern of full-feeding, the stage of growth at restriction, as well as the sex and genetic potential of the animal (Wilson and Osbourn, 1960; Cherry et al., 1978; Pokniak and Cornejo, 1982; Ballay et al., 1992).

Brody et al. (1980), Plavnik and Hurwitz (1985, 1988a, 1989), and Summers et al. (1990) reported a rate of gain that is higher than normal in previously restricted broilers upon subsequent full-feeding. However, some workers (for example Yu et al., 1990) failed to observe this in their work. Using a feeding regimen similar to that reported by Plavnik and Hurwitz (1985) but keeping the birds for 49 days instead of 56 days, Pinchasov and Jensen (1989) were unable to observe compensatory growth.

Washburn and Bondari (1978) found no evidence for compensatory growth when feed was restricted for a period of 3 to 5 days in 3 to 8 wk old birds. Wilson and Osbuorn (1960) reported that compensatory growth was obtained after short periods (upto 3 days) of restriction whereas longer periods (more than 5 days) diminish recovery and may result in delay in achieving normal weights or in permanent stunting of the animal. Fontana et al. (1992) allowed 40 kcal ME/day for broiler chicks at 6 days for 5 or 7 days and found that recovery (at 56 days) of body weight lost during restriction period was higher and faster in birds restricted for 5 days than for those restricted for 7 days. Too long periods (more than 7 days) of restriction have been shown to lower recovery. Fontana et al. (1992) allowed 40 kcal ME/day for broiler chicks at 6 days for 5 or 7 days and found that recovery of body weight lost at 56 days was higher and faster for birds restricted for 5 days than for those restricted for 7 days.

Yu et al. (1990) restricted broiler feeding at various frequencies: full feeding, once every other day, once every day, and once every hour (ad libitum, skip-a-day, daily, and hourly) between 8 to 14 days posthatch. Restricted birds received maintenance energy level of 23 kcal ME/day while control birds received 75 kcal ME/day. Restricted birds lost

fat (hourly lost most, daily intermediate while skip-a-day the least). No compensatory growth was observed.

Several reports (Plavnik and Hurwitz, 1985; Plavnik et al., 1986; McMurtry et al., 1988) showed that by severely restricting feed intake for a short time (from 3 to 7 days) in life, it is possible to take advantage of the phenomenon of compensatory growth to reduce total feed intake without compromising final body weight in broiler chickens. Reid and White (1977) reviewed the literature on this phenomenon and concluded that the existence of compensatory growth in chickens is still controversial.

In view of the inconsistent results obtained by the different workers concerning the phenomenon of compensatory growth, there is need for more research to explore further on this important aspect of growth of the broiler chicken.

2.5.5. Carcass Quality

Leeson et al. (1992) using feed restriction at 10, 20, 30, 40, or 50% of the control from 35 to 49 days of age found that there was a significant correlation between degree of feed restriction and weight of the carcass, breast muscle and abdominal fat pad. Following 7 days feed restriction (from 35 to 49 days) there was no significant ($P > .05$) change in carcass weight as a percentage of live weight or breast muscle and abdominal fat as a proportion of

carcass weight. However, they found that, at 49 days, breast and abdominal fat pad weights were significantly decreased ($P < .05$) as feed restriction became more severe. Severe feed restriction of broiler type pullets causes a reduction in mean adipocyte size but an increase in adipocyte number (Ballam and March, 1979). These researchers inferred that it is the adipocyte size and not the number that determines the size of abdominal fat pad.

Cherry et al. (1984) concluded that although hyperplasia proceeds during periods of nutrient restriction the adipocyte cells remain smaller. Similarly, Rosebrough et al. (1986) observed reductions in both liver size and lipogenesis in 12-day old birds subjected to feed restriction. However, there is some evidence of increased lipogenesis and greater fat accumulation following full-feeding. Thus, Rosebrough et al. (1986) indicated an 80% increase in lipogenic activity 2 days after full-feeding, whereas Osbourn and Wilson (1960) indicated a 24% more fat in birds after full-feeding depending upon the method of full-feeding used. Hargis and Creger (1980) reported that feeding low-energy starter diets with no supplemental fat from 0 to 7 days of age consistently reduced fatness in 49-day old broilers. March and Hansen (1977) restricted nutrient intake either by diluting the diet 3:1 or 1:1 by weight with pulverized oat hulls or by fasting the birds for

3 days at 1 or 10 days of age. Both programs not only reduced abdominal fat, but also severely depressed body weight. On the other hand, Jensen et al. (1987) observed a significant increase in abdominal fat at 7 wk of age for birds fed on a starter diet diluted with cellulose or sand (1:1) for the first 7 days of life. Pokniak and Cornejo (1982), and Pokniak et al. (1984) limited feed intake to 15 and 45% of feed consumption of the controls from 8 to 23 days of age and found no significant ($P > .05$) differences for the content of carcass fat by 56 days of age. Similarly, Griffiths et al. (1977) limited caloric intake by feeding a low-energy diet for the first 3 wk of age and did not observe any effect on abdominal fat content at 8 wk of age. Cabel and Waldroup (1990) reported that fasting for 1 or 3 days did not affect the abdominal fat content at 49 days, although 3 days of fasting significantly ($P < .05$) reduced abdominal fat.

Restriction at an early age minimizes deposition of abdominal fat by reducing adipocyte hypertrophy.

2.5.6. Mortality and Leg Abnormalities.

Sudden Death Syndrome (SDS) is a sporadic problem that occurs in broiler flocks where birds are found dead, lying on their backs, while exhibiting good fleshing and body weight. The dead birds usually do not show any sign of ill

health but postmortem results often reveal presence of water in the belly (water belly). SDS has been associated with rapidly growing broilers (Hulan et al., 1980; Julian and Bowes, 1984). It is therefore possible that by reducing the rate of early growth of broilers, the mortality associated with SDS and consequently total mortality at market age can be reduced.

Bowes et al. (1988) and O'Sullivan et al. (1991) reported a lower rate of mortality caused by Sudden Death Syndrome (SDS) in broilers restricted by 25% of the feed intake of the control birds from 5 to 39 days of age and restricted for 6 to 27 days on an alternate-day feeding similar to that used for breeder pullets.

Classen and Riddell (1989) examined the impact of changing photoperiod length on the performance of broiler chickens by providing long constant (23 h) photoperiod, intermittent lighting of 6 to 23 h abruptly after 21 days (6 h), or gradually during the experiment (gradual). These workers found that the incidence of total leg abnormalities, angular leg deformities and rotated tibiae were significantly ($P < .05$) lower for the 6 h and gradual lighting than for the 23 h program. This was probably due to decreased feed consumption since compared to the birds that received longer light hours (23L:1D) their cumulative feed intake was lower than for those on continuous lighting.

Hester et al. (1990) restricted protein intake and amino acid intake in commercial male turkeys (at 6 to 12 wk of age) and found a reduction in incidence of leg abnormalities in the restricted birds compared to the controls (those on ad lib. feeding). Clarke et al. (1993) examined the effect of dietary protein restriction and intermittent lighting on lameness and performance of male turkeys by providing young turkeys (7 to 23 days) with diets containing 100, 90, 80, and 70% of control value and 15L:9D (control) and 10L:2D, 2L:2D, 1.5L:1.5D. Intermittent lighting improved body weight and feed efficiency but increased the incidence of leg abnormalities. The incidence of leg abnormalities among toms decreased linearly with decreasing dietary protein. The increase in leg lameness may be due to the redistribution of body weight towards increased breast muscle deposition and a corresponding reduction in leg muscle for turkeys reared in intermittent lighting (Clarke et al., 1993). A redistribution of body weight has been implicated as a possible cause of leg abnormalities and aggravated mobility in large strains of turkey (Nestor, 1984). Williams (1987) postulated that the high rate of growth of the broiler chicken has caused the "repartitioning" of nutrients such that most nutrients are channelled to organs involved in metabolism and the breast muscle at the expense of the

skeletal tissue hence the problem of leg weakness and deformities in broilers and turkeys.

Intermittent lighting as a form of feed restriction reduces feed intake and consequently the incidence of leg abnormalities and sudden death syndrome in broilers and turkeys.

2.5.7. Broiler Breeder Pullets.

These are female broiler chickens raised for breeding purposes between the age of 9 wk and the end of the first laying cycle (12 months after the first egg is laid). Feed restriction may be imposed during the prelay period (9 wk to 20 wk) or during the laying period (20 wk to 104 wk).

Feed restriction is commonly applied to broiler breeder pullets during the rearing period (9 wk to 20) to minimize mortality rates and ensure maximum production of settable eggs (Fuller et al., 1973). However, it is rarely practiced for egg type pullets as its commercial benefits are doubtful (Lee, 1987).

Blair (1973) reviewed the effects of feed restriction in breeder pullets (from 9 to 20 wk) and concluded that restriction during the rearing period resulted in reduced weight gain, delay in sexual maturity, reduced fat content and often increased mortality. He further reported that restricted feeding led to higher peak production of settable

eggs. Brody et al. (1980); Bornstein et al. (1984) and Dunnington and Siegel (1984) found that in broiler chickens decreased weight due to feed restriction resulted in delayed onset of egg production, suggesting that a minimum body weight is required for sexual maturity. However, in egg type pullets, Gous and Stielau (1976) and Muir and Gerry (1978), showed that when feed was restricted egg production could commence even if body weight was reduced. The reduction in adult body weight, if maintained during the production period could minimize the maintenance requirements and improve feed efficiency during that time. McDaniel et al. (1981) found that feed restricted broiler pullets (9 to 20 wk) had higher egg production rates, higher fertility and hatchability, and laid heavier eggs when compared to the controls (fed ad libitum).

Robinson and Sheridan (1982) noted that different restriction programs during the rearing period reduced mean body weight at 20 wk of age by 14 to 33% and increased time to sexual maturity by 8 to 33 days. They further noted that all restriction regimens during rearing increased mean egg size and tended to reduce post-lay mortality. Pym and Dillon (1974) reported that sexual maturity was progressively delayed by increasing severity of feed restriction and that birds reared on restricted feeding during laying showed compensatory feed intake. From the foregoing discussion, it

is apparent that information regarding the effect of feed restriction on performance of broilers is conflicting. There is therefore need for more research to try and investigate further the effect of feed restriction on performance of broiler chickens.

Further, most of the work has been done in the temperate countries and it would be interesting to find out how broiler chickens in the tropics would respond to feed restriction.

In the present study the effects of feed restriction initiated at different ages (7, 14, 28, and 35 days) and at different levels of restriction (10, 20, and 30% of full-fed birds) on the performance and carcass quality of the Cobb (hybrid) broiler under Kenyan conditions were investigated.

3. MATERIALS AND METHODS.

3.1.0. Experimental set-up

The study was conducted at the Poultry Unit of Tatton Demonstration Unit, Egerton University, Njoro from January 13, 1995 to March 13, 1995. The study commenced after the research proposal had been discussed and approved by the Department of Animal Science, Faculty of Agriculture, Egerton University. One pen within the poultry house, with solid walls and floor measuring 40m x 13m was modified for the experiment. The pen was washed and disinfected using 38% v/v neutral tar acid (kerol) and rested for 5 days. It was then partitioned into 39 pens each measuring 1m² and 1m high. A layer of 2.5 cm deep of dry fresh woodshavings was put in each pen for litter. Provision was made for working space of 1/2m all round the pens (Appendix I). Using a twin flex cord and additional sockets electric power was tapped from the main supply on the building and extended to every pen. By means of an electric bulb (150W) both heating and lighting were provided to the chicks. Pens were preheated for 6 h before arrival of the chicks in order to raise the temperature to the required initial brooding temperature of approximately 33 C. Every pen had one plastic feed hopper each with 16 eating spaces of 7 cm eatlength, centrally placed and one water fountain placed at one end of the pen

and each provided sufficient eating and drinking space for the chicks. Brooding and rearing were done in the same pen.

A 4×3 imbalanced factorial arrangement of treatments in a completely randomized design was used, with age at initiation of restriction at 4 levels: 7, 14, 28, and 35 days) and the severity of restriction at 3 levels: 10%, 20% and 30%) as the main effects. One positive control (no restriction at any age or level) was used to compare with all other treatments. Each treatment was replicated 3 times giving a total of 39 experimental units ($4 \times 3 \times 3$ plus 3 for the control).

Pens were numbered 1 to 39 with the starting point chosen from one end. Randomization of treatment allocation was done as follows: treatment names were written on small pieces of paper, folded and placed in a container. The container was agitated first before a piece of paper was picked. The name of the first treatment thus picked was assigned to pen number 1. This was repeated until all the 39 pens were assigned treatments. Treatments were identified by age, level, and replicate number as follows:

T₀L₀R₁ - Control or no restriction at any age or any level and replicate number 1.

T₁L₁R₁ - Restriction at 7 days of age and at 10%

T₁L₂R₁ - " " 20%

T₁L₃R₁ - " " 30%

T₂L₁R₁ - " 14 10%

T₂L₂R₁ - " " 20%

T₂L₃R₁ - " " 30%

T₃L₁R₁ - " 28 10%

T₃L₂R₁ - " " 20%

T₃L₃R₁ - " " 30%

T₄L₁R₁ - " 35 10%

T₄L₂R₁ - " " 20%

T₄L₃R₁ - " " 30%

All the treatments were replicated 3 times. Restriction period lasted 2 weeks after which birds were returned to ad libitum feeding until the end of the experiment (56 days of age).

3.1.1 Birds

Four hundred and sixty eight (468) day-old broiler chicks of same hybrid (Cobb) and of mixed sex, hatched on the same day (January 12, 1995) were obtained from a commercial hatchery (Kenchic Ltd., Kenya) and used for the experiment. The chicks had been vaccinated against Marek's

disease at the hatchery. Chicks were weighed then equally and randomly distributed (12 chicks per pen) among the 39 floor pens. A pen of 12 chicks served as the experimental unit.

