# THE EFFECT OF AGE AND SEVERITY OF FEED RESTRICTION ON ABDOMINAL FAT PAD, COMPENSATORY GAIN AND DRY MATTER DIGESTIBILITY OF MALE BROILER-TYPE CHICKENS

By

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Submitted to the Faculty of Graduate Studies
The University of Manitoba
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**ABSTRACT**

In recent years great interest has been displayed in increasing the productive performance of broilers after a period of feed restriction, and studying the effect this has on percent abdominal fat (PAF). With this in mind, a series of four experiments were conducted to evaluate what effect feed restriction of varying degrees of severity and duration had on compensatory weight gain, PAF, selected blood serum parameters and percent dry matter digestibility of fast growing modern day broilers.

The results of experiment 1, where birds where male broilers were restricted to a maintenance feed intake for 3, 6 or 9 days from day 8 of age, clearly indicate that the length of feed restriction is an important factor in determining whether final weights are similar to controls. Only those birds restricted for 3 days achieved the same final body weight as control birds ($P<.05$).

In experiments 2, 3, and 4, male broilers were restricted for 5 days to maintenance feed intakes starting on days 7, 12 or 17 of age.

It is unclear at the present why some changes in blood parameters occured. Specifically, serum protein, albumin and uric acid were signficantly ($P<.05$) reduced in experiment 1 and aspartate amino transferase and cholesterol were found to be significantly ($P<.05$) increased in experiment 2.

In experiment 3, the investigation of the age at which feed restriction was imposed revealed that broilers restricted from day 17, were less able to compensate sufficiently to achieve the same final body weight as control birds. This was directly related to the fact that

insufficient time for re-alimentation was allowed.

Compensatory gain was calculated as average period gains as a percent of average period weights. Using this formula it was possible to demonstrate that significant (P<.05) compensatory gains occurred in all the post-restriction periods. Compensatory gains were more pronounced immediately following the end of feed restriction. Subsequent to the initial period post-restriction, percent weight gains remained significantly greater than controls although the differences were not as great.

As a result of difficulties in determining what exactly the definition of compensatory gain should be, several different methods and their relevancy are discussed.

The carcass data of experiments 1 and 3, revealed no significant (P>.05) differences in PAF between any of the treatments. In experiment 3, no significant (P>.05) differences in gastro-intestinal tract weight were found. Percent liver weight was significantly (P<.05) increased in birds restricted from day 17.

Experiment 4 was a preliminary type experiment that measure percent dry matter digestibility (PDMD) as a possible indicator of the physiological changes that occur in response to feed restriction. The results showed that there was a significant (P<.05) change in the pattern of PDMD developement in feed restricted broilers. Restricting older birds evoked a large significant (P<.05) reduction in PDMD.

The results of these experiments suggested that the effects of age at which feed restriction was imposed and the severity with which it is imposed, need to be investigated further to determine what combination results in the most desired effect for final weight, abdominal fat pad, carcass components and blood serum parameters.

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# ABBREVIATIONS

°C - degree Celcius

cm - centimeter

C/P - calorie:protein ratio

g - gram

GIT - gastro-intestinal tract

I.U. - international units

kcal - kilocalories

kg - kilogramm

lb - pounds

m - meter

Mg - miligram

ME - metabolizable energy

MEC - maintenance energy coefficient

ml - milliliter

# - number

PAF - percent abdominal fat

PCO - percent chromic oxide

PDMD - percent dry matter digestibility

RPM - revolutions per minute

sq. m. - square meters

T (1,2,3 or 4) - treatment

VLDL - very low density lipoproteins

wt - weight

# I. INTRODUCTION

With the controversy surrounding the consumption of animal fats by humans and the resulting reluctance of consumers to purchase high fat meats, it has become desirable from a marketing standpoint, to reduce the amount of "waste" fat that is found in meats. Various nutritional manipulations have been attempted with varying degrees of success to reduce the amount of abdominal fat in broilers. These include: altering the calorie:protein ratio, level of added dietary fat, temperature, water consumption and varying degrees of protein and energy restriction over a variety of ages.

Abdominal fat in birds is the most visible depot fat and represents approximately 25% of the total carcass fat. Many studies have been conducted to estimate the total carcass fat by measuring live and dressed bird characteristics. If a method of determining carcass fat could be developed using live birds, then the effects of various nutritional regimes would become easier to determine. Live bird measurements that have been attempted with varying degrees of success at determining total carcass fat include caliper techniques that measure the thickness of the abdominal fat pad externally and the excision of a small piece of backskin for fat analysis. Analysis of carcass parameters have primarily looked at sibling carcass analyses and the weight of several fat depots as estimates of the total carcass fat. While correlations between these factors and carcass fat are quite variable it appears that the best predictor of total carcass fat is the abdominal fat pad weight.

A second aspect that has received much attention in recent years, is the phenomenon of compensatory weight gain. The ability of broilers to compensate for gains sacrificed during a period of undernutrition has been found to be dependent on the length of time allowed for recovery and the magnitude of the gains sacrificed.

To study the effect of a severe feed restriction regime on the amount of abdominal fat pad that was deposited, and to determine what degree of compensatory gain could be achieved, three experiments were conducted. In an effort to come to a clearer understanding of the physiological changes that may accompany broilers whose energy consumption had been restricted to maintenance levels for a period of time, a fourth experiment was conducted to determine whether any differences in percent dry matter digestibility were evident during and following feed restriction.

# II. LITERATURE REVIEW

## A. PREDICTION OF ABDOMINAL FAT AND CARCASS FAT

Several indirect methods have been devised to predict the total carcass fat or abdominal fat of broilers. These include the specific gravity of the carcass and its parts (Fortin and Chambers, 1981), sartorial fat (Burgener et al., 1981), wing web and humeral feather tract measurements (Mirosh et al., 1980, 1981), fat weight and thickness (Sonaiya, 1985) and backskin and abdominal fat weights (Becker et al., 1979). These methods are being developed to assist poultry breeders in selecting birds with low overall carcass and abdominal fat.

### a. SPECIFIC GRAVITY

Specific gravity, as a predictor of carcassfat, is based on the premise that fat and muscle tissue have different densities and thus, the relative proportions of each will determine what the overall density of the carcass or its component parts are (Pearson et al., 1968). The major problem encountered when measuring specific gravity in broilers is due to the air that is trapped in various air sacs and in the body cavity (Feduccia, 1975).

Fortin and Chambers (1981) investigated the relationship between carcass fat content and specific gravity of broiler chicken parts and found a significant ($P<.05$) linear relationship for all parts except for abdominal fat which contained a significant quadratic term ($P<.05$). Except for the specific gravity of the back, strain or rearing method did not affect the relationship between carcass fat and the specific gravity of the individual carcass components (P<.05).

Even though the residual error was small (0.56-1.15), the regression coefficient between specific gravity of component parts and abdominal fat remained quite small (.07-.35). Consequently, the use of specific gravity as a method for estimating carcass fat should be restricted to comparisons between strains rather than as a predictor of carcass fat within a strain.

b. **WING WEB THICKNESS**

Mirosh et al. (1980) initially found wing web thickness to be a moderate predictor of abdominal fat weight (r=0.61, P<.01). In a subsequent experiment, Mirosh et al. (1981) found the correlation between abdominal fat weight and left wing web thickness to be poor (0.05 and 0.14 for females and males respectively). The correlation coefficient for females was not significantly different from zero (P>.05), while that for males was (P<.05). When these values were corrected for differences in abdominal fat as a percent of body weight, correlation coefficients for both males and females (r=0.09 and 0.01 respectively) were found not to be different from zero (P>.05). The differences in these results are most likely due to the differences in sample size in the two experiments. In the first, Mirosh et al. (1980) used only 25 broilers, while in the second, Mirosh et al. (1981) used 661 broilers.

Because of these low correlation coefficients between wing web thickness and abdominal fat, this measurement should not be used as criteria when estimating abdominal fat.

c. **ABDOMINAL FAT PAD THICKNESS**

Abdominal fat pad thickness and its relation to total body fat was determined by Sonaiya (1985) and Sonaiya and Benyi (1983). It was suggested that since total abdominal fat weights are not always obtainable, that the thickness of the pad might be a reliable predictor of the total body fat. Strain by age interaction for fat pad thickness was not significant (P>.05) suggesting that thickness was an unbiased estimator of total body fat. When total body fat was regressed on age, carcass weight and fat thickness (r = 0.86, 0.91, 0.91) it was found that fat thickness was superior to age (P<.05) and not significantly different from carcass weight in estimating total carcass fat.

In a second experiment, Sonaiya (1985) determined that abdominal fat pad thickness was not as good a predictor of carcass fat as either carcass weight or abdominal fat weight (r = .68, .90, .86, P<.01 respectively for males).

d. **SARTORIAL FAT MEASUREMENTS**

Burgener et al. (1981) investigated the relationship between sartorial fat, abdominal fat deposition and total carcas fat in broiler chickens. Since the sartorial fat depot is outside the body cavity, it can be readily biopsied and may thus be a non-destructive selection tool. The correlation between sartorial fat and abdominal fat was highly significant (r=0.71, P<.05) and almost twice that found between sartorial fat and carcass fat (r=0.36, P<.05). The correlation (r) to carcass fat was increased to 0.71 in a second experiment primarily as a result of increasing the number of observations. In a third experiment, the relationship between sartorial fat and carcass fat was not significant (P>.05) at 56 days of age, however, its relation to abdominal fat was (r=0.79, P<.01). This relationship was already evident at 28 and 42 days of age.