3.1.2 Diets and Feeding

Two types of mash diets formulated in accordance with the National Research Council (NRC, 1984) were used for the experiment. The feed was made on request as a "tailor-made ration" by a local feed miller. Use of a "tailor-made ration" was preferred to buying ingredients and mixing on the farm due to lack of a feed mixer that would ensure thorough mixing and a homogeneous product. The calculated and proximate composition of the two diets is given in Table 1. Nutrient composition of the rations particularly energy was calculated basing on the estimated quantities of nutrients contained in different feed ingredients used in poultry feeding (McDonald et al., 1989), while crude protein was calculated using estimates provided by Scott et al. (1982) . A table of the nutritive value of the feed ingredients used in the estimation of energy content of the diets is given in **Appendix II**.

Two types of rations were used : the starter ration at 0 to 28 days of age and the finisher ration at 29 to 56 days of age. All chicks were allowed free access to the starter diet during the first 7 days after which the treatments (quantitative feed restriction at 10%, 20%, and 30% of the control birds) commenced and continued for 2 wk in each group at the ages of 7, 14, 28, and 35 days respectively. Using the NRC (1984) feeding recommendations **Appendix III**, an appropriate amount of feed was weighed out and given to the control groups on ad libitum feeding. After a period of 24 h the remaining feed was weighed back to determine intake. During the restriction period broiler chickens on restriction were fed based on the previous day's intake for the control birds. Consequently restricted feed intake was calculated every day adjusting it according to the average intake of the controls.

TABLE 1. Composition and nutrient content of starter and finisher diets used in the experiment

<u>Ingredient</u>	<u>Starter</u>	<u>Finisher</u>
Whole maize	35.00	40.00
Soybean meal	32.50	23.00
Sunflower Cake	2.50	5.00
Fishmeal	2.50	2.50
Wheat pollard	15.00	0.00
Maize germ	7.00	14.00
Cotton Seed Cake	0.00	3.00
Maize bran	0.00	9.55
Ground limestone	2.95	1.00
Dicalcium Phosphate	2.00	1.00
Broiler Premix	0.25	0.25
Iodized salt	0.30	0.30
	<u>100.00</u>	<u>100.00</u>
Calculated analysis		
Protein	20.00%	18.00%
ME, kcal/kg	2,940	2,990
Calcium	1.00%	1.00%
Available Phosphorous	0.45%	0.45%
Lysine mg/kg	1.00	0.85
Methionine mg/kg	0.72	0.60
Chemical (Proximate) analysis		
<u>Component</u>	<u>Starter</u>	<u>Finisher</u>
Moisture	5.0	5.0
Ash	16.0	9.0
Ether Extract	6.0	7.0
Crude Fibre	6.0	8.0
Crude protein	13.0	14.0
Nitrogen Free Extracts	54.0	57.0

3.1.3 General Management and Disease control

From 1 to 28 days of age, chicks received extra heat from a hanging electric bulb (150W). The height of the electric bulb from the litter was adjusted accordingly to keep the temperatures within the comfort zone for the chicks. Comfortable temperatures within the pens were judged by the behaviour of the chicks. After the 28th day birds were raised at normal room temperature which averaged 25°C. Throughout the experiment, chicks had free access to clean water and after the brooding period (28 days) were exposed to a light:dark cycle of 12L:12D (12h light:12h dark), under natural lighting.

The chicks did not take off well due to Escherichia coli infection of the yolk sac (as confirmed by a bacteriological assay in the Department of Animal Health). Thus mortality during the first two weeks of life was very high, averaging 5%. This necessitated treatment of the entire flock with a broad spectrum tetracycline (Furaprol[®]). Treatment continued for a further period of 7 days after the symptoms and infection had been controlled.

At 5 weeks of age several birds were noticed to have bent hocks and uncoordinated gait. One such bird was sacrificed for autopsy whose findings revealed presence of uric acid crystals around the viscera and between the joints. This was

diagnosed as both visceral and articular gout, a symptom of vitamin A deficiency. This may have been due to the instability of the vitamin in the broiler premix used in the formulation of the feed or a general deficiency in the rations. It should be noted that this deficiency of vitamin A and the low CP level were contributory factors to the slow rate of growth as is evident in the results.

To correct for this, supplemental vitamin Premix (**Appendix IV**) was added to the feed (from the 6th wk to the end of study) at the rate of 1g per 1kg of feed which corrected the symptoms and halted development of new cases of leg abnormalities.

3.2.0 Data Collection

Two types of record sheets were designed for data collection: one for performance data and the other for carcass data (**Appendix Va**). For all type of data collected, pen averages were recorded being adjusted on weekly basis in the event of either mortality or sampling for carcass evaluation.

3.2.1 Growth Rate

Birds were weighed on arrival to obtain initial body weight at 1 day old and thereafter on weekly basis. All weights were taken on group basis per pen and were recorded

to the nearest .01g, using a laboratory scale (Avery), whose maximum capacity was 2,600 g. Average Daily Gain (ADG) was calculated on weekly basis as follows:

$$\text{ADG} = \frac{\text{Av.Wt.at end of wk, (g)} - \text{Av.Wt.at beginning of wk (g)}}{\text{Number of days (7)}}$$

3.2.2. Feed Intake

Feed consumption was recorded on pen basis. Using feeding recommendations by NRC (1984), an appropriate amount of feed was weighed out and given to control broiler chickens on ad libitum feeding at the same time every day. After exactly 24 h the remaining feed was weighed to obtain the intake for the 24 h. Feed wastage was determined by spreading a sheet of polythene paper beneath the feed hoppers (3 selected at random), to collect the spilt feed. This was done on the 25th to 28th day of life of the birds. The feed spilt was collected, sieved and weighed to the nearest .01g. Wastage was calculated to be 0.5% of total amount of feed eaten by the broiler chickens, and using this as the average, the actual feed intake was determined. For example, if 8,000g of feed was weighed and given to the birds for a period of 7 days and the balance at the end of this period was 1,500g, the actual intake would be $[8,000\text{g} - 1,500\text{g} = 6,500 - (.5/100 \times 6,500)]$.

Feeding for the restricted groups was based on the previous day's intake for the controls.

3.2.3 Feed Efficiency

Like growth rate, feed efficiency was calculated on group basis (per pen) and also on weekly basis. Efficiency was determined as Wt.gain(g):feed intake (g) expressed as a percentage.

3.2.4 Mortality

Dead broiler chickens were removed for autopsy to determine the cause of death. Mortality rate was calculated (on pen basis per week) as follows:

$$\text{Mortality} = [\text{Number of birds dead/Initial number}] \times 100$$

3.2.5 Carcass Data.

Carcass data was recorded at two stages for every feeding regimen: at the end of every restriction period and at the end of the study (56 days). Broiler chickens were starved overnight by withdrawing the feed from 12.00 p.m. to 9.00 a.m the following day. The broilers were weighed on pen basis to obtain average pen weight after which two broilers were randomly sampled from every treatment group (9 x 2) and 2 per pen from the control groups giving a total of 24 birds for every carcass evaluation exercise. Weighing was repeated

for every broiler chicken to obtain individual live weight. The broiler chickens were then killed by cervical dislocation. The head was cut off at the 3rd cervical joint to allow for bleeding. Plucking was effected by immersing the birds in hot water (at about 100 C) after which feathers were removed manually, followed by evisceration and scrapping of abdominal fat pad and fat surrounding the viscera, gizzard and proventriculus.

Carcass evaluation was consequently done basing on the physical weighing of the GIT, liver and spleen, heart, abdominal fat, gizzard, carcass and the breast (breast bone plus both the Pectoralis major and Supracoracoideus muscles). Organ weights were expressed as a % of carcass weight.

The killing out percentage (K.O%) was determined as follows:

$$K.O\% = [\text{Carcass weight} / \text{Live weight}] \times 100$$

All measurements were recorded to the nearest .01g (Appendix Vb) .

3.2.6 Data Analyses.

Data were analyzed using the Analysis of variance (ANOVA) for a completely randomized design with a factorial arrangement of treatments, with age at initiation and level

of restriction as two factors. Percentage data were converted to arc sine before analysis.

Data were divided into two: overall responses at end of 56 days, and during the 2 wk restriction and recovery periods. Two separate models were used to analyze the data: Model 1 was used to analyze overall data at end of the experiment (at 56 days), while Model 2 was used to analyze data collected during the restriction and recovery periods. The General Linear Models of SAS Institute (SAS, 1982) used to analyze the data were:

$$Y_{ijk} = \mu + a_i + b_j + (ab)_{ij} + e_{ijk} \quad [\text{Model 1}]$$

Where

Y_{ijk} = individual observation at i^{th} age, j^{th} level, and k^{th} replicate

μ = overall mean

a_i = effect of age, $i = 1, 2, 3, 4$

b_j = effect of level, $j = 1, 2, 3$

$(ab)_{ij}$ = interaction of age and level

e_{ijk} = random error term

Statistical model for the 2 wk restriction and recovery period was:

$$Y_{ij} = \mu + b_i + e_{ij} \quad [\text{Model 2}]$$

Where

Y_{ij} = individual observation at i^{th} level, and j^{th} replicate

μ = overall mean

b_i = effect of level, $i = 1, 2, 3$

e_{ij} = random error term

Where significant differences ($P < .05$) were observed, Duncan's Multiple Range Test (DMRT) was used to separate the means (Steel and Torrie, 1980).

4. RESULTS AND DISCUSSION

4.1.0 Overall effect of age and level on performance

A summary of the results of the experiment which tested the effect of age at initiation of feed restriction and level of restriction on the performance of broiler chickens is given in **Table 2**. The final body weight (at 56 days) was generally low in all groups and this was be attributed to the low crude protein levels as shown in Table 1. There were no significant differences ($P>.05$) among all treatment groups although control groups attained a higher ($P<.05$) final body weight compared to the treatment groups. Similarly there were no differences ($P>.05$) for body weight gain among the restricted groups but this was higher in the control groups. Cumulative feed intake was different ($P<.05$) across the treatments although no specific trend was observed among all the groups. Feed intake was significantly ($P<.05$) higher in control groups, while among the restricted groups those restricted at 28 days and by 30% had the highest FI followed by those restricted at 14 days and by 10%. Feed efficiency was low compared to industry standards and this again was attributed to the nutrient deficiencies in the feed and disease stress such as E.coli infection at 0 to 7 days of age and infectious bronchitis at 28 to 35 days of age. However, there were no differences ($P>.05$) among all the treatments for feed efficiency.

TABLE 2. Overall effect of age and level of restriction on the body weight, weight gain, feed intake, feed efficiency

Factor A	Factor B	Variables			
<u>Age (Days)</u>	<u>Level (%)</u>	<u>BW¹</u>	<u>Gain¹</u>	<u>FI¹</u>	<u>FE²</u>
7	10	831 ^b	753 ^b	3860 ^{cd}	21 ^a
	20	873 ^b	795 ^b	3640 ^d	24 ^a
	30	828 ^b	750 ^b	3580 ^d	23 ^a
14	10	891 ^b	814 ^b	4260 ^b	21 ^a
	20	866 ^b	788 ^b	4090 ^c	21 ^a
	30	946 ^b	867 ^b	3965 ^c	24 ^a
28	10	891 ^b	812 ^b	4170 ^{bc}	21 ^a
	20	852 ^b	777 ^b	4085 ^c	21 ^a
	30	901 ^b	821 ^b	4280 ^b	21 ^a
35	10	886 ^b	813 ^b	4140 ^{bc}	21 ^a
	20	863 ^b	787 ^b	3700 ^d	23 ^a
	30	907 ^b	828 ^b	3880 ^{cd}	23 ^a
Controls	0	1071 ^a	994 ^a	5695 ^a	18 ^a
SE		16	13	120	4

^{a-d}Means in columns with different superscripts are significantly different ($P < .05$).

¹Cumulative means measured in grams at 56 days.²[gain, g/feed, g] x 100 at 56 days

4.1.1 Effect of age and level of restriction on carcass quality

Results of the overall effect of age and level of restriction on the carcass quality of broiler chickens are shown in Table 3.

There was no specific trend for carcass weight among restricted groups but control groups had a higher ($P < .05$) carcass weight compared to restricted groups. Broiler chickens restricted at 7 days and at 10% had the lowest carcass weight compared to all other groups. There is a positive correlation between body weight and carcass weight which can be reflected by the low carcass weight of the groups that also attained low body weight as seen in the results shown in Table 2. Killing out percentage was generally low compared to stipulated standards (for example 65 to 75% as reported by Leeson et al., 1992) and this was attributed to the low final body weight and low carcass weight across the treatments. There were no significant differences ($P > .05$) for killing out percentage among all the groups. Further, there were no differences ($P > .05$) for breast muscle and the GIT among all the treatment groups. Abdominal fat was significantly higher ($P < .05$) in control groups than in feed restricted groups, with no differences among the restricted groups.

TABLE 3. Overall effect of age and level of restriction on carcass weight, killing out %, breast, abdominal fat, and GIT.

Factor A	Factor B	Variables				
Age (Days)	Level (%)	Carc.wt. ¹	K.O. ²	Breas ^{t²}	Fat ²	GIT ²
7	10	317 ^a	35 ^a	21 ^a	1.0 ^D	23 ^a
	20	381 ^a	41 ^a	23 ^a	1.7 ^D	23 ^a
	30	456 ^c	48 ^a	22 ^a	1.5 ^D	25 ^a
14	10	488 ^{bc}	50 ^a	21 ^a	1.2 ^D	25 ^a
	20	444 ^c	46 ^a	22 ^a	1.9 ^D	23 ^a
	30	479 ^{bc}	48 ^a	22 ^a	1.3 ^D	23 ^a
28	10	481 ^{bc}	49 ^a	19 ^a	2.5 ^D	21 ^a
	20	444 ^c	46 ^a	22 ^a	1.9 ^D	23 ^a
	30	479 ^{bc}	48 ^a	22 ^a	2.0 ^D	21 ^a
35	10	517 ^D	53 ^a	21 ^a	1.6 ^D	20 ^a
	20	412 ^a	49 ^a	19 ^a	2.1 ^D	20 ^a
	30	445 ^c	42 ^a	22 ^a	1.3 ^D	23 ^a
Controls		619 ^a	52 ^a	22 ^a	5.7 ^a	22 ^a
SE		11	6	3	2	4

^{a-d}Means in columns with different superscripts are significantly different (P<.05).

¹Measured in grams at 56 days.

²As a % of carcass weight at 56 days.

4.1.2 Effect of age of restriction

A summary of the results of the experiment which tested the effect of feed restriction (initiated at different ages and levels) on the performance and carcass quality of broilers is given in **Tables 4, 5, 6, 7 and 8.**

Table 4 gives the overall effect of feed restriction initiated at different ages on the performance (Body weight, Body weight gain, Feed intake, Feed efficiency, and mortality) of broiler chickens at 56 days.

4.1.3 Body weight

Age at which restriction was initiated did not have a significant ($P < .05$) effect on final body weight at 56 days (**Table 4**). There were no significant differences ($P > .05$) in terms of the initial body weights among the different groups since the chicks were from the same batch, therefore initial weights were excluded from the data shown in **Table 4.**

Mean final body weights were numerically lower for restricted broilers than for those on full feeding being lowest for the birds restricted at 7 days of age (**Figure 1**).

TABLE 4. Effect of age at initiation of feed restriction on body weight, weight gain, feed intake, and feed efficiency

Variable	Age at restriction (in days) ¹					SE
	Control	7	14	28	35	
BW, g/56 days	1071 ^a	900 ^a	943 ^a	929 ^a	932 ^a	26
BW gain,g/56 days	994 ^a	823 ^c	866 ^b	851 ^d	855 ^d	9
FI, g/56 days	5695 ^a	4194 ^d	4502 ^b	4557 ^b	4354 ^c	110
FE ²	18.8 ^a	21.4 ^a	21.0 ^a	20.0 ^a	21.4 ^a	4
Mortality ³	28.0 ^a	28.0 ^a	26.0 ^a	32.0 ^a	26.0 ^a	6

^{a-d}Means in rows with different superscripts are significantly different (P<.05)

¹Restriction lasted for 2 wk after which birds were fed ad libitum upto 56 days

²gain,g/feed,g expressed as a % (at end of 56 days)

³[No. of birds dead/Initial No.] x 100 (at end of 56 days)

However, there were no significant differences ($P>.05$) in body weight at 56 days among all the groups. The first 14 days of life is the physiological stage of high nutrient demand when the cells and tissues are undergoing rapid differentiation and growth (Katanbaf et al., 1989b). Reduction in nutrient supply would consequently curtail increase in body weight. It would also appear that birds restricted at this early age were not able to recover completely from weight loss during the period of restriction, which contrasts the previous observations (Plavnik and Hurwitz, 1988a) who showed that restriction imposed at 7 days resulted in higher final body weight compared to that initiated at either 9 or 11 days. In the present study restriction during the finisher stage (28 and 35 days) resulted in almost similar final body weight compared to the other regimens (during the starter period) and would be preferred over these two (**Figure 1**). This is possibly because at this later stage the bird has already passed the physiological stage of highest nutrient demand and any nutrient intake is used mainly for laying down of fat which is generally lighter than lean tissue. Compared to previous results (Plavnik and Hurwitz, 1985, 1988a, 1989, 1990), who obtained an average of 2 kg liveweight and above, the final body weights in this study were lower mostly due

to the problem of feed deficiencies and bacterial infections as alluded to earlier.

In most previous research on feed restriction (Plavnik and Hurwitz, 1985, 1988a, 1989, 1990), Leeson et al. (1991), Yu et al. (1990), Ballay et al. (1992), Fontana et al. (1992) the restriction period was short (4 to 11 days) and the feeds used contained higher levels of protein and energy 21% to 24% CP and 2,900 to 3,200 kcal ME/kg respectively. The final body weight thus obtained by these workers were much higher (1.8 to 2.7kg) than those obtained in the current study.

4.1.4 Body weight gain

Restriction at different ages had different effects ($P < .05$) on BW gain. Broiler chickens on full feed (controls) had the highest gain while those restricted at 7 days had the lowest average gain. Restriction during the finisher period (28 and 35 days) gave similar average gain while restriction at 14 days gave higher average gain compared to the other restriction groups (**Table 4**). Although birds that had been on restriction tended to grow at a faster rate than control birds during full-feeding, they were not able to completely overcome the earlier growth retardation.

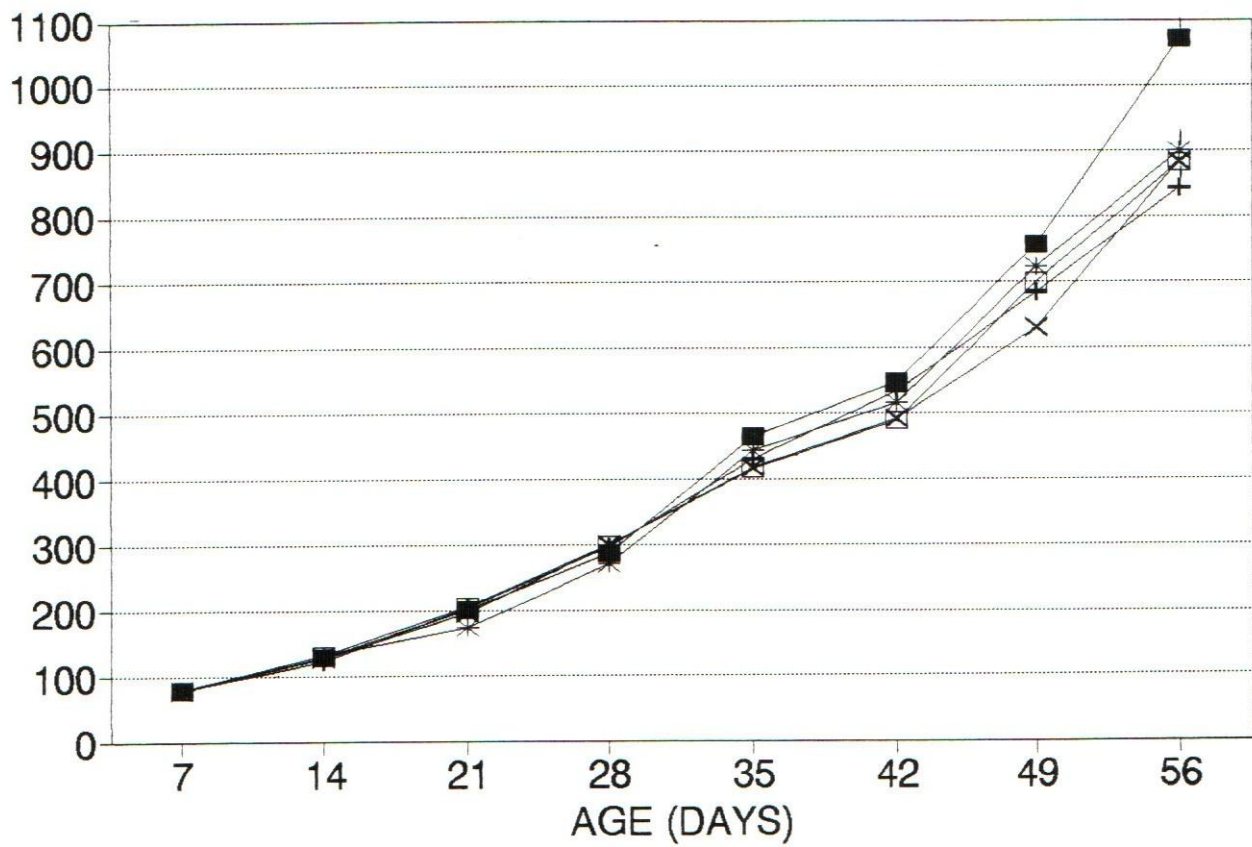


FIGURE 1. Effect of age at restriction on body weight

■ Control	+ Rs at 7 days	* Rs at 14 days
□ Rs at 28 days	× Rs at 35 days	

Observation similar to the above was made by Yu et al. (1990) but this contrasts the findings of Plavnik and Hurwitz (1985, 1988a, 1989) and Leeson et al. (1991) who reported complete recovery of weight gain of broiler chickens subjected to severe energy restriction during early growth. In those studies, Plavnik and Hurwitz (1985, 1988a) supposed that energy was the nutrient most limiting to growth.

Plavnik and Hurwitz (1988a) observed that compensation is not complete in birds marketed at 49 days.

4.1.5 Feed intake

Feed intake was significantly ($P < .05$) affected by age at which restriction was initiated. Broiler chickens on full feeding had the highest intake while birds restricted at 14 and 28 days had similar intakes which was in turn higher than those restricted at 35 days, and finally groups restricted at 7 days had the lowest feed intake. There was no consistent trend among the restricted groups. Broilers restricted at 35 days of age had a lower cumulative feed intake than those restricted at 14 or 28 days at the end of the experiment (56 days). This is probably because at this later stage of growth, the feed conversion ratio is generally high and birds have higher maintenance requirements and therefore tend to have higher intakes.

Restriction in feed intake therefore would be reflected in the low final feed intake as is evident here.

4.1.6 Feed efficiency

Age at initiation of feed restriction did not have a significant ($P>.05$) effect on feed efficiency (Table 4). Feed efficiency values reported here differ from results stipulated in literature and this too can be attributed to the problem with the feed and poor health of the broiler chickens. Plavnik and Hurwitz (1985, 1988a) using diets containing a protein value of 21% CP and 19% CP and energy of 2,900 and 3,000 kcal ME/kg in the starter and finisher diets respectively obtained feed efficiency values of 42% to 45% during both the starter and finisher periods. The two workers also observed that feed efficiency for restricted birds was higher than for the control birds regardless of age of restriction.

This is in agreement with the observation made by Yu et al. (1990) and Leeson et al. (1990) but contrary to the observations of Fontana et al. (1992) who reported that broilers that were subjected to feed restriction at an early age had lower feed conversions at 49 days than full-fed birds which concurred with the findings of McMurtry et al. 1988; Pinchasov and Jensen (1989).

4.1.7 Mortality

Age at initiation of feed restriction did not affect ($P>.05$) mortality of the broiler chickens (Table 4). However, broilers restricted at 28 days had a numerically higher mortality than all other groups which was probably due to an outbreak of infectious bronchitis at this time coupled with the stress of restriction.

Total mortality for the entire period (56 days) remained high (27%) and statistically similar in all the treatments and the control. Most deaths were caused by E. coli infection of the yolk sac (at 0 to 3 days) and infectious bronchitis at 28 to 42 days.

Bowes et al. (1988) and O'Sullivan et al. (1991) reported a lower rate of mortality caused by Sudden Death Syndrome (SDS) in broilers restricted to 25% of the feed intake of control birds from 5 to 30 days of age and restricted from 5 to 27 days of age on alternate day feed restriction program respectively.

Hulan et al. (1980), Julian and Bowes (1984) had earlier postulated that SDS is associated with rapidly growing broilers and that by reducing the rate of early growth for broilers the mortality associated with SDS and hence total mortality at market age could be reduced. Fontana et al. (1992) reported significant reductions in the rates of mortality in restricted broilers compared to control birds. In the current study mortality caused by SDS

was neither observed nor were any of the above differences observed.

4.1.8 Carcass quality

Table 5 gives the results of the effect of age at initiation of feed restriction on carcass quality of broiler chickens. Feed restriction reduced final carcass weight and abdominal fat in all treatment groups.

4.1.9 Carcass weight

Carcass weight for restricted birds was significantly lower ($P < .05$) than for full-fed birds (Table 5). Broilers restricted at 7 days had the lowest carcass weight possibly because their final body weights were also the lowest, while broilers restricted at 14 and 28 days had similar carcass weights but numerically higher than for those restricted at 35 days (Figure 2). There is therefore a positive correlation between body weight and carcass weight. Similar observations were made by Plavnik and Hurwitz (1985; 1988a; 1989; 1990), Leeson et al. (1991), Summers and Leeson (1979). Any factors that enhance body weight will subsequently enhance carcass weight. Such factors as increased feed intake, better feed efficiency, and high body weight gain generally increase body weight and thus carcass weight.

Table 5. Effect of age at initiation of feed restriction on carcass weight, killing out %, abdominal fat, and GIT.

<u>Variable</u>	<u>Age at restriction (in days)¹</u>					
	<u>Control</u>	<u>7</u>	<u>14</u>	<u>28</u>	<u>35</u>	<u>SE</u>
Carc.WT,g/56 days	619 ^a	385 ^c	486 ^b	468 ^b	458 ^b	10.6
Killing out % ²	52 ^a	44 ^a	50 ^a	49 ^a	49 ^a	6.1
Breast ³	22 ^a	22 ^a	22 ^a	21 ^a	21 ^a	2.7
Abdominal fat ³	5.7 ^a	2.7 ^b	2.6 ^b	3.0 ^b	2.7 ^b	4.8
GIT ³	22 ^a	23 ^a	21 ^a	21 ^a	21 ^a	4.5

^{a-b}Means in rows with different superscripts are significantly different (P<.05)

¹Restriction lasted 2 wk after which birds were returned to full feeding upto end of the experiment