Burgener et al. (1981) also found that the relationship between sartorial fat and abdominal fat was markedly affected by strain and should therefore not be used for between population comparisons.

e. **PLASMA VLDL AS A PREDICTOR OF CARCASS AND ABDOMINAL FAT**

Since the fat that is deposited in chickens is almost exclusively synthesized by the liver (Griffin et al., 1982), circulating plasma triglycerides and very low density lipoproteins (VLDL) may be a posssible analytical tool for estimating total body fat. Initial results by Bartov et al. (1974) and Mirosh et al. (1980) showed no significant correlation between these two traits (r = -0.04, -0.05 for male and female broilers respectively) However, the correlation likely was affected by low sample number and by the fact that plasma samples were taken from fasted birds. Since diet and feed intake affect circulating plasma triglycerides and VLDL concentrations, correlations should have been determined in full fed birds.

Therefore, when Griffin et al. (1982) used full fed birds, it was found that plasma VLDL plus low density lipoptotein triglyceride concentration were correlated to the total carcass fat. Phenotypic correlation (r) between total plasma triglycerides and carcass fat ranged from 0.37 to 0.50 for males and approximately 0.33 for females.

This correlation to total body fat was significantly affected by the fat content of the diet at 3 weeks of age ($P<.05$ for males and $P<.01$ for females; Whitehead and Griffin, 1982) but was only evident in a few individuals at 7 weeks of age. The phenotypic correlation between plasma VLDL and carcass fat ranged from 0.11 at three weeks for males ($P>.05$) to 0.70 at seven weeks for males on a low fat diet ($P<.001$).

Whitehead et al. (1984) found that plasma VLDL correlated significantly ($r=0.59$, $P<.05$) with abdominal fat and total body fat when the data from lines and sexes were combined. These results support the hypothesis that birds with the greatest amount of abdominal fat have the highest rate of hepatic lipogenesis as evidenced by high circulating plasma VLDL. In their investigation of four broiler lines, Whitehead et al. (1984) found no significant difference in the slopes of the regression lines correlating abdominal fat with VLDL ($P>.05$), but that the elevation of the various lines were significantly different ($P<.05$). Therefore, absolute comparisons between strains are not possible. However, the use of plasma VLDL as a simple non-destructive procedure in estimating abdominal fat of broiler chicks in nutritional studies seems to be possible because of the relatively high correlations that are found within strains.

### f. THE USE OF CALIPERS TO ESTIMATE ABDOMINAL FAT

Pym and Thompson (1980) developed a technique that estimated the abdominal fat pad weight with a caliper. The instrument measured the thickness between the inside of the cloaca and the outer skin. This was to reflect the amount of abdominal fat that would be found in this region. Correlations of 0.80 were determined by Pym and Thompson

(1980).

Whitehead and Griffin (1982) found phenotypic correlations between abdominal caliper measurements and abdominal fat of 0.15 for males on a high fat diet (P>.05) and 0.55 for females on a high fat diet (P<.001).

Mollison (1983) using calipers to estimate abdominal fat pad found that the calipers were stiff and difficult to use. Correlation between the caliper reading and abdominal fat was significant (P<.01) but relatively low (0.39) when compared to the results of Pym and Thompson (1980). Hand fatique and an uncertainty of how much pressure should be applied to the calipers lead Mollison (1983) to conclude that calipers would need to be greatly refined before their use as a practical research tool would be assured.

## B. NUTRITIONAL FACTORS AFFECTING ABDOMINAL FAT

### a. THE EFFECT OF WATER CONSUMPTION ON ABDOMINAL FAT PAD

Some recent work (Marks and Washburn, 1983 and Marks and Pesti, 1984) reveals that increased water:feed ratios resulting from increased salt in either the feed or water, may be significantly correlated to abdominal fat pad deposition.

Marks and Pesti (1984) found that water consumption progressively decreased as the protein in broiler diets decreased from 26 to 17%. As a result, the water:feed ratio was significantly ($P<.05$) different between all treatments (1.98, 1.81 and 1.52 for diets containing 26, 22 and 17% protein). Since feed intake was not affected by protein level, the differences in water:feed ratios were attributed to the effect that the protein intake per se had on water consumption.

Marks and Washburn (1983) investigated the effect that increasing the salt level in the feed had on water:feed ratios and on abdominal fat pad deposition of broilers. While no difference in feed intake was noticed, increasing the salt from 0.4% to 2.4% significantly ($P<.05$) increased water consumption by 100% (220 to 440 g/bird/day). As a result, water:feed ratios were significantly ($P<.05$) higher for birds receiving 1.6 and 2.4% salt diets. Reducing the salt to 0.4% again, returned the water consumption and water:feed ratios to normal. This indicated that the stimulus for increased water consumption did not remain after the salt stimulus was removed. The conclusion was made therefore that water intake was not a response determined by dietary or environmental conditions, but rather a genetically determined parameter.

This theory is supported by the work of Marks (1980) who showed that the water:feed ratio of selected fast growing broilers was significantly ($P<.05$) greater than a slower growing non-selected line.

A 1.6% salt diet decreased the abdominal fat weight in one line (35.3 g to 28.9 g, $P<.05$) and slightly increased it in a different line (36.6 to 40.9 g, $P>.05$). The 2.4% salt diet reduced the abdominal fat pad weight significantly in both lines ($P<.05$) by a factor of 17 - 28%. The same trend also appeared for total carcass fat.

This relationship between increased water:feed ratio and abdominal fat seems to be related to the inverse relationship found between carcass fat and moisture (Twinnings et al., 1978). Increasing either fat or moisture in the carcass is accomplished at the expense of the other parameter.

b. **EFFECT OF DIETARY ENERGY AND FAT ON ABDOMINAL FAT**

Donaldson et al. (1956) showed that carcass fat was directly related to the energy content of the diet when diets differed only in energy level. Hargis and Creger (1980) showed that increasing dietary energy concentration from 2758 to 3080 kcal ME/kg resulted in significant ($P<.01$) increases in percent abdominal fat (PAF) at 49 days of age. The effect that increasing dietary energy has on (PAF) is also supported by Jones and Wiseman (1985), Deaton and Lott (1985) and Mabray and Waldroup (1981). Conversely, Griffiths et al. (1977b) showed that if 0, 3, 6 or 9% fat was added isocalorically to a broiler grower diet, that no difference in abdominal fat could be detected. Thus, it appears that dietary fat level <u>per se</u> may affect carcass fat as much as total energy consumption.

This is in contrast to the results of Deaton et al. (1981) who demonstrated that when 4, 7 or 10% fat was added isocalorically to the diet, that PAF increased significantly (P<.05). For males the PAF was 1.72 and 2.05% respectively for diets containing 4 and 10% added fat. Deaton et al. (1983) also demonstrated that increasing the energy concentration of the diet significantly influenced abdominal fat. Broilers fed a high energy (3325 kcal/kg) grower diet from 21-47 days of age, had significantly (P<.05) greater abdominal fat than birds fed a lower energy diet (3100 kcal/kg).

The basic difference underlying these results appears to be related to the total energy consumption by broilers. Energy consumption was not reported and therefore, differences observed in PAF on the various energy and fat levels may be related to the overall energy consumption by these birds. Alternatively, there is evidence to support the claim that more energy is deposited in the carcass of birds receiving part of their dietary energy in the form of fats (Scott et al., 1982) possibly due to the preferrential shunting of excess energy directly to fat depot sites.

Thus, the effect that dietary energy and fat level have on PAF are not entirely resolved. However, most of the evidence appears to support the theory that increasing the energy content of the diet leads to an increased PAF.

c. **CALORIE:PROTEIN RATIO**

The generally accepted view is that if the calorie:protein (C/P) ratio is kept constant, that no differences in carcass fat will be observed even though the absolute levels of each is varied. Conversely, widening the C/P ratio will increase abdominal fat (Bartov et al., 1974; Robbins, 1981; Khahil et al., 1968; Combs, 1962). Yoshida and Morimoto (1970) and Bartov (1979) have shown that rapid and reversible changes in carcass fat occur as a result of changing the C/P ratio in the diet.

Bartov et al. (1974) using two C/P ratios (158 and 176), and two energy levels within each C/P ratio, found that the low C/P diets produced birds with significantly ($P<.01$) less backskin fat (43.9 vs. 52.3 g/kg) when the diets contained added fat. When the diets were not supplemented with fat, the birds on the low C/P diets still had a lower back skin fat content, but this was not significant.

By increasing protein from 16 to 36% in broiler diets while keeping the energy levels constant, Jackson et al. (1982) showed a significant ($P<.01$) 52% decrease in PAF. Over the same range, carcass fat was reduced by only 32%. Increasing the energy level from 2600 to 3600 kcal ME/kg at a constant protein level, resulted in a significant ($P<.05$) increase in abdominal fat from 1.46 to 2.70% of carcass weight.

The concept of C/P ratio and its effect on carcass fat and abdominal fat pad deposition has however, become more complex in light of recent evidence that suggests that it is the actual amount of energy consumed which affects the fat content of broilers rather than its fixed relation to protein (Griffiths et al., 1977a). In many of the reports cited, the actual amount of energy consumed at varying C/P ratios was not detailed (Bartov et al., 1974; Cherry et al., 1984). Consequently, the assertion that no differences in abdominal fat occurred as long as the C/P ratio was kept constant may prove to be misleading if at the same time the total energy consumption was not changed.