²Carcass weight as a % of live weight

³As a % of carcass weight measured at 56 days

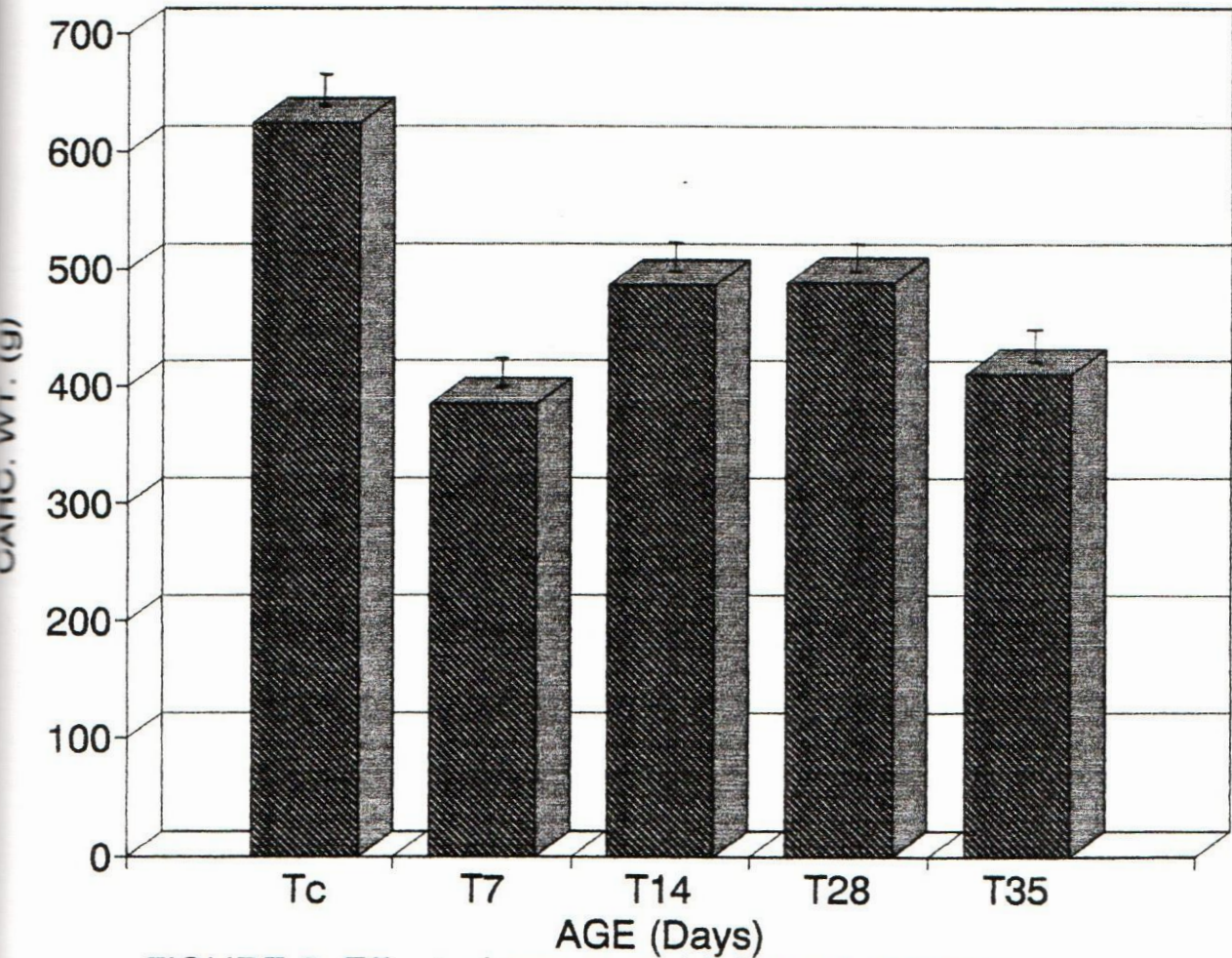


FIGURE 2. Effect of age at restriction on carcass wt.

4.1.10 Breast weight and GIT

Age at initiation of feed restriction did not have a significant ($P > .05$) effect on both breast weight and GIT expressed as a percentage of carcass weight (Table 5). However, when considered as actual weights (not expressed as a % of carcass weight), control birds had higher weights for both breast and the GIT as shown in Figures 3 and 4.

Hester et al. (1990) and Newcombe et al. (1992) also observed a reduction in breast yield for feed restricted turkeys and broilers respectively, which was attributed to greater proportion of thigh muscle.

Katanbaf et al. (1989b) reported that restricted feed intake increased relative weights and lengths of various segments of the GIT and pancreas and in turn caused a reduction in relative abdominal fat depot weights and total carcass fat.

However these workers examined the effects of feed restriction in broiler breeder pullets which are kept for a longer period of time, their observations were made from 6 days to 250 days. Hence this effect was evident which is unlike the situation in the present study where commercial broilers were restricted for only 2 wk and kept for 56 days. It is therefore possible that birds may have made up for any differences encountered during the actual restriction period.

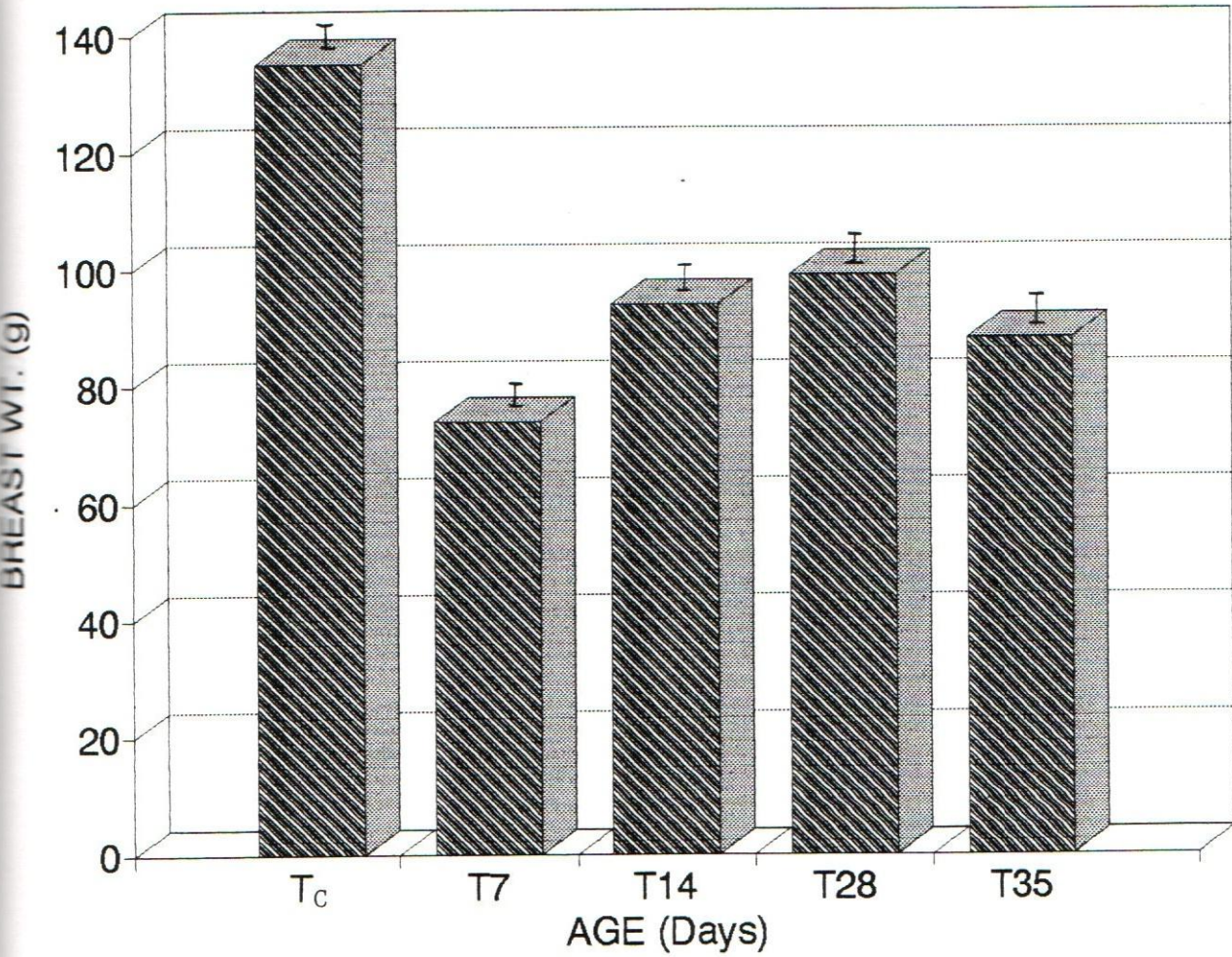


FIGURE 3. Effect of age at restriction on breast wt.

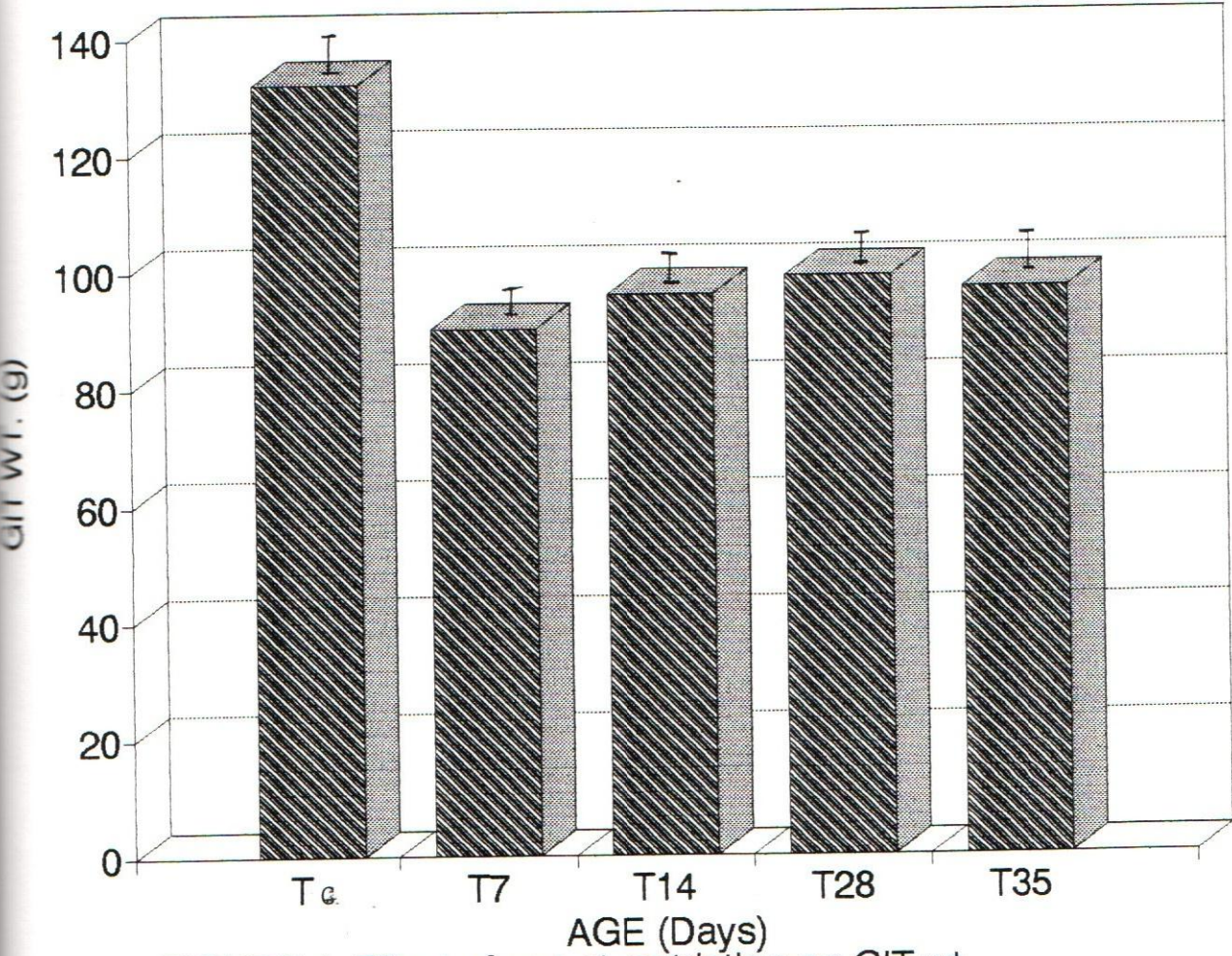


FIGURE 4. Effect of age at restriction on GIT wt.

4.1.11 Abdominal fat

Age at initiation of feed restriction significantly ($P<.05$) lowered the amount of abdominal fat of the broiler chickens (Table 3). Control birds had higher amounts of abdominal fat as compared to all other feeding regimens (Figure 5). It can be inferred from this that ad libitum feeding of broiler chickens enhances fat deposition. This concurs with the findings of Hulan et al. (1980), who postulated that any dietary energy not required for growth is stored as fat.

Similar observations have been made by other workers (Plavnik and Hurwitz, 1985; 1988a; 1990). Cherry et al. (1984) suggested that early feed restriction (at 3 to 7 days of age), arrests adipocyte hypertrophy with the fat cells remaining small and not filled with fat. Yu et al. (1990) reported that broilers that were feed-restricted had higher abdominal fat pads than control groups at 49 days of age. Similarly, restricted-fed broilers had a significantly ($P<.05$) larger abdominal fat pad at both 42 and 49 days of age, which is contrary to what was observed here.

In this experiment the size of the abdominal fat pad was reduced significantly ($P<.05$) by restriction with no significant differences among groups restricted at different ages or levels except for the group restricted at 7 days,

Restricted birds at the 3 levels of 10, 20, and 30% had similar body weights but significantly ($P < .05$) less than the control groups (Table 6). The body of broiler chickens is composed of living tissues that require food nutrients such as proteins, energy feeds, minerals and vitamins. In order for the different tissues to develop and increase in size and weight, food must be made available to the animal. Requirements for different nutrients changes with the stage of growth of the bird.

4.2.1 Body weight

4.2.0 Effect of level of restriction

A summary of results of the main effects of level of restriction (10, 20, and 30%) on performance of broilers is given in Table 6.

which was notably less. There is a correlation between body weight, carcass weight and abdominal fat. Groups restricted at 7 days had the lowest body weight and carcass weight and consequently the lowest abdominal fat.