Alternatively, some reports have shown that increasing the energy level of the diet while keeping the C/P ratio the same has resulted in an increased energy consumption while not changing the PAF. Emmans (1981) stated that one of the reasons that an increase in abdominal fat is not seen is that the resulting overconsumption of protein must be eliminated via increased uric acid synthesis. This entails considerable energy expenditure which is derived from the increased energy consumption usually associated with high energy diets and as a result, no increase in abdominal fat is observed. This is supported by evidence from Griffiths et al. (1977b) who showed that even low quality protein sources (feathers) are effective in decreasing abdominal fat pad synthesis.

d. **EFFECT OF FEED RESTRICTION ON ABDOMINAL FAT PAD**

Plavnik and Hurwitz (1985) subjected broiler chicks to severe feed restriction for 6 to 28 days beginning at one week of age. As a result of restricting energy intake to 30 - 45 kcal/day for two weeks, PAF in feed-restricted birds was significantly decreased (2.07, 1.89, and 1.55% for control, 45 kcal and 30 kcal/day respectively; $P<.05$). Body weight of restricted birds was significantly less than that of control birds. Consequently, the period during which accelerated fat pad deposition usually occurs, was not observed in the feed restricted bird. This could possibly be due to the retarded physiological developement of the feed-restricted birds.

In a second trial, during which feed was restricted for 6, 10 or 14 days to 40 kcal/day, body weight at 8 weeks of age was not significantly different between control and 6 or 10 day restricted birds and PAF decreased progressively as the length of feed restriction increased. These differences were significant ($P<.05$) between the control birds (2.28%) and 6, 10 or 14 day restricted birds (1.87, 1.68 and 1.54% respectively). No difference in PAF was detected between birds on different feed-restriction regimes.

Pokniak and Cornejo (1982) and Pokniak et al. (1984) restricted feed intake from day 8 to 23 and did not find any significant difference in PAF at 56 days of age. Griffiths et al. (1977a) also could not find any difference in PAF in birds whose caloric intake was restricted from 0 - 3 weeks. Likewise, Plavnik et al. (1986) found a consistent trend for birds restricted for 6 or 12 days to maintenance energy intakes, to have a lower PAF. In the first trial, PAF was reduced from 1.91 for controls to 1.35 and 1.31 for 6 and 12 day restricted birds. These differences however, were not significant. In a second trial similar non-significant trends were apparent.

Significant differences in abdominal fat weight are difficult to obtain. This difficulty arises for several reasons. Firstly, the amount of data collected is usually from a relatively small sample size (For example Plavnik et al. (1986) used 10 birds/treatment). Secondly, the coefficient of variation of PAF is quite high and variable ranging from 25 - 40% (Griffiths et al., 1977a,b; Griffiths et al., 1978).

## C. THE EFFECT OF FEED RESTRICTION ON BROILER CHICKENS

### a. EFFECT OF FEED RESTRICTION ON INTESTINAL INTEGRITY

Restricted feeding of meat type pullets is often accomplished by feeding a 2 day portion of feed every second day (skip-a-day feeding) (Summers and Leeson, 1976). Some concern exists that this absence of feed for up to 47 hours may cause temporary or permanent damage to the mucosal lining of the duodenum or jejunum (Peer et al., 1984).

Peer et al. (1984) investigated the effect a skip-a-day feeding regime from 3-18 weeks of age would have on the intestinal lining of the duodenum and jejunum of dwarf broiler pullets. Examining section samples under a scanning electron microscope showed no differences in the amount of damaged lining that could be attributed to the treatment. Duodenal sections showed a marked increase in tissue damage when compared to jejunum sections, but this damage was due to post mortem desquamation of epithelial cells and denuded villi tips.

These results are in contradiction to the results of Bayer et al. (1981). Twenty one-week old male broilers were fasted for 3, 5 or 7 days. This resulted in marked increase in epithelial damage compared to the control birds. After 3 days, marked depressions in the villi tips as well as extensive sloughing were evident. This extensive sloughing however, was not as apparent in birds that had been fasted for 5 or 7 days. By day 5, crop epithelial damage was extensive, with large sections of the crop lining being sloughed off.

After a 7 day fast, ileum villi displayed abnormal evaginations. Duodenal cells from fasted birds showed some necrosis and detachment from surrounding cells.

Desquamation of intestinal cells appeared to by quite high initially but was gradually reduced with time. This is possibly due to the reduction in mitotic activity observed by Goldsmith (1973) in cats fed a protein deficient diet.

Goldsmith (1973) and Bayer et al. (1981) suggest that the evagination seen may be a type of dormant state whereby the animal conserves its requirements for protein and amino acids until such a time as feed is available to replenish epithelial cells.

The evaginations reported by Bayer et al. (1981) are suported by Michael and Hodges (1973) who found a marked atrophy of the intestinal mucosa of 6 week old birds fed a restricted amount of feed for 8 days. This atrophy was found also, to be accompanied by an increased activity of mucosal enzymes. This may be a basis for the enhanced nutrient utilization of semi-starved rats observed by Riecken et al. (1965).

The level of starvation imposed by Bayer et al. (1981) is unlikely to occur in normal broiler management. The restricted feeding of birds by Michael and Hodges (1973), more closely resembles feeding regimes currently being investigated as a management practice to enhance the economics of broiler production (Plavnik and Hurwitz, 1985; Plavnik et al., 1986). However, since the ages of the birds studied varied so widely (6 weeks vs. 18-20 weeks), no clear answer is available as to the effect of feed restriction on the integrity of the intestinal mucosa or the effect that altered intestinal integrity has on nutrient absorption.

b. **EFFECT OF FEED RESTRICTION ON FEED:GAIN**

Moran (1979) found that the feed:gain of broiler chickens during the grower phase (2-5 weeks of age) became progressively worse as the level of protein restriction increased (1.80, 1.88, 1.93 for male broilers fed 24, 22 or 20% protein respectively; $P<.05$). However, subsequent to being fed an adequate protein diet for 2 weeks, the feed:gain became progressively better as the level of protein fed during the previous restriction period was reduced (2.41, 2.39, and 2.25 for male broilers fed 24, 22 or 20% protein respectively). Only the feed:gain (2.25) of birds fed the 20% protein grower diet was significantly ($P<.05$) better than the control birds (2.41). The improvement during the finisher phase was enough to reverse the detrimental effects observed during the grower phase such that overall feed:gain (0-7 weeks) was not significantly different between any treatment group.

The feed:gain for protein restricted birds in the trials of Marks (1979) was higher than for controls. Following the return to an adequate protein diet, feed:gain ratios were lower than for the controls for a period of 3-4 weeks. These differences however, were not statistically significant. Marks (1979) suggested that the better feed:gain in the compensatory phase was due possibly to the fact that body weights were lower than those of control birds. Therefore, the protein restricted birds would have a lower maintenace requirement resulting in better feed:gains.

## c. EFFECT OF FEED RESTRICTION ON COMPENSATORY GAIN

Compensatory gain is usually defined as birds, subsequent to a period of undernutrition during which time they are fed ad libitum, achieving body weights that are similar to ad libitum fed control birds at market age. This requires that birds for some portion of their post-restrictive growth period must demonstrate a significantly greater gain in order to compensate for the weight lost during the restriction period.

Various forms of nutrient restriction have been employed to examine their effect on compensatory gain. These include restricting protein (Auckland and Morris, 1971a, b), energy (Deaton et al., 1973) or total feed (Washburn and Bondari, 1978a, b; Plavnik and Hurwitz, 1985; Plavnik et al., 1986). Restricting or limiting the intake of these nutrients is desirable in an effort to reduce the cost of production. However, this restriction must be accompanied by subsequent compensatory weight gain.

### i. PROTEIN RESTRICTION

Considerable research has been conducted to determine the effects of early protein restriction on compensatory growth of turkeys (Auckland and Morris, 1971a, b; Auckland et al., 1969; Moran, 1981) and broilers (Washburn and Bondari, 1978a, b,; Marks, 1979; Moran, 1979; Twinnings et al., 1978).

Auckland et al. (1969) fed turkeys 5 protein levels to 6 weeks of age calculated to supply between 60% and 110% of the required amino acids. As a result, 6 week body weights of turkeys fed suboptimal amino acid levles were reduced by 8% to 50% below the levels of control

(100%). During the grower phase (6-14 weeks) 2 grower diets were fed, calculated to supply 140% or 110% of the lysine required for maximum growth. Turkeys fed a restricted amino acid starter diet, consumed more feed than controls during the grower phase such that they exhibited greater absolute gains. The growth rate, relative to body weight, increased progressively with the increasing severity of the starter protein restriction imposed. Restricting protein intake up to 70% of required levels during the starter phase resulted in nearly equal 14 week body weights (P<.05).

During the 6-14 week recovery period, all turkeys previously fed restricted amino acid levels showed a tendency to gain faster than the controls although these differences were not significant (P>.05). This supports the hypothesis of Lister et al. (1966) that no permanent damage results from protein restriction at an early age, even though restrictions of up to 60% of requirements were imposed, since birds continued to grow at an accelerated growth. Since no decrease in the growth rate relative to the controls had occurred, it appears that no reduction in the mature size would be expected.

Auckland and Morris (1971a) extended the experiments of Auckland et al., (1969) to determine the optimum protein levels necessary to maximize growth in the compensatory phase. Protein restriction to 6 weeks of age resulted in body weights 17% below that of the control (P<.05). From 6 to 10 weeks of age, growth of turkeys increased as the grower protein increased from 15% to 21%. Protein levels above 21% did not elicit a significant increase in growth (P>.05). From 10-20 weeks, all birds were ad libitum fed a protein adequate diet. Compensatory growth was greatest in those turkeys that had the lowest body weights at 10 weeks of age.

As a result, birds that were restricted such that 6 week body weights were 17% below control, were able to compensate completely provided they were offered an adequate protein diet from 6-20 weeks of age. If not, compensatory gain was insufficient to overcome the weight deficit that resulted from the earlier protein restriction.

Moran (1981) conducted a protein restriction trial with turkey broiler toms. Four different protein sequences ranging from adequate to deficient were fed up to 8 weeks of age. From 8-14 weeks, all broiler toms received the same feed ad libitum. At 8 weeks of age, birds started on 32% protein diets had significantly ($P<.05$) greater body weights than those started on 28%. However, by 14 weeks of age, no significant differences in body weights were detectable.

In an earlier study, Moran (1979) investigated the compensatory response of broiler chickens fed a protein restricted diet. Birds were fed one of three experimental protein diets from 2-5 weeks of age (24, 22 or 20% for males and 24, 20 or 16% for females). There was a progressive reduction in growth performance as the level of protein decreased in the grower phase. This reduced performance was significant ($P<.05$) only for males fed the 20% protein diet. After a 2 week compensatory phase, there were no significant differences in body weights. Similar results were observed for females. Five week body weights were significantly lower ($P<.05$) only for those birds fed the 16% protein diet. At seven weeks of age no significant difference in body weight were observed. Females were kept for an additional week to monitor weight gains. During the 7-8 week period, no differences in weight gain were detectable between the control and protein restricted birds. Moran (1979) concluded that the compensatory gain phase lasted only for the first 2 week period post-restriction.

Marks (1979) conducted 2 trials by feeding a restricted protein diet (16%) from 0-2 weeks of age. This was followed by the 22% protein control diet to 8 weeks of age. Performance was comnpared to birds receiving a 22% diet throughout (control). The result was that birds receiving a 16% starter diet weighed significantly (P<.05) less at 2 weeks of age. By 8 weeks, the differences (P>.05) had disappeared, although there still was a trend for restricted protein groups to be lighter.

Similar results were obtained by Twinnings et al. (1978) who fed broilers a restricted protein diet to 4 weeks of age. Four week body weight was poorer than control, yet final weight and performance was nearly equal.

ii. **ENERGY RESTRICTION**

Deaton et al. (1973) restricted the caloric intake of broilers from 0-4 weeks of age by using 2 energy levels in the starter feed (3306 and 3141 kcal/kg). This was followed by one of three energy levels in the grower-finisher phase (3372, 3207 or 3042 kcal/kg). At 4 weeks of age, there was a significant reduction (P<.05) in average body weight for both male (4%) and female (4.4%) broilers fed the 3141 kcal/kg starter diet. As well, the feed:gain was significantly (P<.05) poorer in birds fed the low energy starter (1.60 vs. 1.67).

Complete compensation for the lost weight occurred only in birds fed 3372 kcal finisher diet. Males fed the 3207 kcal starter diet weighed significantly less (P<.05) than the control birds at 8 weeks of age. Females appeared to require only a 3207 kcal finisher diet to compensate for initially lower gains. Therefore no difference in 8 week body weight was seen between females fed the 3207 kcal diet and the control birds.

Griffiths et al. (1977a) fed a low energy (2233 kcal/kg) starter ration for 1, 2 or 3 weeks followed by a control starter (3087 kcal/kg) to 4 weeks of age. The finisher diet contained 3200 kcal/kg and was fed to 8 weeks of age. Those birds fed a low energy starter diet to 3 weeks of age were significantly lighter at 3 weeks of age (P<.05). However, the level of energy restriction was not severe enough to affect the 4 week body weights. Consequently, no differences in 8 week body weights were found.

Boone et al. (1980) restricted the caloric intake of broilers from 66 - 77% of control birds for 10 days prior to marketing while maintaining adequate intakes of all other nutrients. Restricting caloric intake to 75% of control birds resulted in a 25% reduction in abdominal fat pad weight as well as in final body weight.

Arafa et al. (1985) restricted the dietary energy intake up to 23% of controls for 12 days prior to marketing. There was a significant (P<.05) reduction in body weight for birds whose energy intake was restricted by 19 or 23%. Restricting energy intake by 15% significantly (P<.05) reduced the fat content and increased the moisture content of individual chicken parts.

## D. CONCLUSION

Much interest has been directed in recent years to studying compensatory growth and abdominal fat pad deposition in broiler chickens. There are still many conflicting reports on whether compensatory growth actually occurs, and if so, whether it is accompanied by reduced fat pad deposition. To gain some insight, and possibly shed some light on the phenomenon of compensatory growth and fat pad deposition of broilers, a series of experiments were designed to investigate the effects of the severity of feed restriction and the age at which feed restriction was imposed.

# III. MATERIALS AND METHODS

## A. GENERAL

Three experiments were conducted to study the effects of severe feed restriction at a young age on compensatory weight gain and percent abdominal fat. In a fourth experiment, the percent dry matter digestibility was measured in birds subjected to severe feed restriction.

### a) BIRDS

All the trials used day old male broiler chicks that had been vaccinated for Marek's. In experiments 1 and 2, Cobb*Cobb chicks were used, while in experiments 3 and 4, Arbor Acre*Ross chicks were used. All chicks were obtained from Carlton Hatcheries, Grunthal, Manitoba.

### b) HOUSING

In experiments 1, 2 and 3, the birds were raised in 1.52m x 4.27m floor pens. Stocking density in experiment 1 was 65 birds/pen (0.10 sq.m./bird) and for experiments 2 and 3, 70 birds/pen (0.093 sq.m./bird). All pens were in an environmentally controlled barn with 24 hours lighting. Light intensity varied between pens due to the spacing of the lights, but mean light intensity at feeder level was found not to differ between treatments (18.44 lux, P>.05).

In experiment 4, birds were raised in electrically heated Petersime battery brooders (Petersime Incubator Company, Gettysburg, Ohio). Three batteries, each with eight individual wire floor pens equipped with one trough feeder and one water trough per pen were employed. Temperature and lighting regimes were similar to those utilized for birds raised in floor pens.

c) **MANAGEMENT**

Standard management procedures were followed in starting birds. In experiments 1, 2 and 3, initial temperature under the electric brooder lights was 35°C. After the first week, the temperature was gradually reduced by raising the brooders and by removing 1 or 2 of the 3 light bulbs in each brooder until a temperature of 21°C was reached at 3 weeks at which time the brooders were removed entirely. In experiment 4, similar temperatures were employed using electrically heated Petersime battery cages.

In experiments 1, 2 and 3 all birds were initially fed from an egg flat until the birds were found to be eating satisfactorily from the floor type trough feeders which were used until 1 week of age. The control birds were fed from 2 hanging tube feeders (40 cm diameter) from day 7 to the end of the trial. Birds on restricted feed treatments were kept on trough feeders until the end of the restriction period. Treatment 2 and 3 were fed using 3 - 36 inch trough feeders, while for treatment 4, 4 - 36 inch trough feeders were used to enable all birds to eat at the same time. After the end of the feed restriction period, restricted birds were also fed from 2 hanging feeders until the end of the trial. For the first 5 days, water was available from a 1 gallon plastic water fount. Thereafter, water was available from an automatic drinking cup, 15 cm in diameter.

All rations were fed in mash form. Except for the period during which feed restriction was implemented, feed was available ad libitum. Water was also available continuously. All starter and finisher feeds used in the four experiments, contained the same mineral and vitamin premixes at levels of 0.35% and 1.0% respectively and were formulated to meet or exceed NRC (1984) requirements. Tables 1 and 2 list the mineral and vitamin packages used. All experimental diets were composed of the same basal ingredients, varying only in the amounts of each required to achieve the desired protein and energy levels.

The formulae used to calculate daily maintenance energy requirements of birds on feed restriction were a modification of the formula used by Plavnik and Hurwitz (1985). They were:

1. Experiment 1 - 1.26 x 1.5 kcal x Body weight $(g)^{2/3}$.
2. Experiment 2 - Treatment 2 - 1.5 kcal x Body weight $^{2/3}$.
   Treatment 3 - 1.3 kcal x Body weight $^{2/3}$.
   Treatment 4 - 1.0 kcal x Body weight $^{2/3}$.
3. Experiment 3 - 1.0 kcal x Body weight $^{2/3}$.

Daily management practices included daily culling of birds, shaking down feeders, cleaning waterers and cleaning up wet spots around feeders and waterers by removing the litter and replacing with dry fresh litter. All mortalities occurring in the first four days of the trials were replaced with spare birds. All mortalities occurring subsequently were recorded by pen, treatment, wingband, date and weight and were necropsied to ascertain the cause of death. Necropsies for experiments 1, 3 and 4, were performed by Dr. N. E. Stanger at the Department of Animal Science, University of Manitoba, while the necropsies for experiment 2 were conducted by Dr. B. Boycott at the Poultry Pathology

**TABLE 1. CHICKEN BROILER STARTER AND FINISHER MINERAL PREMIX[1]**

| INGREDIENT | SUPPLIES/KG DIET |
|---|---|
| | (mg/kg diet) |
| Manganese Oxide (Mn - 60% Mn) | 55 Mn |
| Zinc Oxide (ZnO - 72% Zn) | 50 Zn |
| Ferros Sulfate ($FeSo_4:1H_2O$ - 31% Fe) | 80 Fe |
| Copper Sulfate ($CuSO_4:5H_2O$ - 25.2% Cu) | 5 Cu |
| Sodium Selenite micromix (0.02% Se) | 0.1 Se |
| Iodized Salt (NaCl:KI - 0.007% I)[2] | 0.18 I |