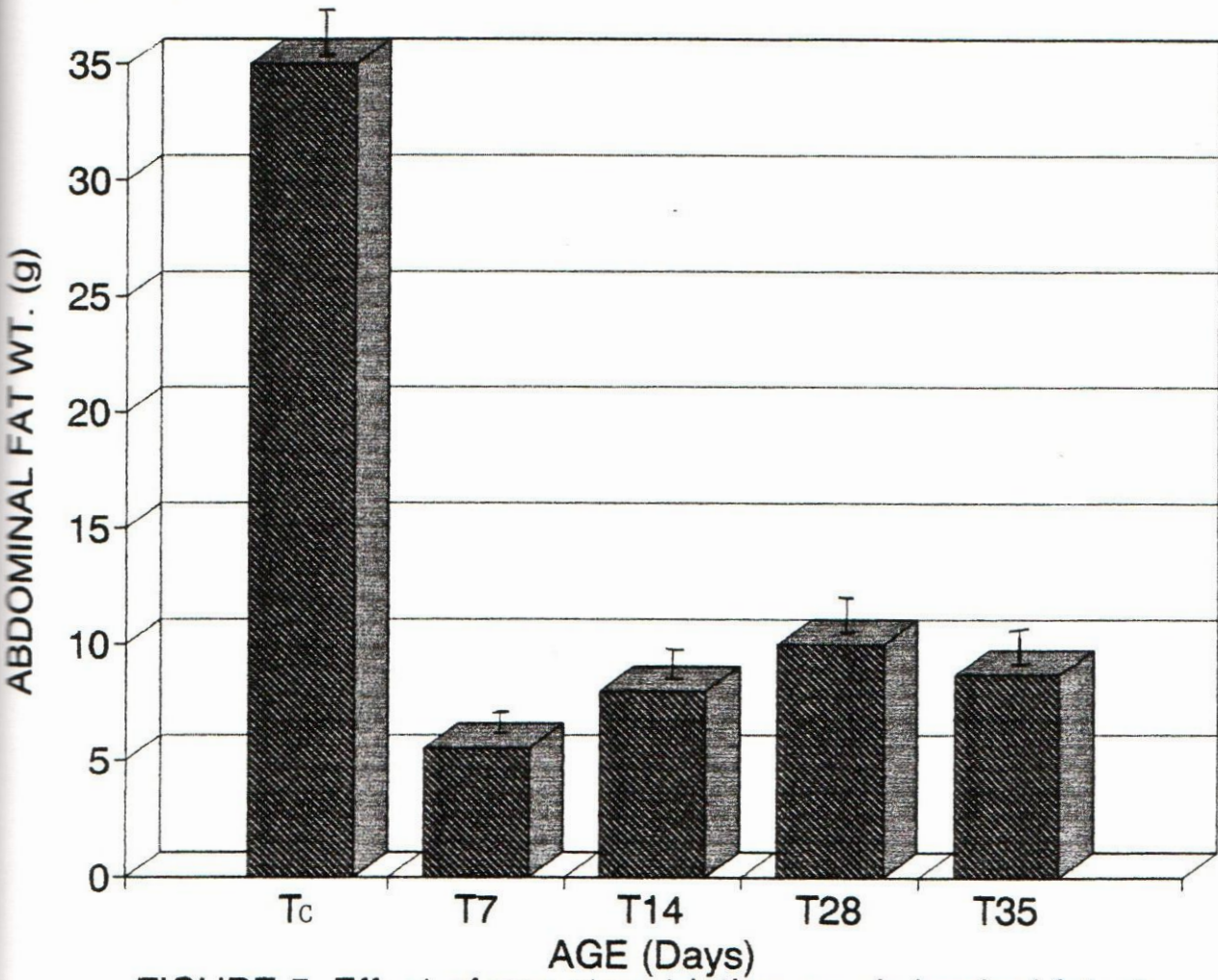


FIGURE 5. Effect of age at restriction on abdominal fat wt.

Broiler chicks like all other young animals have a biological urge to grow. The starter period (0 to 28 days of age) is the most critical stage in the life of the chicken. This is the period of highest rate of growth and differentiation of the different tissues of the body. During this time therefore the bird needs the correct amount and quality of food to be able to meet its requirements for growth and maintenance.

Growth continues during the finisher stage although at this time the bird lays down more of fat tissue than lean tissue, thus it requires more of the energy feeds.

Reducing the amount of nutrients whether by 10, 20, or 30% would consequently curtail the increase in size and weight of the tissues that collectively give the total body weight of the bird.

Similar observations were made by Yu et al. (1990), Ballay et al. (1992) and Fontana et al. (1992) who reported lower final body weights for broilers that had been on feed restriction compared to those that were on full feeding throughout.

TABLE 6. Effect of level of feed restriction on body weight, weight gain, feed intake, feed efficiency, and mortality

Variable	Level of restriction ¹				SE
	Control	10%	20%	30%	
BW, g/56 days	1071 ^a	875 ^b	863 ^b	895 ^b	22
BW gain, g/56 days	994 ^a	798 ^c	787 ^c	816 ^b	15
FI, g/56 days	5695 ^a	4107 ^b	3879 ^c	3976 ^c	79
FE % ²	18.8 ^a	21.3 ^a	22.3 ^a	23.0 ^a	2
Mortality ³	28.0 ^a	27.0 ^a	27.0 ^a	30.0 ^a	3

^{a-d}Means in rows with different superscripts are significantly different (P<.05)

¹Restriction lasted for 2 wk after which birds were fed ad libitum upto 56 days

²gain, g/feed, g expressed as a %, cumulative upto 56 days

³[No. of birds dead/Initial No.] x 100 at end of 56 days

4.2.2 Body weight gain

The level of feed restriction significantly ($P < .05$) depressed average body weight gain over the 56 days (Table 6). However, birds restricted at 30% intake of full-fed birds had higher body weight gain than those restricted at 10 and 20%. This is probably because the group on 30% restriction having been more severely restricted was at a much lower maintenance requirement and hence compensation was more evident here than in the other groups.

In this study all nutrients were being restricted at varying proportions (by 10%, 20% or 30% of nutrient intake of full-fed birds), due to quantitative feed restriction. A 20% restriction in feed intake resulted in a 19% reduction in weight gain whereas a 30% restriction gave a lower reduction (of 15%) in weight gain at 56 days. Wilson and Osbourn (1960) suggested that total compensatory growth is possible following either protein or energy restriction but is higher for energy restriction than for protein restriction.

Newcombe et al. (1992) found that feed restriction resulted in some compensatory growth immediately following the restriction period, which was not sufficient to make up for all the weight lost during restriction.

4.2.3 Feed intake

The level of feed restriction significantly ($P < .05$) depressed overall feed intake where birds restricted by 20% had the lowest though not different ($P > .05$) intakes compared to those restricted by 20%. Control birds had the highest intake followed by those restricted by 10%.

A 10% feed restriction resulted in a 29% reduction in cumulative feed intake while a 20% and 30% feed restriction gave a 31% and 32% reduction in feed intake respectively.

Yu et al. (1990) observed similar reduction in feed intake for birds that were restricted either daily or hourly or even in those provided feed on a skip-a-day basis.

Wilson and Osbourn (1960) postulated that the alimentary canal of animals continues to grow during periods of undernutrition, and that upon subsequent full-feeding the animal has a bigger capacity to accommodate more food. Compensation in feed intake was partially observed in groups restricted at 28 days and at 30% and in those restricted at 35 days and at 30%, whose intakes were higher than of the same age groups but restricted at 20%.

4.2.4 Feed efficiency

The level of restriction did not have a significant ($P > .05$) effect on feed efficiency although birds restricted by 30% had a numerically higher value compared to all other feeding regimens (Table 6). Thus restricted broiler chickens

at the 3 levels had similar ($P > .05$) cumulative feed efficiency to the controls.

Forsum et al. (1981) suggested that animals that had been on previous feed restriction are at a low basal metabolic rate (therefore low maintenance requirements), and have a lower specific dynamic action of food. This would imply that on subsequent full feeding such animals utilize most of the food supplied on growth and hence their feed efficiency should be high. This was not observed in the present study.

4.2.5 Carcass quality

The effect of level of feed restriction on carcass traits at 56 days of age is given in **Table 7**.

4.2.6 Carcass weight

There were some ($P < .05$) differences for carcass weight between birds restricted by 10%, 20, and 30% and the controls, where the controls had the highest carcass weight. Among the restricted groups, those restricted by 30% had a higher ($P < .05$) carcass weight compared to those restricted by either 10 or 20%.

TABLE 7. Effect of level of feed restriction on carcass weight, killing out%, breast, abdominal fat, and GIT.

Variable	Level of restriction ¹				SE
	Control	10%	20%	30%	
Carcass WT., g/56 days	619 ^a	451 ^c	420 ^d	465 ^b	11
Killing out % ²	52 ^a	47 ^a	46 ^a	48 ^a	6
Breast ³	22 ^a	20 ^a	22 ^a	22 ^a	2
Abdominal fat ³	5.7 ^a	1.5 ^b	1.4 ^b	1.5 ^b	5
GIT ³	22 ^a	21 ^a	23 ^a	21 ^a	4

^{a-b}Means in rows with different superscripts are significantly different ($P < .05$)

¹Restriction lasted 2 wk after which birds were returned to full feeding upto end of the experiment

²Carcass weight as a % of live weight

³As a % of carcass weight measured at 56 days

There is a positive correlation between body weight and carcass weight since groups that had lower final body weight also had lower carcass weight. The present results are in agreement with those of Plavnik and Hurwitz (1985, 1988a) and Yu et al. (1990), who reported lower carcass weight for broiler chickens that had previously been on feed restriction, either at 35 kcal ME/kg or those restricted hourly respectively.

4.2.7 Abdominal fat

The level of feed restriction significantly ($P < .05$) reduced the size of the abdominal fat in all restricted groups compared to control groups. There were no differences ($P > .05$) among birds restricted at different levels. Carcasses were generally very lean because of the low final body weight and hence deposition of fat was very minimal. However, control birds had the highest amount of abdominal fat possibly since they had the highest feed intake and are likely to have deposited any extra energy not required for growth as fat.

Similar observations have been made by other researchers (Plavnik and Hurwitz, 1985, 1988a, 1988b, 1990; Summers and Leeson, 1979).

It is therefore possible to reduce the amount of abdominal fat in broiler chickens by minimizing the amount of feed

given to the birds by 10, 20 or 30% level of full-fed broilers.

4.2.8 Breast weight and GIT

The level of feed restriction did not have a significant ($P > .05$) effect on the size of breast and the GIT (Table 7).

The breast gives a measure of the amount of lean tissue in the carcass (Katanbaf et al., 1989a). Consequently low final body weight coupled with low carcass weight would result in low breast muscle.

In their study, Katanbaf et al. (1988a) showed that broilers on feed restriction had significantly ($P < .05$) higher weights for the GIT compared to control birds, which was not observed in the current study. The reason for the difference was not known.

4.3.0 Interactive effect of age and level of restriction

In addition to the main effects of the two factors, age and level of feed restriction, interactive effects of the two factors on both performance and carcass traits were investigated. Results of the interactive effect of age and level of restriction are given in Tables 8 and 9.

Table 8 summarizes the interactive effects of age and level on performance of broiler chickens.

There was no significant ($P > .05$) interactive effect between age and level of restriction on BW among the restricted groups but, BW of control groups was higher ($P < .05$) compared to restricted groups (**Table 8a**). However, among the restricted groups, there were no significant ($P > .05$) interactive differences implying that the factors age and level acted independently to depress BW.

TABLE 8. Interactive effect of age and level of restriction on body weight, weight gain, feed intake, feed efficiency.

Age at restriction (Days)									
% level									
of Rs	7	14	28	35	7	14	28	35	
a. <u>Body WT. (g)</u> ¹					b. <u>WT. Gain (g)</u> ¹				
0	1071 ^a	1071 ^a	1071 ^a	1071 ^a	994 ^a	994 ^a	994 ^a	994 ^a	
10	831 ^b	891 ^b	891 ^b	886 ^b	753 ^b	814 ^b	812 ^b	813 ^b	
20	873 ^b	866 ^b	852 ^b	863 ^b	795 ^b	788 ^b	777 ^b	787 ^b	
30	827 ^b	946 ^a	901 ^b	907 ^b	750 ^b	867 ^b	821 ^b	828 ^b	
SE	16	11	17	16	14	9	11	15	
c. <u>Feed Intake (g)</u> ¹					d. <u>Feed Efficiency (%)</u> ¹				
0	5695 ^a	5695 ^a	5695 ^a	5695 ^a	18 ^a	18 ^a	18 ^a	18 ^a	
10	3860 ^b	4260 ^b	4170 ^c	4140 ^b	21 ^a	21 ^a	21 ^a	21 ^a	
20	3640 ^c	4090 ^b	4085 ^c	3700 ^d	24 ^a	21 ^a	21 ^a	23 ^a	
30	3580 ^c	3965 ^c	4280 ^b	3880 ^d	23 ^a	20 ^a	21 ^a	23 ^a	
SE	110	122	125	115	4	4	4	5	

^{a-d} Means in columns with different superscripts are significantly different ($P < .05$)

¹Data (in g) represent the cumulative responses at the end of the experiment (56 days)

Broiler chickens restricted at 35 days and at 30% had a numerically higher body weight than all other groups on restriction. Further, there was no significant ($P > .05$) interaction between age and level on BW gain among feed restricted groups but control groups had higher ($P < .05$) final BW gain compared to restricted groups (Table 8b).

A significant ($P < .05$) age by level interaction was observed for feed intake where control groups had the highest FI while those restricted at 10% had similar feed intake at all ages of feed restriction.

Groups restricted at 7 and 14 days and at 20% or 30% had statistically ($P < .05$) similar feed intake but significantly lower than those restricted at 10%. A significant ($P < .05$) interaction between age and level was observed for groups restricted at 28 and 35 days and at 20% and 30% compared to those on full-feeding or those on 10% restriction at 7 and 14 days. This is probably because at this later stage of growth the feed conversion ratio is generally high and broiler chickens tend to have a high feed intake. Restricting the amount of feed offered to the broilers would consequently reduce the cumulative feed intake.

Restriction consistently decreased overall feed intake since control birds had significantly ($P < .05$) higher intakes than any other group on restriction (Table 8c). Groups

restricted at 7 days and 20% had lower intakes followed by those restricted at 35 days and 20%. There was no significant ($P > .05$) interaction between age and level among all the groups for feed efficiency (Table 8d).

- A significant ($P < .05$) interaction was observed for killing out percentage in groups restricted at 7 days and at 10%, 7 days and at 20%, and at 35 days and at 30% (Table 9a). Broiler chickens restricted at 7 days and at 10% had the lowest ($P < .05$) body weight which may have been reflected in the low killing out percentage.

There was no significant ($P < .05$) interactive effect for breast weight for all the groups (Table 9b). Hence, restriction regardless of age or level did not have any significant effect on the breast weight. Feed restriction significantly ($P < .05$) decreased the weight of the abdominal fat regardless of age or level. This is consistent with the results of Plavnik and Hurwitz (1985, 1988a, 1989, 1990), and Cherry et al. (1978). Ballam and March (1979) postulated that when feed is restricted at an early age, the adipocyte cells do not fill up with fat.

In the current study all birds on feed restriction had less abdominal weight compared to control birds.

TABLE 9: Interactive effect of age and level of restriction on killing out %, breast, abdominal fat, and GIT.