1. Use at 0.35% of the diet

2. Supplies 2.5 g NaCl/kg of diet

TABLE 2. STANDARD CHICKEN BROILER VITAMIN PREMIX[2]

| INGREDIENT | AMOUNT/KG (g) | SUPPLIES/KG DIET |
|---|---|---|
| Vitamin A (500,000 IU/g) | 33.0 | 8250.0 IU |
| Vitamin $D_3$ (90,000,000 IU/1b) | 10.0 | 991.2 IU |
| Vitamin E (40,000 IU/kg) | 545.0 | 10.9 IU |
| Vitamin $B_{12}$ (1,000 mg/kg) | 23.0 | .0115 mg |
| Vitamin K | | |
| (Men.Na-Bisulfite) (50%) | 4.4 | 1.1 mg |
| Vitamin $B_{58}$ (2-4-6)[1] | 2500.0 | |
| Niacin (98%) | 75.0 | 36.8 mg |
| Choline Chloride (60%) | 3000.0 | 781.2 mg |
| Folic Acid (Pure) | 1.5 | .75 mg |
| Biotin (20,000 mg/kg) | 25.0 | .25 mg |
| Delaquin (66.6%) | 375.0 | 125.0 mg |
| Methionine -Dl (99%) | 1000.0 | 500.0 mg |
| Strep-Pen (pen-55g/kg;Strep-165g/kg) | 200.0 | Pen 27.5 mg<br>Strep 82.6 mg |
| Amprol | 1000.0 | |
| Vegetable oil | 200.0 | |
| Wheat Middlings | 11008.1 | |

1. Vitamin $B_{58}$ contains/kg :

| | | |
|---|---|---|
| Riboflavin | 4400 mg | 5.5 mg |
| Ca-Pantothenate | 8800 mg | 11.0 mg |
| Niacin | 13200 mg | 16.5 mg |
| Choline chloride | 220000 mg | 238.7 mg |

2. Use at 1.0% of the diet.

Laboratory, Manitoba Department of Agriculture.

## d) LABORATORY ANALYSES

All feed samples were ground through a 1 mm screen using a Wiley Mill (Model #3) according to recognized AOAC (1984) procedures. Protein was analyzed using the macro-Kjeldahl technique. Ether extract (fat) was determined by direct ethyl ether elution techniques and calcium and phosphorus were determined by atomic absorption. Modifications for calcium analysis were made in accordance with the recommended procedures of Perkin Elmer (1976).

## e) DATA CALCULATIONS

In all experiments, average body weights for each pen were calculated by dividing total pen weight by the number of live birds at the time of weighing:

$$\frac{\text{Total live pen weight}}{\text{Total \# live birds}} = \text{average body weight per bird}$$

Average gain per bird per pen was calculated by subtracting the average body weight of the previous weigh date from the average body weight of the current weigh date:

Average gain = Current average bird wt. - previous average bird wt.

Feed:gain ratios were calculated by dividing the total pen feed consumption in a particular period by the total weight gain of the birds in the same period, including the weight gained by mortalities. That is, the weight of the mortalities was added to the current live pen weight before the previous pen weight was subtracted, thus arriving at a total pen gain over the respective period.

Therefore:

$$\text{Feed:Gain} = \frac{\text{Total pen feed consumption}}{(\text{Total pen wt} + \text{mortality wt}) - \text{Previous pen weight}}$$

f) **STATISTICS**

All statistical analyses of data were carried out using the SAS (1986) general linear models procedures computer program. Prior to analysis, all % mortalities, % abdominal fat and dressing % were converted using Arc-sin transformations. Data reported here however, have been expressed as percentages.

## B. EXPERIMENTAL PROCEDURES

a) **EXPERIMENT 1.** Effect of severe feed imposed for 3, 6 or 9 days on compensatory weight gain, percent abdominal fat and blood serum parameters of male broiler chickens.

This experiment was designed to explore the length of feed restriction which could be imposed and still have birds attain statistically similar final body weights as ad libitum fed controls. Also, the effect on abdominal fat pad deposition was determined.

2080 Cobb*Cobb male broiler chicks were randomly distributed among 32 floor pens (65 birds/pen) and assigned to one of 4 treatments in a completely randomized design. Treatment 1 (control) had 11 pens/treatment (715 birds/treatment) and were fed ad libitum at all times while treatments 2, 3, and 4 had 7 pens/treatment (455 birds/treatment) and were restricted as follows: Treatment 2 (T2)- restricted to maintenance energy intake for a period of 3 days beginning at 8 days of age, Treatment 3 (T3) - restricted to maintenance energy intake for a period of 6 days beginning at 8 days of age, and Treatment 4 (T4) - restricted to maintenance energy intake for a period of 9 days beginning at 8 days of age.

Starter feed was fed to 20 days of age and finisher feed was fed from 20 to 43 days of age. Starter and finisher ration formulations are presented in table 3. Pen weights were recorded on days 0, 8, 11, 14, 17, 20, 28, 35, and 43. Feed consumption was recorded and weight gainand feed:gain ratios were calculated for the periods 0-8, 8-11, 11-14, 14-17, 17-20, 20-28, 28-35, 35-43, 0-20, 20-43 and 0-43.

TABLE 3. **STARTER AND FINISHER RATIONS FOR EXPERIMENTS 1 AND 2**

| INGREDIENT | STARTER | FINISHER |
|---|---|---|
| | kg | kg |
| Wheat (14.5%)[1] | 625.24 | 732.75 |
| Soybean oil meal (47.5)[1] | 250.00 | 159.00 |
| Tallow (7800 kcal ME/kg) | 52.00 | 41.00 |
| Fishmeal (58%)[1] | 30.00 | 30.00 |
| Limestone | 16.00 | 14.75 |
| Biophos | 12.00 | 9.00 |
| Vitamin premix | 10.00 | 10.00 |
| Mineral premix | 3.50 | 3.50 |
| Lysine-HCl (98% pure) | 0.62 | - |
| Methionine-dl (98% pure) | 0.64 | - |
| **Calculated Analysis:** | | |
| Protein (%) | 23.09 | 20.02 |
| Energy (kcal/kg) | 3063 | 3090 |
| Calcium (%) | 1.01 | 0.90 |
| Phosphorus (% available) | 0.46 | 0.40 |
| Lysine (%) | 1.22 | 1.20 |
| Methionine (%) | 0.55 | 0.38 |
| **Chemical Analysis:** | | |
| Protein (%) | 23.59 | 20.90 |
| Ether Extract (%) | 6.49 | 4.88 |
| Calcium (%) | 1.02 | 0.93 |
| Phosphorus (% total) | 0.76 | 0.76 |

1. Crude protein

At 5 weeks of age, approximately 10 ml of blood from 4 birds/pen from T4 and 4 birds/pen from 7 randomly selected T1 pens were taken by wing vein puncture to determine whether any major differences could be detected between the two extreme treatment groups (0 and 9 day feed restriction).

Blood was collected in non-heparinized vacutainers and immediately placed on ice. After coagulating for approximately 3 hours, the blood samples were rimmed and then centrifuged for 15 minutes at 2000 RPM in a JOUON CR 3000 model centrifuge. 0.5 ml of serum were taken from each sample and pooled with the serum from another bird in the same pen having a similar weight. This resulted in 13 pooled samples for T4 (no analysis was possible on one sample due to jelling) and 14 pooled samples for T1.

The pooled serum samples were then refrigerated overnight until they could be analysed at the Manitoba Veterinary Services Branch the following morning. Analysis was with DACOS auto-analyser (Coulter Electronics, Inc.). Serum electrolytes were determined using an ion selective memebrane supplied by Coulter Electronics, Inc.

Based on the results obtained, a decision would be made as to whether blood samples would be taken in subsequent trials.

At 43 days of age, individual body weights were recorded for all birds. Based on the legscore system of Stevens et al. (1984) and in consultation with Dr. N. E. Stanger, leg score determinations were made based on the degree by which the legs deviated from normal. That is, birds were held upside down in such a manner that the legs were forced to be extended. A score of 1-3 was subjectively assessed based on the following criteria: (a) the degree to which the leg deviated from a straight extension, (b) whether one or both legs deviated and (c) whether the hock joint appeared to be infected or inflamed.

At 43 days of age, 4 birds per pen (7 pens/treatment) were randomly selected and kept back for slaughter analysis. These birds were wing banded to identify the pen and treatment from which they came. The birds were then slaughtered on consecutive days after being starved overnight. Slaughter analysis included liveweight, dressed weight, abdominal fat pad weight (the fatty tissue between the abdominal wall and the intestines and extending from the Bursa of Fabricius up to and including that surrounding the gizzard) and liver weight. Abdominal fat pad weight and liver as a percentage of live weight were also calculated.

All data were analyzed as a completely randomized design using the SAS (1986) general linear models procedure and multiple pairwise comparisons (Steel and Torrie, 1980). Significant differences between least squares means were determined using Bonferonni's procedure (Miller, 1981).

b) **EXPERIMENT 2.** Effect of severe feed restriction imposed at varying ages on compensatory weight gain, percent abdominal fat and blood serum parameters of male broiler chickens.

This experiment was designed to study the effect of a 5 day restriction period on compensatory gain and abdominal fat pad deposition when the restriction period was initiated at three different ages.

A total of 1960 male Cobb*Cobb broiler chicks were randomly distributed among 28 floor pens (70 birds/pen). Each of the four treatments were randomly allocated to 7 pens (490 birds/treatment).

The treatment groups were fed as follows: Treatment 1 (T1, control) - fed ad libitum throughout, Treatment 2 (T2) - restricted to a maintenance energy intake for 5 days beginning at 7 days of age, Treatment 3 (T3) - restricted to a maintenance energy intake for 5 days beginning at 12 days of age, and Treatment 4 (T4) - restricted to a maintenance energy intake for 5 days beginning at 17 days of age.

The same starter and finisher feeds were fed to all treatment groups from 0-22 and 22-42 days of age respectively. Starter and finisher diets were the same as those described for experiment 1 and are detailed in table 3. Pen weights were taken at 0, 7, 12, 17, 22, 27, 35, and 42 days of age. Feed consumption was recorded and pen weight gain and feed:gain ratios were calculated for the following intervals: 0-7, 7-12, 12-17, 17-22, 22-27, 27-35, 35-42, 0-22, 22-42 and 0-42.

Twenty-four hours after each restricted group was put back on ad libitum feeding, 4 birds/pen were randomly selected for blood sampling. One bird/pen from T1 at each sampling was also selected so that comparisons could be made with the control birds. Blood samples were taken from decapitated birds. Blood was collected in 10 ml glass tubes and allowed to coagulate for two hours at room temperature. All tubes were then rimmed to release the clot from the sides of the tube and allowed to stand for an additional hour before they were centrifuged in a Jouon CR 3000 model centrifuge for 15 minutes at 2000 RPM. Approximately 0.5 ml serum from each sample was taken and pooled with an equal volume from another sample from the same pen. This resulted in two pooled samples/pen in the treated groups. The seven control samples were divided into one single sample and three pooled samples of two birds each. For the treated groups, serum samples from the two heaviest and the two lightest birds in each pen were pooled together. For all of the control birds, serum from the overall two heaviest birds were pooled then the next two heaviest birds etc. while the serum from the lightest bird was treated as a single sample. Serum samples were pooled in this manner to test whether any significant weight correlated trends could be distinguished. Pooled serum samples were analyzed in the same manner as in experiment 1 (see page 34).

Due to the difficulties in determining the maintenance energy requirements for the birds, final individual body weight and slaughter carcass analysis was not carried out.[1]

All data were analyzed as a completely randomized design using the

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[1]. Formulae derived from Plavnik and Hurwitz (1986) seemed to overestimate the requirements and as a result, birds were gaining more weight than anticipated. For that reason, the degree of feed restriction was progressively increased with each treatment group until by the time the third group (T4) came off restriction, a reasonably accurate formula had been established that would estimate the daily maintenance energy requirements of broilers under practical management conditions.

general linear models procedure (SAS, 1986). Differences between treatment means were determined by Tukey's test (Steel and Torrie, 1980).

c) **EXPERIMENT 3.** Effect of severe feed restriction imposed at varying ages on compensatory weight gain and percent abdominal fat of male broiler chickens.

This experiment was a replication of experiment 2 using the formula developed to successfully restrict birds to their maintenance level for 5 days.

Although the experimental design and treatment groups of experiment 3 was the same as for experiment 2, several experimental parameters were altered. Due to the availability of birds, this experiment employed Arbour Acre x Ross male broiler chicks. In an effort to augment any differences that may occur in abdominal fat pad deposition, changes were made to the feed. The calorie:protein ratio was widened by increasing the amount of tallow in the diet and by reducing the protein. Starter and finisher feeds used are detailed in table 4. The trial was extended by 16 days to 58 days of age resulting in one additional period (42-58).

Since the blood analysis results from experiments 1 and 2 were not deemed to be very helpful in explaining the compensatory weight gains in experiments 1 and 2, and because of the cost and time involved, blood analysis was not done for experiment 3.

At 58 days of age, individual body weights were recorded for all birds. Leg score determinations were also made based on criteria outlined in experiment 1. Four birds from each pen were randomly selected for slaughter analysis. Two birds from each pen were slaughtered on two consecutive days following an overnight fast.

**TABLE 4. STARTER AND FINISHER RATIONS (EXPERIMENTS 3 AND 4)**

| INGREDIENT | STARTER | FINISHER |
|---|---|---|
| | (kg) | (kg) |
| Wheat (14.5%)[1] | 607.24 | 754.0 |
| Soybean meal (47.5%)[1] | 245.0 | 118.75 |
| Tallow (7800 kcal ME/kg) | 75.0 | 60.0 |
| Fishmeal (58%)[1] | 30.0 | 30.0 |
| Limestone | 16.0 | 14.75 |
| Biophos | 12.0 | 9.0 |
| Vitamin Premix | 10.0 | 10.0 |
| Mineral Premix | 3.5 | 3.5 |
| Methionine (98%)[1] | 0.64 | - |
| Lysine HCl (98%)[1] | 0.62 | - |
| Chromic oxide (experiment 4 only) | 0.30 | 0.30 |
| **CALCULATED ANALYSIS:** | | |
| Protein (%) | 22.10 | 18.50 |
| Energy (kcal/kg) | 3170 | 3197 |
| Calcium (%) | 1.01 | 0.90 |
| Phosphorus (% available) | 0.46 | 0.40 |
| Methionine (%) | 0.50 | 0.38 |
| **CHEMICAL ANALYSIS:** | | |
| Protein (%) | 22.98 | 18.95 |
| Ether extract (%) | 8.39 | 6.76 |
| Calcium (%) | 1.10 | 1.00 |
| Phosphorus (% TOTAL) | 0.80 | 0.72 |
| Chromic oxide (%) | 0.30 | 0.33 |

1. Crude Protein

Slaughter analysis included liveweight, dressed weight, abdominal fat pad weight ( as defined in experiment 1 ), liver wight, and the weight of the gastro-intestinal tract (GIT) ( that portion extending from the cloaca up to and including the gizzard, but not the proventriculus ). Weight of the abdominal fat pad, liver and GIT as a percentage of live weight were also calculated.

All data was analyzed as a completely randomized design using the general linear models procedure of SAS (1986). Differences between means were determined by Tukey's test (Steel and Torrie, 1980).

d) **EXPERIMENT 4.** The effect of severe feed restriction imposed at varying ages on the percent dry matter digestibility of broiler chickens raised in battery brooders.

This experiment was designed to study the effect on dry matter digestibility of severe early feed restriction for a period of 5 days initiated at 3 different ages. Percent dry matter digestibility (PDMD) was determined by measuring the dry matter concentration relative to chromic oxide in the feed and excreta.

A total of 124 male Arbor Acre x Ross broiler chicks were randomly allocated to 24 battery pens (6 birds/pen). Three batteries were used, each containing 2 pens from each treatment (8 pens) randomly distributed throughout the battery. Six pens were randomly allocated to each treatment (36 birds/treatment).

The treatment groups were as follows: Treatment 1 (T1, control)- fed ad libitum throughout the trial, Treatment 2 (T2) - restricted to maintenance energy intakes for a period of 5 days beginning at 7 days of age, Treatment 3 (T3) - restricted to maintenance energy intakes for a period of 5 days beginning at 12 days of age, and Treatment 4 (T4)- restricted to maintenance energy intakes for a period of 5 days beginning at 17 days of age.

Starter and finisher feeds were fed from 0-22 and 22-27 days of age respectively. Diet composition and analysis are found in table 4. Pen weights were recorded on days 0, 7, 12, 17, and 22 for all treatments and on day 27 for T1 and T4 only. Feed consumption was recorded and weight gain and feed:gain ratios calculated for the periods 0-7, 7-12, 12-17, 17-22 for all treatments and 22-27 for T1 and T4 only. Due to the 1 mortality that occured, average feed consumption for that period was calculated by the method of Rotter et al. (1986).

On day 22, treatments 2 and 3 were terminated. Treatments 1 and 4 were continued until day 27 at which time the trial was terminated. On day 22, 2 birds from each of the treatment 1 pens were removed. This was necessitated by the fact that treatment 1 birds were heavier than those of treatment 4 and in order to keep the total weight, and consequently the weight/unit area the same for both treatments, 2 birds were removed.

Excreta samples were collected on each weigh date from all pens. In addition, after the restricted birds were returned to full feed, daily excreta samples were collected for 5 days to monitor the PDMD in the post-restriction phase. That is, in addition to the excreta samples collected on each weigh day, excreta samples were also collected on the following days: for T2, on days 13, 14, 15, 16; for T3, on days 18, 19, 20, 21; and for T4, on days 23, 24, 25, and 26. To determine whether comparative differences would appear between restricted birds and control birds, excreta samples for T1 were collected daily from day 20-27.

On the day that excreta samples were collected they were placed in a forced-air drying oven at 60°C overnight. Samples were then passed through a 1 mm screen in a Wiley Mill (Model #3) and stored in sealed plastic bags until analyzed for chromic oxide. Prior to analysis, dry matter was done on all samples.

Starter and finisher feeds and excreta samples collected during the trial were analyzed for chromic oxide. Chromic oxide concentration

(COC) in ug Cr/ml were determined in a model 551 Instrumentation Laboratory aa/ae spectrophotometer according to the procedures described by Williams et al. (1962). Percent chromic oxide (PCO) was calculated using the following formula:

$$PCO = \frac{COC \times 2.92 \times 10^{-2}}{\text{Sample weight (g)}}$$

The experiment was analylzed as a randomized block design, with the three batteries representing the blocks,using the general linear models procedure of SAS (1986). Differences between means were determined using Tukey's Test (Steel and Torrie, 1980).

# IV. RESULTS

A. Effect of imposing feed restriction for 3, 6, or 9 days on compensatory weight gain, percent abdominal fat and blood serum parameters of male broiler chickens (Experiment 1).

## a) LEAST SQUARES MEAN BODY WEIGHTS AND WEIGHT GAINS

Least squares mean body weights and weight gains for the 6 week trial period are presented by treatment in tables 5 and 6 respectively. Mean squares from the analysis of variance tables are presented in appendices E-1 and F-1 respectively. There were no significant (P>.05) differences in body weight prior to feed restriction being imposed on day 8.

On day 11 after 3 days of feed restriction all restricted groups weighed significantly (P<.05) less than the control (T1) birds. Each additional 3 days of feed restriction for T3 and T4 resulted in body weights being significantly (P<.05) less than T1 (Table 5). Although 35 day body weights of all treatments were significantly (P<.05) different, by 42 days of age, the difference between the controls and the 3 day restricted birds (T2) had disappeared, suggesting that some compensatory gain had occurred following feed restriction.