% level of Rs	Age at restriction (Days)							
	7	14	28	35	7	14	28	35
	a. <u>Killing out %</u> ¹				b. <u>Breast</u> ¹			
0	52 ^a	52 ^a	52 ^a	52 ^a	22 ^a	22 ^a	22 ^a	22 ^a
10	35 ^b	50 ^a	49 ^a	53 ^a	21 ^a	21 ^a	19 ^a	21 ^a
20	41 ^b	47 ^a	46 ^a	49 ^a	23 ^a	23 ^a	22 ^a	19 ^a
30	48 ^a	54 ^a	48 ^a	42 ^b	22 ^a	22 ^a	22 ^a	22 ^a
SE	6	6	5	6	3	3	2	3
	c. <u>Abdominal fat</u> ¹				d. <u>GIT</u> ¹			
0	5.7 ^a	5.7 ^a	5.7 ^a	5.7 ^a	22 ^a	22 ^a	22 ^a	22 ^a
10	1.0 ^b	1.6 ^b	2.5 ^b	1.6 ^b	23 ^a	19 ^a	21 ^a	20 ^a
20	1.7 ^b	1.2 ^b	1.9 ^b	2.1 ^b	23 ^a	24 ^a	23 ^a	20 ^a
30	1.5 ^b	2.0 ^b	2.0 ^b	1.3 ^b	25 ^a	17 ^a	21 ^a	23 ^a
SE	2	2	2	2	5	4	4	4

^{a-b} Means in columns with different superscripts are significantly different ($P < .05$)

¹Data (in g) were collected at end of the experiment (56 days)

Similarly, there was no significant ($P < .05$) interaction between age and level of restriction on the GIT. This observation contradicts that of Katanbaf et al. (1989b) who reported higher weights for the GIT for restricted broilers compared to the controls. This difference may have been due to the type of birds used. In the present study commercial broilers were used while in the former study broiler breeder pullets were used and data were collected for a longer period (from 6 to 250 days).

4.4.0. Response of birds during restriction period and recovery

Performance data for 2 wk during restriction and 2 wk on full feeding following restriction (recovery) were compared to the controls during the same periods. Sets of data were subjected to ANOVA as a Completely Randomized Design. A summary of the results is given in **Tables 10 to 13**. There were no significant ($P < .05$) differences among the treatment groups on body weight during the first four weeks (0 to 28 days). However, birds restricted at 28 days had lower body weight during the recovery period (two weeks immediately following restriction). Full-fed birds consistently weighed more than restricted birds during the first 14 days but this was not statistically different from the treatment groups (**Table 10**).

Cumulative body weight (at 56 days) for groups restricted at 35 days and 30% was slightly higher than for other restricted groups. During the actual restriction period groups that had been on restriction had higher average weight gain than the controls but this was not consistent (Table 11).

4.4.1 Body weight

During the 2 wk restriction period, feed restriction did not have a significant ($P > .05$) effect on body weight for groups restricted at 7 days compared to control groups. At the end of the recovery period control groups had numerically higher weights than all the restricted groups. However, during the recovery period restricted broiler chickens grew at a rate that was comparable to the controls but stabilized at a lower BW than the controls at the end of the recovery period with no significant differences ($P > .05$) among the different restriction groups (Figure 6).

TABLE 10. Response of body weight to feed restriction during period of restriction and recovery

% level of Rs	Age at restriction (in days) ¹							
	7		14		28		35	
	Rs	Rc	Rs	Rc	Rs	Rc	Rs	Rc
0	202 ^a	464 ^a	287 ^a	549 ^a	549 ^a	1071 ^a	756 ^a	1220 ^a
10	204 ^a	429 ^a	263 ^a	525 ^a	489 ^b	890 ^b	643 ^b	1028 ^b
20	194 ^a	434 ^a	284 ^a	535 ^a	481 ^b	851 ^b	617 ^b	1015 ^b
30	189 ^a	430 ^a	270 ^a	542 ^a	497 ^b	901 ^b	634 ^b	1050 ^b
SE	14	16	12	16	12	17	14	16

^{a-b}Means in columns with different superscripts are significantly different ($P < .05$)

¹Data expressed in grams were collected at the end of each restriction period and at end of recovery period.

Full compensation was not realized among the restricted groups upon subsequent full-feeding. Groups restricted at 14 days did not show any significant ($P > .05$) differences in body weight at the end of the restriction period, although during the recovery period groups on 30% restriction appear to have a higher compensatory growth as shown in **Figure 7**. There does not appear to be any difference in the rate of growth among the different restriction levels since all the groups at all levels of restriction attained almost the same BW at the end of recovery period.

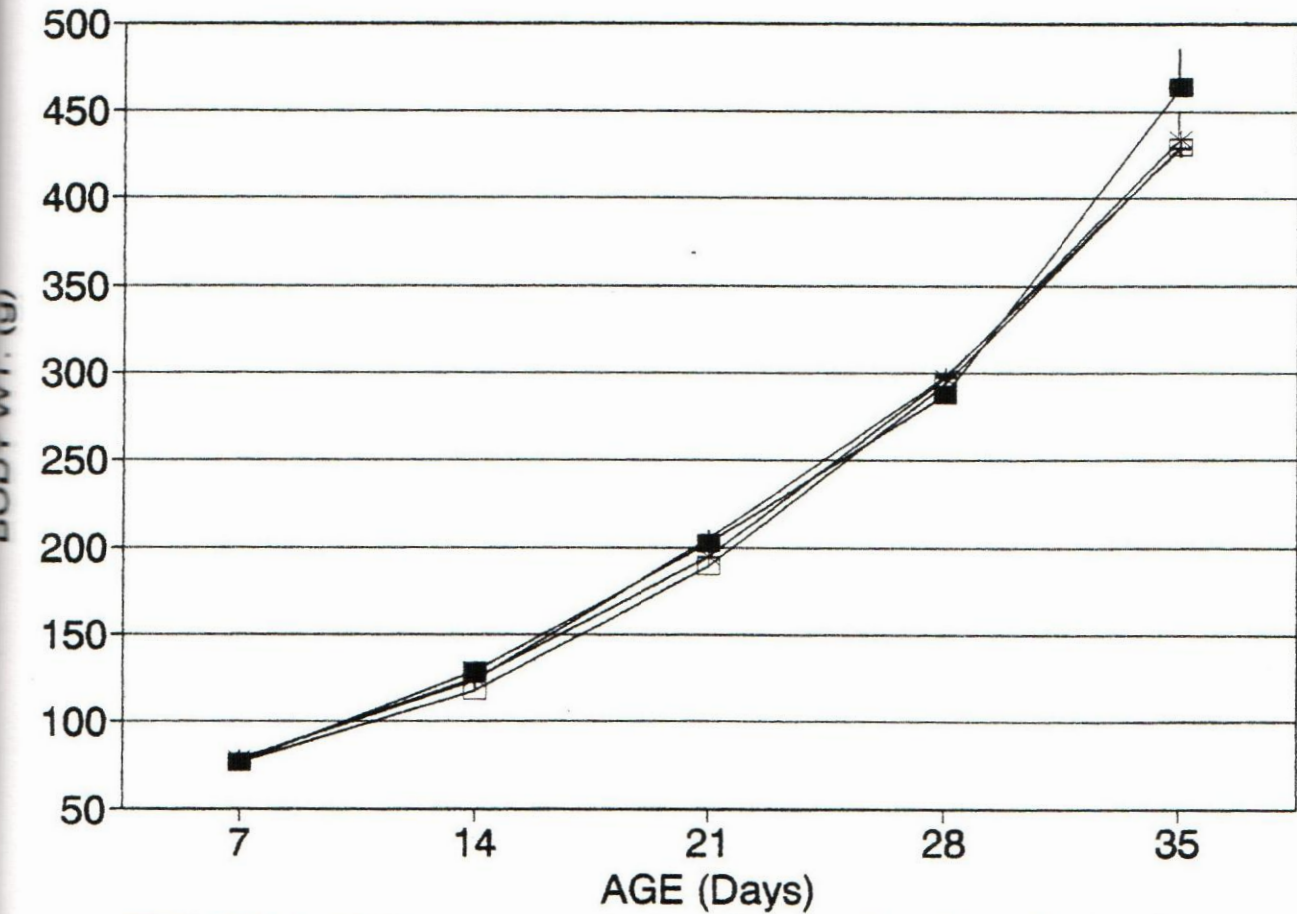
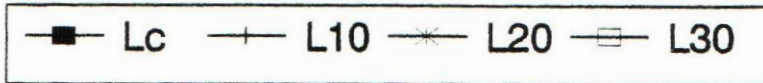


FIGURE 6. BW response during Rs and Rc (Rs at 7 days)



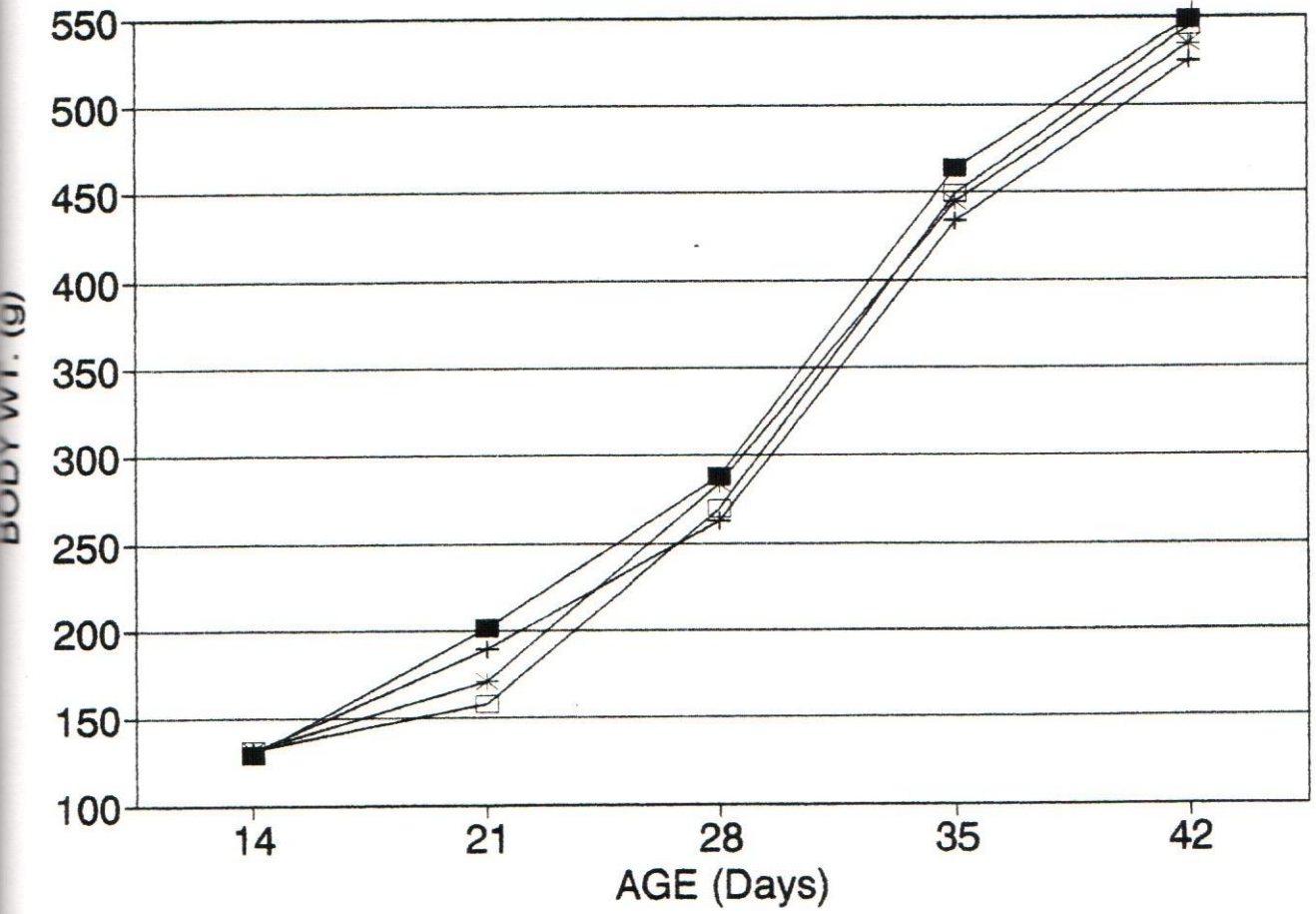
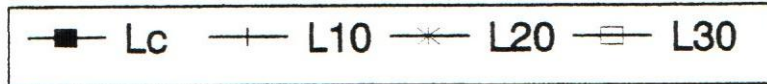


FIGURE 7. BW response during Rs and Rc (Rs at 14 days)



Among the broiler chickens restricted at 14 days, the groups restricted at 30% were initially more affected than the other groups on restriction but during the recovery period they seem to have grown at a faster rate and attained a BW close to that of the controls as shown in **Figure 7**. This is probably because the broiler chickens were at a lower maintenance requirement by the end of the restriction period and therefore most of the food consumed was used for growth. Although there were minimal differences in body weight between the controls and the restricted groups as reflected in **Figures 6 and 7**, control groups still attained a higher BW at the end of the recovery period compared to restricted birds, implying that there was no full compensation among the restricted groups.

Feed restriction at 28 days similarly depressed body weight and even though control birds started at a numerically lower BW, their rate of growth remained higher than for all the restricted groups. Restriction level does not appear to have affected BW during the restriction period but on subsequent full-feeding broiler chickens restricted at 30% seem to have gained weight faster compared to other restricted groups, as is reflected by their higher BW at the end of the recovery period (**Figure 8**). Groups restricted at 20% had the lowest numerical BW at the end of the recovery period meaning that compensation was very minimal in this

group than in those restricted at either 10 or 30%. This is probably because the groups restricted by 30% were at lower maintenance requirements at the end of the restriction period and therefore were able to gain weight faster upon subsequent full feeding.

Feed restriction at 35 days depressed BW at end of the restriction period at all levels of restriction.

Control groups maintained a higher rate of growth compared to feed restricted groups both during the restriction period and recovery as is reflected by their higher body weight. Restricted broiler chickens continued to grow at a slower rate but those restricted at 30% superseded (although not significantly) the ones restricted at 10 or 20% (**Figure 9**). This is probably because compensation was more pronounced in the group restricted at 30% due to lower maintenance requirements compared to those restricted at 10 or 20%. This is in agreement with the observations made by Plavnik and Hurwitz (1985, 1988a, 1989, 1990); Leeson et al. (1991, 1992); Ballay et al. (1992) and Fontana et al. (1992). It is therefore possible that restriction at the levels investigated depresses body weight.