Based on weight gain data (Table 6), restricting feed for 3 days resulted in a significant reduction in weight gains. Continued restriction for 6 and 9 days further reduced the gains. In the 3 days following feed restriction, the weight gains of T2 and T3 were significantly (P<.05) greater than T1. Subsequent to this, the weight

**TABLE 5. LEAST SQUARES MEAN BODY WEIGHTS FOR BROILERS FED AD LIBITUM OR VARIOUS RESTRICTION REGIMES (EXPERIMENT 1)**

| AGE | TREATMENT[1] | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| 0[2] | 41.1±0.11a | 41.1±0.13a | 41.2±0.13a | 41.0±0.13a |
| 8 | 132.1±1.19a | 133.9±1.49a | 130.2±1.49a | 134.9±1.49a |
| 11 | 190.5±1.68a | 158.1±2.11b | 158.0±2.11b | 160.2±2.11b |
| 14 | 267.1±1.90a | 243.9±2.39b | 191.8±2.39c | 192.3±2.39c |
| 17 | 374.3±2.09a | 347.2±2.62b | 305.1±2.62c | 223.6±2.62d |
| 20 | 507.0±2.79a | 472.6±3.49b | 424.6±3.49c | 357.3±3.49d |
| 28 | 972.5±3.16a | 939.3±3.97b | 874.4±3.97c | 767.8±3.97d |
| 35 | 1410.6±5.55a | 1377.3±6.95b | 1324.3±6.95c | 1203.1±6.95d |
| 42 | 1887.7±11.1a | 1848.2±13.9a | 1791.2±13.9b | 1681.2±13.9c |

a,b,c,d - means within a row not followed by the same letter are significantly different at $P<.05$.

1. Treatments used were : T1 - ad libitum fed control; T2- restricted for 3 days from day 8-11; T3 - restricted for 6 days from day 8-14; T4 - restricted for 9 days from day 8-17.

2. Means ± standard error.

**TABLE 6. LEAST SQUARES MEAN WEIGHT GAINS FOR BROILERS FED AD LIBITUM OR VARIOUS RESTRICTION REGIMES (EXPERIMENT 1)**

| AGE | TREATMENT[1] | | | |
|---|---|---|---|---|
| (DAYS) | 1 | 2 | 3 | 4 |
| 0-8[2] | 91.1±1.20a | 92.8±1.50a | 89.1±1.50a | 93.8±1.50a |
| 8-11 | 58.3±1.23a | 24.2±1.54b | 27.8±1.54b | 25.3±1.54b |
| 11-14 | 76.7±1.08b | 85.8±1.35a | 33.8±1.35c | 32.1±1.35c |
| 14-17 | 107.2±0.91b | 103.3±1.14b | 113.3±1.14a | 47.3±1.14c |
| 17-20 | 132.7±1.27a | 125.4±1.59b | 119.6±1.59b | 133.7±1.59a |
| 20-28 | 465.4±2.32a | 466.7±2.92a | 449.8±2.92b | 410.5±2.93c |
| 28-35 | 438.2±3.95a | 438.0±4.95a | 449.9±4.95a | 435.4±4.95a |
| 35-42 | 477.1±9.33a | 470.8±11.7a | 466.9±11.7a | 478.1±11.7a |
| 0-20 | 466.0±2.78a | 431.5±3.49b | 383.5±3.49c | 316.2±3.49d |
| 20-42 | 1380.7±11.8a | 1375.5±14.8ab | 1366.6±14.8ab | 1324.2±14.8b |
| 0-42 | 1846.7±11.12a | 1807.1±13.9a | 1750.0±13.9b | 1640.2±13.9c |

a,b,c - means within a row not followed by the same letter are significantly different at P<.05.

1. See table 5 for explanation of treatments used.

2. Means ± standard error.

gains of T2 were significantly different from T1 only during the period of days 17-20 when gains were significantly less (P<.05).

T3 weight gains were significantly less (P<.05) than T1 for the period of days 17-28 after which weight gains were not significantly different (P>.05).

Post-restriction weight gains of T4 were signifiantly different from T1 only for the period of days 20-28 when weight gains were significantly (P<.05) poorer than T1.

b) **LEAST SQUARES MEAN FEED CONSUMPTION AND FEED:GAIN**

Least squares means for feed consumption and feed:gain data are presented in tables 7 and 8 respectively. Mean squares from the analysis of variance tables are presented in appendices G-1 and H-1.

No differences in feed consumption were noted prior to feed restriction being initiated on day 8. During the periods of feed restriction, feed consumption was always significantly (P<.05) less for the restricted birds than for the ad libitum fed controls.

Subsequent to being returned to ad libitum feeding, feed consumption for T2, T3 and T4 remained equal to or significantly (P<.05) less than T1. For T2 and T3, feed consumption was significantly (P<.05) less than T1 for the period of days 14 to 28, while for T4, feed consumption was significantly less than T1 for the period of days 17 to 35. During the starter phase (days 0-20), significant differences in feed consumption were evident between all treatment groups (762 g, 693 g, 599 g, and 479 g respectively for T1, T2, T3 and T4; P<.05), reflecting the length of feed restriction

**TABLE 7. LEAST SQUARES MEAN FEED CONSUMPTION OF BROILERS FED AD LIBITUM OR VARIOUS RESTRICTION REGIMES (EXPERIMENT 1)**

| AGE | TREATMENT[1] | | | |
|---|---|---|---|---|
| (DAYS) | 1 | 2 | 3 | 4 |
| 0-8[2] | 142.2±1.30a | 143.3±1.64a | 140.8±1.64a | 143.6±1.64a |
| 8-11 | 105.2±1.77a | 47.4±2.22b | 46.9±2.22b | 48.2±2.22b |
| 11-14 | 126.5±1.01a | 127.5±1.26a | 46.5±1.26b | 46.5±1.26b |
| 14-17 | 171.1±0.94a | 166.7±1.18b | 164.4±1.18b | 46.6±1.18c |
| 17-20 | 217.0±1.81a | 207.9±2.27b | 199.9±2.27bc | 194.6±2.27c |
| 20-28 | 819.8±3.51a | 801.1±4.40b | 775.4±4.40c | 711.3±4.40d |
| 28-35 | 887.4±6.00a | 869.8±7.53a | 870.9±7.53a | 820.3±7.53b |
| 35-42 | 994.5±10.7a | 983.0±13.4a | 981.4±13.4a | 961.1±13.4a |
| 0-20 | 761.9±4.34a | 692.7±5.44b | 598.5±5.44c | 479.4±5.44d |
| 20-42 | 2701.7±16.4a | 2653.9±20.6ab | 2627.7±20.6b | 2492.6±20.6c |
| 0-42 | 3463.6±17.6a | 3346.7±22.1b | 3226.2±22.1c | 2972.1±22.1d |

a,b,c,d - means within a row not followed by the same letter are significantly different at P<.05.

1. See table 5 for explanation of treatments used.

2. Means ± standard error.

**TABLE 8. LEAST SQUARES MEAN FEED:GAIN RATIOS OF BROILERS FED AD LIBITUM OR VARIOUS RESTRICTION REGIMES (EXPERIMENT 1)**

| AGE | TREATMENT[1] | | | |
|---|---|---|---|---|
| (DAYS) | 1 | 2 | 3 | 4 |
| 0-8[2] | 1.56±0.02a | 1.55±0.02a | 1.58±0.02a | 1.53±0.01a |
| 8-11 | 1.81±0.04ab | 1.99±0.05b | 1.70±0.05a | 1.91±0.05b |
| 11-14 | 1.65±0.03b | 1.49±0.04a | 1.38±0.04a | 1.46±0.04a |
| 14-17 | 1.60±0.04a | 1.61±0.04a | 1.45±0.04a | 1.51±0.04a |
| 17-20 | 1.64±0.02b | 1.66±0.02b | 1.67±0.02b | 1.46±0.02a |
| 20-28 | 1.76±0.01b | 1.72±0.01a | 1.72±0.01a | 1.73±0.01a |
| 28-35 | 2.03±0.01c | 1.99±0.01cb | 1.94±0.01b | 1.88±0.01a |
| 35-42 | 2.09±0.03a | 2.09±0.04a | 2.11±0.04a | 2.02±0.04a |
| 0-20 | 1.63±0.01c | 1.60±0.01c | 1.56±0.01b | 1.51±0.01a |
| 20-42 | 1.96±0.01b | 1.93±0.02ab | 1.92±0.02a | 1.88±0.02a |
| 0-42 | 1.87±0.01b | 1.85±0.01ab | 1.84±0.01ab | 1.81±0.01a |

a,b,c - means within a row not followed by the same letter are significantly different at P<.05.

1. See table 5 for explanation of treatments used.

2. Means ± standard error.

imposed.

Finisher phase (days 20-42) feed consumption was greater for T1 than all other treatments, but this difference was significant only when compared to T4 (P<.05). Feed consumption data during the finisher phase was 2702, 2654, 2628, and 2493 g respectively for T1, T2, T3 and T4.

Overall, feed consumption was progressively less as the length of feed restriction was increased, resulting in significant (P<.05) differences between all treatments.

For the first 8 days, during which all treatment groups were fed ad libitum, no statistical differences were noted in the feed:gain ratios. The feed:gain ratios of T2 were equal to or less than T1 for all periods except during the feed restriction period when the feed:gain was significantly (P<.05) greater. For the periods of days 11 to 14 and 20 to 28, the feed:gain for T2 was significantly (P<.05) better than T1.

Although the feed:gain of T3 and T4 were less than T1 during the feed restriction period, this was significant (P<.05) only for the period of days 11 to 14. In the post-restriction period, feed:gain for T3 and T4 were numerically smaller than T1 and significantly better (P<.05) for the periods of days 20-28 and 28-35.