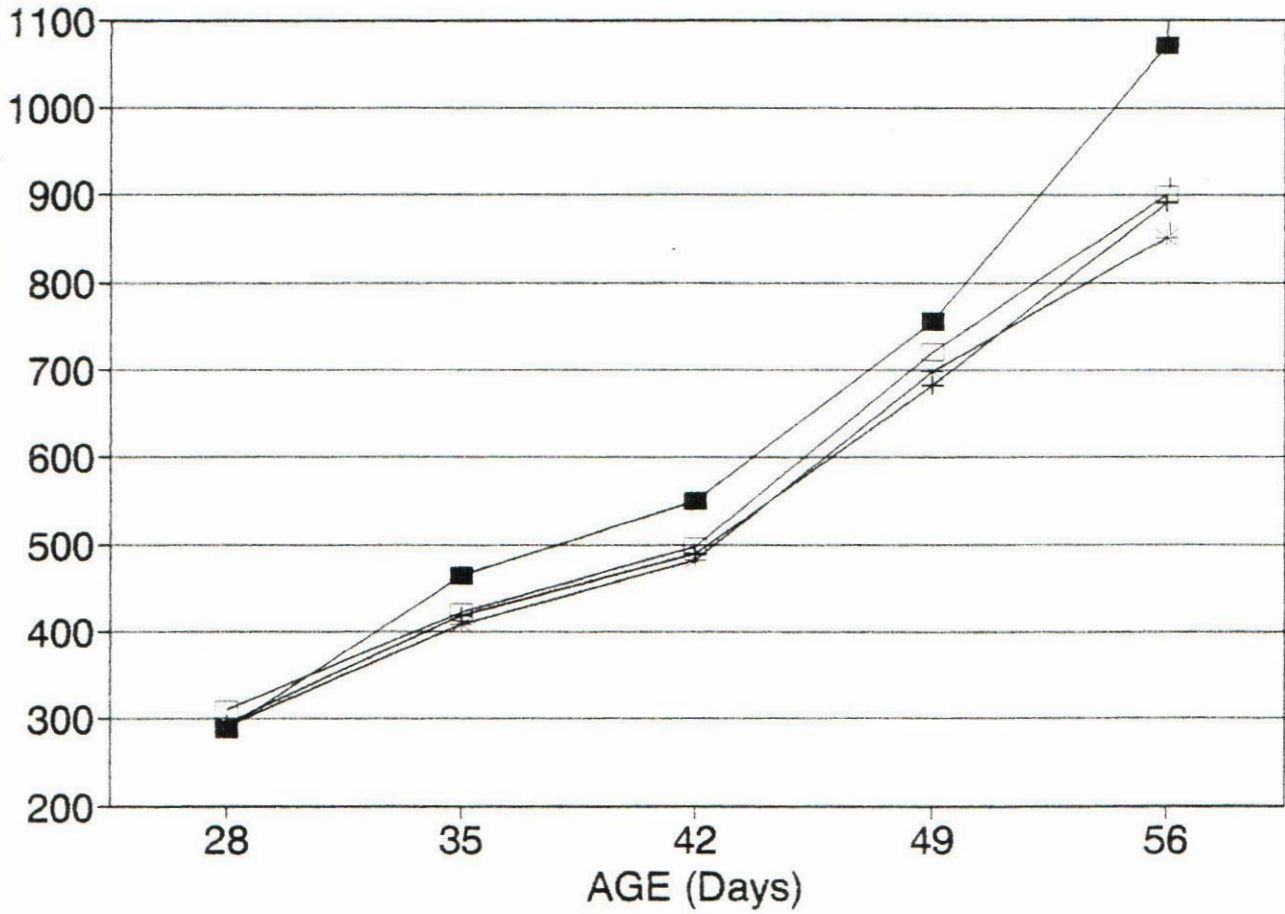
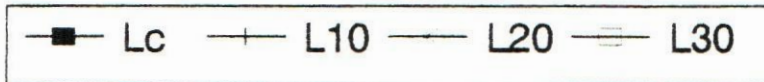


FIGURE 8. BW response during Rs and Rc (Rs at 28 days)



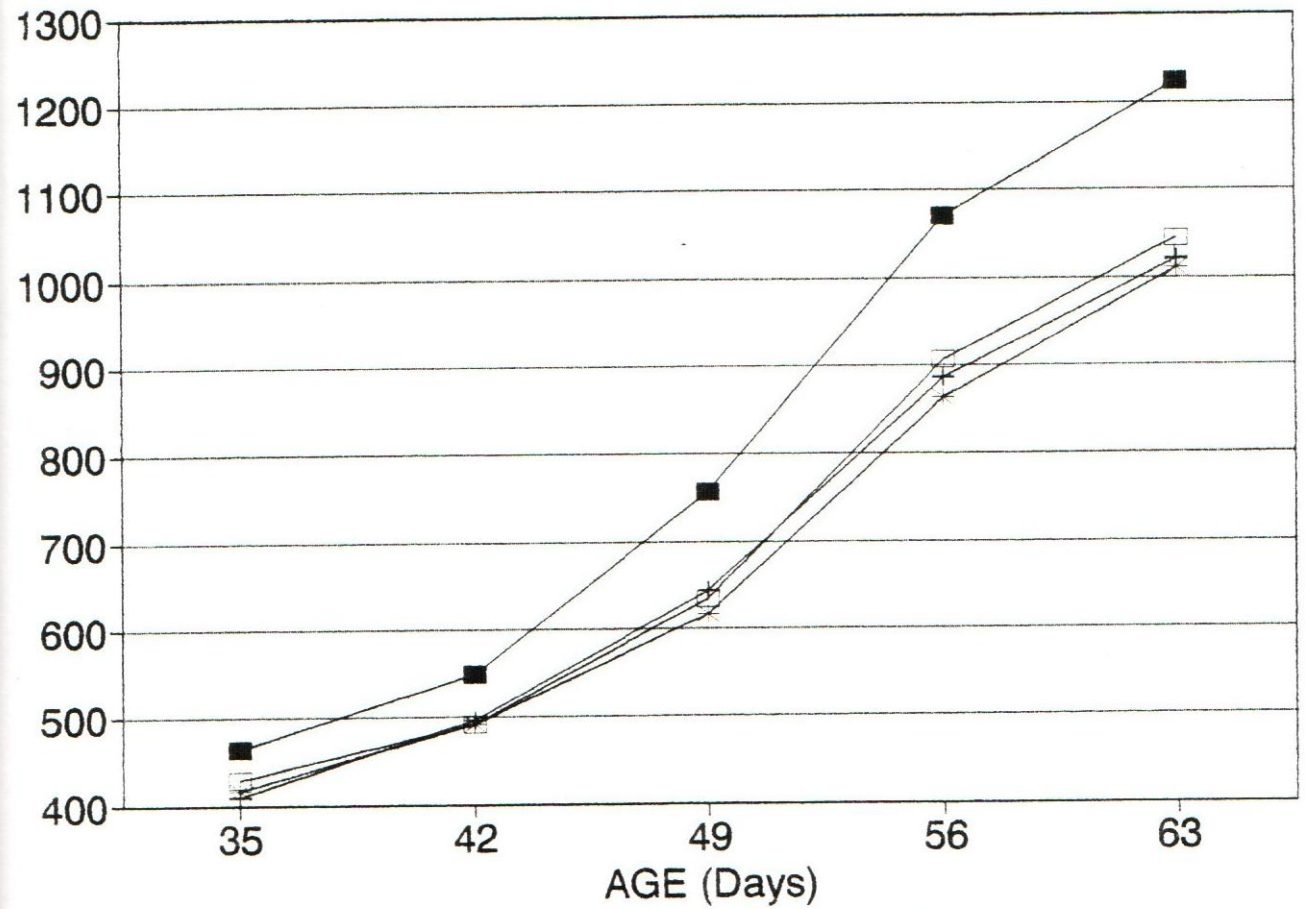
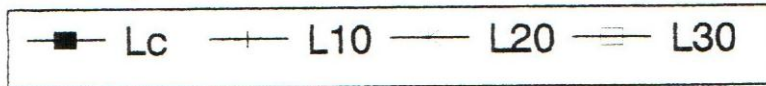


FIGURE 9. BW reponse during Rs and Rc (Rs at 35 days)



4.4.2 Body weight gain

Results of the response of body weight gain to feed restriction during the 2 wk period of restriction and 2 wk recovery period following restriction are shown in **Table 11**. During the actual restriction period BW gain was lower for all the restricted birds but changed during the recovery period. Upon subsequent full-feeding, groups that had been on restriction showed higher gains compared to control groups (**Table 11**). This was particularly evident for groups restricted during the starter period 7 and 14 days. Restriction during the finisher period (28 and 35 days) did not give similar results, rather BW gains were higher in the controls than in restricted groups.

It can therefore be inferred that restriction at an early age of 7 or 14 days gives higher compensatory gains than would be the case if restriction is effected at the older age of 28 or 35 days.

Forsum et al. (1981) postulated that feed restriction reduces maintenance requirements by lowering the basal metabolic rate and reducing heat increment of feeding. Hence upon subsequent full-feeding, birds on previous restriction utilize more of the feed for growth and thus tend to have higher gains and better FE.

Increased BW weight gains have been reported by most other researchers (Plavnik and Hurwitz, 1985, 1988a, 1990);

Pinchasov and Jensen (1989); McMurtry et al. (1989); Summers et al. (1990); Leeson et al. (1991, 1992). Although compensatory growth was observed among groups that had been on feed restriction, it was not complete since unrestricted controls attained higher cumulative body weights (at 56 days) than any other group on restriction.

4.4.3 Feed intake

Results of the response of feed intake to restriction during the 2 wk restriction period and 2 wk following restriction are shown in Table 12.

Restriction significantly ($P < .05$) reduced feed intake during and after the actual restriction period.

Broiler chickens restricted at 7 days all had reduced ($P < .05$) feed intake during the 2 wk restriction and 2 wk recovery period.

No compensation in feed intake was observed in this group but those restricted a 20% had a higher ($P < .05$) feed intake at the end of the recovery period compared to other feed restriction groups. Restriction at 14 days reduced ($P < .05$) feed intake at all levels of restriction at the end of the restriction period compared to control groups. Feed intake for control groups remained higher ($P < .05$) at the end of the recovery period compared to all the restricted groups, with some significant ($P < .05$) differences among feed restricted groups.

TABLE 11. Response of body weight gain to feed restriction during period of restriction and recovery

% level of Rs	Age at restriction (in days) ¹							
	7		14		28		35	
	Rs	Rc	Rs	Rc	Rs	Rc	Rs	Rc
0	72 ^a	109 ^a	86 ^a	85 ^a	85 ^a	314 ^a	207 ^a	264 ^a
10	81 ^b	130 ^b	74 ^b	91 ^b	69 ^b	203 ^b	145 ^b	223 ^b
20	68 ^a	150 ^c	97 ^a	93 ^b	78 ^c	246 ^c	126 ^c	259 ^a
30	61 ^c	136 ^b	92 ^a	98 ^c	75 ^c	180 ^d	143 ^b	213 ^c
SE	6	8	6	7	8	9	9	12

^{a-b}Means in columns with different superscripts are significantly different ($P < .05$)

¹Data (in g) were collected at the end of each restriction period and at end of recovery

TABLE 12. Response of feed intake to feed restriction during period of restriction and recovery

% level of Rs	Age at restriction (in days) ¹							
	7		14		28		35	
	<u>Rs</u>	<u>Rc</u>	<u>Rs</u>	<u>Rc</u>	<u>Rs</u>	<u>Rc</u>	<u>Rs</u>	<u>Rc</u>
0	315 ^a	744 ^a	426 ^a	810 ^a	811 ^a	1158 ^a	899 ^a	1540 ^a
10	255 ^b	550 ^b	282 ^b	710 ^b	476 ^b	795 ^b	726 ^b	968 ^b
20	253 ^b	626 ^c	275 ^b	659 ^c	413 ^c	610 ^c	489 ^c	770 ^c
30	247 ^b	590 ^b	274 ^b	783 ^d	424 ^c	1075 ^d	496 ^c	852 ^d
SE	25	56	60	75	78	110	95	115

^{a-b}Means in columns with different superscripts are significantly different ($P < .05$)

¹Data (in g) were collected at the end of each restriction period and at end of recovery

Broiler chickens restricted at 28 days similarly had reduced ($P < .05$) feed intake (FI) at the end of the restriction period compared to full-fed control group. Groups restricted at 10% had a higher ($P < .05$) FI at end of restriction period than those restricted at 20 or 30%. At the end of the recovery period, all feed restricted groups at all levels (10, 20, and 30%) had significantly ($P < .05$) lower feed intake than control groups but those restricted at 30% appear to have compensated for FI as is reflected in the higher ($P < .05$) FI compared to those restricted at 20 or 10%.

Similarly restriction at 35 days reduced ($P < .05$) FI in all restricted groups compared to control groups. Groups restricted at 10% had a higher ($P < .05$) FI than those restricted at 20 or 30%. At the end of the recovery period control groups maintained higher ($P < .05$) FI than all the groups on feed restriction followed by those restricted at 10%. This is possibly because broiler chickens in the two groups had more feed at their disposal which enhanced voluntary feed consumption.

Using diet dilution as a means of feed restriction, Leeson et al. (1992) reported that birds on diet dilution had higher feed intakes than those on conventional diets and that this was probably due to an attempt to satisfy the

requirements for deficient nutrients such as vitamins and trace minerals.

In the current study some compensatory feed consumption was observed among groups restricted by 30%.

4.4.4 Feed efficiency

Results of response of feed efficiency to feed restriction during 2 wk restriction period and 2 wk recovery following restriction are shown in Table 13.

There were no statistical ($P > .05$) differences between the restricted groups and the controls but FE for groups on restriction was numerically higher than for those on full-feeding (Table 13). Efficiency was higher during the actual restriction period and remained numerically high for the restricted groups compared to controls.

Forsum et al. (1981) suggested that birds on previous feed restriction are at a low maintenance requirement and therefore whatever amount of feed consumed at this stage is utilized for growth hence the improved feed efficiency among the restricted groups.

TABLE 13. Response of feed efficiency to feed restriction during period of restriction and recovery

% level of Rs	Age at restriction (in days) ¹							
	7		14		28		35	
	<u>Rs</u>	<u>Rc</u>	<u>Rs</u>	<u>Rc</u>	<u>Rs</u>	<u>Rc</u>	<u>Rs</u>	<u>Rc</u>
0	23 ^b	15 ^b	20 ^b	10 ^a	10 ^b	27 ^b	23 ^a	17 ^c
10	32 ^a	22 ^b	26 ^b	13 ^a	14 ^b	25 ^b	20 ^a	23 ^b
20	27 ^b	24 ^a	35 ^a	14 ^a	19 ^a	40 ^a	26 ^a	34 ^a
30	24 ^b	23 ^a	34 ^a	13 ^a	18 ^a	16 ^c	29 ^a	25 ^b
SE	5	4	7	6	6	5	6	5

^{a-b}Means in columns with different superscripts are significantly different ($P < .05$)

¹Data [(gain/intake) x 100] were recorded at the end of each restriction period and at end of recovery.

4.5.0 Feeding costs

The raw data shown in Appendix VI gives a summary of feed costs at different regimens. Overall, feed cost was highest for control groups and lowest for groups restricted at 7 days and 10%, followed by those restricted at 28 days and 20%. Restriction during the rearing period (0 to 28 days) proportionately reduced the starter consumption of the starter ration by approximately 18% in feed-restricted groups compared to control groups.

Restriction during the finisher period (29 to 56 days) reduced consumption of the finisher ration by approximately 29%. There appears to have been a slight compensatory feed intake for groups restricted at 7 days and at 20%, as well as those restricted at 28 days and at 30%.

However, to produce 1 kilogram live weight using the current restriction method was shown to save on total feed costs by 6% during the rearing period compared to the controls. A similar restriction method during the finisher period reduced total feed costs by about 13% compared to control groups. Feed restriction during the finisher period reduced feed consumption by a higher margin probably because at this latter stage of growth intakes are generally high while feed conversion efficiency is low. Restricting the quantity of feed offered to the broiler chickens would therefore save on total feed costs, as is shown in Appendix VI.

Considering feed costs when restriction is imposed during the rearing period (7 days and 14 days), restriction at 14 days was found to be cheaper by 13% compared to cost when feed was restricted at 7 days. Further, restriction during the finisher period (28 days and 35 days) indicated that it is approximately 10% cheaper to restrict at 35 days than at 28 days. In both cases feed cost for control groups was the highest.

Under the feeding regimens investigated in this study, restriction level did not have a parallel effect on feed cost per kilogram live weight. This may have been due to interactions between age, level and compensatory growth effects.

Leeson et al (1992) reported that when feed was restricted during the rearing period, it was possible to save on production costs by about 19% of total feed costs. In this study savings of approximately 6% and 13% to put on 1 kilogram live weight when restriction was imposed during the rearing and finishing periods respectively were realized. This should give an incentive to broiler farmers especially since feed costs take the highest proportion of the total production costs in any broiler enterprise.

CONCLUSIONS AND RECOMMENDATIONS

From the preceding results and discussions, it is concluded that feed restriction at the ages and levels investigated depressed body weight and weight gain in broiler chickens. Broilers restricted at 7 days seemed to have been more affected since recovery of body weight was very minimal compared to other restricted groups. Further, it is concluded that restriction at all the ages and levels investigated depressed carcass weight and abdominal fat. Although feed efficiency was statistically the same in all the groups, restricted-fed broilers had a numerically better feed efficiency than the controls.

In addition, compensatory growth was evident although only partial, being highest in groups restricted by 30% and lowest in groups restricted by 10%. Restriction during the rearing period (0 to 28 days) reduced consumption of the starter ration by about 18% and saved on total feed costs by about 6% compared to the controls.

Restriction during the finisher period (29 to 56 days) reduced consumption of the finisher ration by 23% and saved on total feed costs by about 13%.

Feed restriction at 14 days and at 30% may be an alternative feeding method during the starter period, while restriction at 35 days and at 30% may be an alternative feeding method during the finisher period. However, further research is necessary to try and elucidate the effects of feed restriction at ages and levels other than those investigated here.

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Appendix I

A layout of the experimental house.

Poultry Office										Water Source			

Appendix II

Nutritive value of feed ingredients

used to calculate the energy levels of the experimental diets (McDonald et al., 1987).

	<u>Fresh basis</u>					<u>DM basis</u>		
	<u>DM</u>	<u>CP</u>	<u>EE</u>	<u>Ash</u>	<u>DCP</u>	<u>ME</u>	<u>DCP</u>	<u>ME</u>
<u>Cereals & by-products</u>	<u>g/kg</u>	<u>g/kg</u>	<u>g/kg</u>	<u>g/kg</u>	<u>g/kg</u>	<u>MJ/kg</u>	<u>g/kg</u>	<u>MJ/kg</u>
Whole maize	887	87	32	12	67	13.2	76	15.0
Maize germ	897	250	19	53	223	9.75	249	10.9
Maize bran	860	95	42	9	90	15.6	105	8.1
Wheat pollard	874	149	39	42	127	9.75	145	11.2
Soy bean meal	873	499	15	47	428	10.7	490	12.3
Sunflower cake	916	321	27	64	248	8.83	270	9.6
Cotton seed cake	901	378	61	67	280	10.9	311	12.6
fish meal	910	655	42	215	590	11.5	648	12.6

Appendix III

Daily nutrient requirements

per broiler (NRC, 1984)

Age of growing broiler (wk)

	2	4	5	6	7	8
Body weight, g	300	620	800	1200	1800	2400
Total feed intake, g	60	90	100	150	180	220
Crude Protein, g	12	18	20	22	24	24
Calcium, g	.35	.6	.75	.9	1	1
Phosphorous, g	.25	.5	.55	.6	.8	.8
Sodium, g	.05	.08	.1	.15	.2	.2
Potassium, g	.07	.1	.1	.18	.2	.2
Magnesium, mg	17	28	36	42	50	50
Manganese, mg	2	3	4	5	6	6
Iodine, mg	0.01	0.02	0.025	0.03	0.04	0.04
Vitamin A IU	52	86	110	126	150	150
Vitamin D ICU	7	11	15	17	20	20
Thiamine, mg	.06	.1	.13	.15	.2	.2
Riboflavin, mg	.12	0.2	.26	.3	.4	.4
Pantothenic, mg	.35	.3	.7	.8	1	1
Niacin, mg	.95	1.5	2.0	2.3	3.0	3.0
Pyridoxine, mg	.1	.17	.22	.25	.3	.3
Biotin, mg	.003	.005	.007	.008	.009	.009
Choline, mg	45	74	95	109	130	130
Folacin, mg	.02	.03	.04	.05	.06	.06
Vitamin B ₁₂ , mg	.0003	.0005	.0007	.0008	.0009	.0009

Appendix IV**Composition of the Booster Premix**

used to supplement the vitamin A and trace mineral deficiencies in the feed.

A - D - Vit - 25^R

Each kg contained

Vitamin A	7,000,000 IU
Vitamin D ₃	1,000,000 IU
Vitamin E	2,500 IU
Vitamin K ₃	2,000 mg
Riboflavin	4,000 mg
Nicotinic acid	100,000 mg
Pantothenic acid	5,000 mg
Pyridoxine	1,000 mg
Folic acid	300 mg
Vitamin B ₁₂	5 mg
Choline	50,000 mg
Antioxidant	20,000 mg
Iron (Fe)	25,000 mg
Manganese (Mn)	40,000 mg
Zinc (Zn)	30,000 mg
Copper (Cu)	2,000 mg
Cobalt (Co)	200 mg
Iodine (I)	1,100 mg
Selenium (Se)	75 mg

Appendix V

a. Performance Record Sheet used for data collection.

Pen Number

Experimental Unit

[illegible]

b. Carcass Data

Pen Number

Experimental Unit

Variable	At end of study
Live weight g	
Head, feathers & blood g	
Shanks g	
GIT g	
Liver and spleen g	
Heart g	
Abdominal fat pad g	
Carcass weight g	
Breast g	
Killing out%	
Abdominal fat as a % of carcass weight	
Breast as a % of Carcass weight	

Appedix VI

Effect of restriction regimen on feed costs¹

Factor A	Factor B	Starter ²	Cost	Finisher ³	Cost	Total	Cost/Kg
Age (Days)	Level (%)					Cost	LWT. ⁴
7	10	910	14.30	2361	32.10	46.40	55.80
	20	905	14.20	3223	43.80	58.00	66.40
	30	907	14.20	2720	37.00	51.20	61.80
14	10	762	12.00	3476	47.55	59.55	66.80
	20	814	12.80	3101	42.20	55.00	63.50
	30	775	12.20	3316	45.10	57.30	60.60
28	10	1045	16.40	2713	36.90	53.30	59.80
	20	983	15.40	2296	31.20	46.60	54.70
	30	1134	17.00	3082	41.90	58.90	65.40
35	10	1076	16.90	2394	32.55	49.45	55.80
	20	1032	16.20	2294	31.20	47.40	54.90
	30	1082	17.00	2581	35.10	52.10	57.40
Controls	0	1033	16.20	4046	55.00	71.20	66.50

¹Feed cost in Kshs used to raise one broiler from 0 to 56 day

²Starter ration in g, fed at 0 to 28 days

³Finisher ration in g, fed at 29 to 56 days

⁴Total feed cost required to produce 1kg live weight at the different feeding regimens.

Appendix VII

General Linear Models Procedure
Class Level Information

Class	Levels	Values
REP	3	1 2 3
AGE	5	1 2 3 4 5
RESTR	4	0 1 2 3

Number of observations in data set = 235

General Linear Models Procedure

Dependent Variable: BW

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	14	133946.3638	9567.5974	0.09	1.0000
Error	220	23559034.7301	107086.5215		
Corrected Total	234	23692981.0939			
R-Square		C.V.	Root MSE	BW Mean	
0.005653		69.50814	327.2408	470.794894	

SAS

15:44 Monday, April

17, 1995

General Linear Models Procedure

Dependent Variable: BW

Source	DF	Type I SS	Mean Square	F Value	Pr > F
RESTR	3	85909.55938	28636.51979	0.27	0.8488
AGE	3	18671.76063	6223.92021	0.06	0.9816
AGE*RESTR	6	10199.22289	1699.87048	0.02	1.0000
REP	2	19165.82090	9582.91045	0.09	0.9144

Source	DF	Type III SS	Mean Square	F Value	Pr > F
RESTR	2	4908.19212	2454.09606	0.02	0.9773
AGE	3	19481.45391	6493.81797	0.06	0.9804
AGE*RESTR	6	8527.48747	1421.24791	0.01	1.0000
REP	2	19165.82090	9582.91045	0.09	0.9144

General Linear Models Procedure

Dependent Variable: AG

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	14	45813.92922	3272.42352	0.59	0.8699
Error	220	1215752.77741	5526.14899		
Corrected Total	234	1261566.70664			
R-Square		C.V.	Root MSE	AG Mean	
0.036315		62.02493	74.33807	119.851915	

Dependent Variable: AG

Source	DF	Type I SS	Mean Square	F Value	Pr > F
RESTR	3	21528.79393	7176.26464	1.30	0.2758
AGE	3	9660.18660	3220.06220	0.58	0.6269
AGE*RESTR	6	4998.22128	.833.03688	0.15	0.9888
REP	2	9626.72742	4813.36371	0.87	0.4200

Source	DF	Type III SS	Mean Square	F Value	Pr > F
RESTR	2	2005.639425	1002.819712	0.18	0.8342
AGE	3	9672.490756	3224.163585	0.58	0.6265
AGE*RESTR	6	3661.308268	610.218045	0.11	0.9952
REP	2	9626.727417	4813.363708	0.87	0.4200

General Linear Models Procedure

Dependent Variable: FI

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	14	1734423.520	123887.394	1.14	0.3249
Error	220	23923575.179	108743.524		
Corrected Total	234	25657998.699			
R-Square		C.V.	Root MSE	FI Mean	
0.067598		68.59891	329.7628	480.711489	

Source	DF	Type I SS	Mean Square	F Value	Pr > F
RESTR	3	1080060.949	360020.316	3.31	0.0209
AGE	3	76702.639	25567.546	0.24	0.8718
AGE*RESTR	6	192453.237	32075.540	0.29	0.9389
REP	2	385206.695	192603.348	1.77	0.1726

Source	DF	Type III SS	Mean Square	F Value	Pr > F
RESTR	2	23115.9777	11557.9888	0.11	0.8992
AGE	3	70148.4872	23382.8291	0.22	0.8859
AGE*RESTR	6	177261.0355	29543.5059	0.27	0.9497
REP	2	385206.6953	192603.3476	1.77	0.1726

Dependent Variable: FE

Source	DF	Squares	Sum of Square	F Value	Mean	Pr > F
Model	14	2256.345627	161.167545	0.60		0.8661
Error	220	59398.965181	269.995296			
Corrected Total	234		61655.310809			
R-Square		C.V.	Root MSE		FE Mean	
0.036596		54.43513	16.43153		30.1855319	

Source	DF	Type I SS	Mean Square	F Value	Pr > F
RESTR	3	262.894408	87.631469	0.32	0.8076
AGE	3	32.798309	10.932770	0.04	0.9891
AGE*RESTR	6	692.061427	115.343571	0.43	0.8604
REP	2	1268.591484	634.295742	2.35	0.0978

Source	DF	Type III SS	Mean Square	F Value	Pr > F
RESTR	2	377.108094	188.554047	0.70	0.4985
AGE	3	50.659971	16.886657	0.06	0.9795
AGE*RESTR	6	654.025883	109.004314	0.40	0.8761
REP	2	1268.591484	634.295742	2.35	0.0978

Correlations Among the Original Variables
Correlations Among the 'VAR' Variables

	BW	AG	FI	FE
BW	1.0000	0.8579	0.6286	0.0341
AG	0.8579	1.0000	0.6617	0.1607
FI	0.6286	0.6617	1.0000	-0.4742
FE	0.0341	0.1607	-0.4742	1.0000

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