The only significant difference in the post-restriction feed:gain ratios between restricted birds occurred during the period of days 28 to 35 when T4 had a significantly (P<.05) lower feed:gain than either T2 or T3.

Overall, feed:gain in the starter phase was progressively better as the length of the restriction period increased (1.63, 1.60, 1.56 and 1.51 for T1, T2, T3 and T4 respectively). Although T1 and T2 were not significantly different P>.05) both were significantly different from T3 and T4 (P<.05). T3 and T4 were also significantly different from each other (P<.05).

During the finisher phase (days 20-42) feed:gain improved as the length of early feed restriction was increased, however only T1 and T4 were significantly different (P<.05) from each other. This trend was also maintained for the overall (0 to 42) feed:gain ratios.

c) **MORTALITY**

Mean percent total mortality and means squares from the analysis of variance tables are presented in appendix D-1 and M-1 respectively.

No significant differences or trends in mortalities could be detected when comparing the mortalities by either starter (days 0-20) or by finisher (days 20-42) phase. Percent mortalities during the starter phase were 4.90, 2.42, 5.06 and 3.52 for T1, T2, T3 and T4 respectively. For the finisher phase, percent mortalities were 3.36, 1.76, 3.30 and 2.42 for T1, T2, T3 and T4 respectively.

d) **CARCASS DATA**

Carcass data analysis are presented in table 9. Mean squares from analysis of variance tables are presented in appendix J-1.

Significant differences in abdominal fat weight were evident in the slaughter analysis. T4 had significantly less abdominal fat than did T1 or T3 (P<.05). T1, T2 and T3 were not significantly different nor were

**TABLE 9. LEAST SQUARES MEAN CARCASS DATA OF BROILERS FED AD LIBITUM OR VARIOUS RESTRICTION REGIMES (EXPERIMENT 1)**

| PARAMETER | TREATMENT[1] | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| | ---------- g ---------- | | | |
| LIVE WT | 2370±27.82a[2] | 2262±31.91bc | 2301±27.26ac | 2115±26.87b |
| DRESS WT | 1622±18.59a | 1541±23.90b | 1559±21.46ab | 1401±19.91c |
| LIVER WT | 42.9±1.06a | 41.5±1.20a | 44.5±1.57a | 40.4±1.24a |
| FAT WT[3] | 57.2±2.51a | 52.6±2.15ab | 56.0±1.69a | 45.6±1.39b |
| LEG SC | 1.31±0.02b | 1.19±0.02a | 1.29±0.02b | 1.20±0.02b |
| | ---------- %[4] ---------- | | | |
| DRESS | 68.4±0.21b | 68.2±0.84b | 67.7±0.44ab | 66.3±0.31a |
| LIVER | 1.80±.032a | 1.83±.043a | 1.93±.054a | 1.91±.046a |
| FAT | 2.41±.101a | 2.32±.085a | 2.43±.061a | 2.16±.061a |

1. See table 5 for explanation of treatments used.

2. Means ± standard error.

3. This represents the abdominal fat pad found between the abdominal wall and the intestines and extending from the Bursa of Fabricius up to and including that surrounding the gizzard.

4. Percent of live weight
a,b,c - means within a row not followed by the same letter are significantly different at $P<.05$.

T2 and T4. When abdominal fat weight was expressed as a percent of dressed weight, no significant differences were detected.

Dressing percentage tended to decrease as the level of feed restriction increased (68.4, 68.2, 67.7 and 66.3 % respectively for T1, T2, T3 and T4). Significant differences however, were noted only between T4, and T1 or T2 ($P<.05$).

No significant difference in liver weight could be detected. Expressing it as a percent of live weight, did not generate any significant trends.

The results of the legscore data indicate that significant ($P<.05$) differences occurred, with control birds (T1) having the highest legscore value. Although T2 and T4 had significantly ($P<.05$) better legscore values than T1, T3 which was intermediate in age of feed restriction was not significantly ($P>.05$) different from T1.

e) **SELECTED BLOOD SERUM PARAMETERS**

Least squares means of selected T1 and T4 blood parameters analyzed are presented in table 10. Mean squares from the analysis of variance are presented in appendix L-1.

Most blood parameters measured were not significantly different. The exceptions to this were albumin, total protein and uric acid which were significantly ($P<.05$) less for feed restricted birds (T4) than for ad libitum fed control birds (T1).

**TABLE 10. SELECTED MEAN 5 WEEK BLOOD SERUM PARAMETERS OF MALE BROILERS FED AD LIBITUM OR VARIOUS RESTRICTION REGIMES (EXPERIMENT 1)**

| | TREATMENT[5] | | |
|---|---|---|---|
| PARAMETER | 1 | 4 | PR>F |
| AST[1] (U/L) | 210.1±4.30[6] | 210.3±4.30 | .97 |
| AMYLASE (U/L) | 692±40.6 | 760±43.8 | .2687 |
| CK[2] (U/L) | 3808±295 | 3347±267 | .2625 |
| TOTAL BILIRUBIN (umol/L) | 3.0±.292 | 3.0±.303 | .9289 |
| ALBUMIN (G/L) | 12.2±.19a | 11.4±.20b | .0137 |
| URIC ACID (umol/L) | 452±20.6a | 378±21.4b | .0189 |
| TOTAL PROTEIN (G/L) | 33.4±.42a | 31.9±.43b | .0145 |
| TRIGLYCERIDE (mmol/L) | 1.07±.04 | 0.98±.05 | .147 |
| ALP[3] (U/L) | 3974±723 | 5136±616 | .2376 |
| ALT[4] (U/L) | 5.4±1.24 | 6.2±1.40 | .6907 |
| CHOLESTEROL (mmol/L) | 3.6±.10 | 3.6±.10 | .99 |

1. Aspartate aminotransferase
2. Creatine kinase
3. Alkaline phosphatase
4. y-glutamyltransferase
5. See table 5 for explantion of treatments used.
6. Means ± standard error.

B. Effect of severe feed restriction at varying ages on compensatory weight gain and blood serum parameters of male broiler chickens. (Experiment 2).

a) **MEAN BODY WEIGHTS AND WEIGHT GAINS**

Mean body weights and weight gains for the 43 day trial are presented in tables 11 and 12. Mean squares from the analysis of variance are presented in appendices E-2 and F-2 respectively.

On days 0 and 7, prior to starting feed restriction, no differences in average body weight were observed (P>.05). On day 12 when birds restricted from day 7 (T2) came off feed restriction, their body weights were significantly (P<.05) lower than non-restricted (T1, T3 and T4) birds. Subsequent to being returned to ad libitum feeding, the body weights of T2 remained significantly (P<.05) lower than those of T1 birds.

Similar trends were noted for T3 and T4. In the periods when T3 and T4 were place on a restricted feeding regime (days 12-17 and 17-22 respectively), their weight became significantly lower than the controls and remained that way to the end of the experiment. Also, the body weights between the birds restricted at different ages remained significantly different from each other after they were returned to ad libitum feeding. As a result, the final body weights between all four treatment groups were significantly different (P<.05) from each other at 43 days of age (1932, 1861, 1785 and 1724 g for T1, T2, T3 and T4 respectively).

Prior to being placed on feed restriction, no differences in average period gain were evident between any of the treatment groups and

**TABLE 11. MEAN BODY WEIGHTS OF MALE BROILERS FED AD LIBITUM OR VARIOUS RESTRICTION REGIMES (EXPERIMENT 2)**

| AGE (DAYS) | TREATMENT[1] 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 0[2] | 42.2±.08a | 42.2±.09a | 41.9±.08a | 42.1±.09a |
| 7 | 118.7±.65a | 122.2±1.1a | 120.3±1.2a | 121.0±.94a |
| 12 | 231.4±1.7a | 158.2±2.1b | 232.3±2.3a | 228.1±3.1a |
| 17 | 397.5±1.4a | 320.7±1.2b | 281.2±4.7c | 389.7±3.0a |
| 22 | 625.9±2.3a | 535.4±2.5b | 489.0±7.1c | 408.1±4.0d |
| 27 | 899.3±6.2a | 808.4±12.6b | 744.1±7.7c | 674.7±9.9d |
| 35 | 1381.8±6.8a | 1303.8±9.7b | 1241.3±8.8c | 1162.7±14.8d |
| 43 | 1931.7±17.0a | 1861.3±8.0b | 1784.8±13.0c | 1724.1±18.7d |

a,b,c,d - means within a row not followed by the same letter are significantly different at P<.05.

1. Treatments used were: T1 - ad libitum fed control; T2 - fed maintenance energy requirements from day 7-12; T3 - fed maintenance energy requirements from day 12-17; T4 - fed maintenance energy requirements from day 17-22.

2. Means ± standard error.

**TABLE 12. MEAN AVERAGE WEIGHT GAINS OF MALE BROILERS FED AD LIBITUM OR VARIOUS RESTRICTION REGIMES (EXPERIMENT 2)**

| AGE (DAYS) | TREATMENT[1] 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 0-7[2] | 76.5±.64a | 80.0±1.06a | 78.3±1.22a | 78.9±.97a |
| 7-12 | 112.7±1.2a | 36.0±2.0b | 112.0±1.1a | 107.1±2.5a |
| 12-17 | 166.1±1.8a | 162.5±2.0a | 48.9±5.2b | 161.7±1.4a |
| 17-22 | 228.4±1.3a | 214.7±1.5ab | 207.8±6.3b | 18.4±2.4c |
| 22-27 | 273.4±6.4a | 273.1±11.5a | 255.1±2.6a | 266.5±10.4a |
| 27-35 | 482.5±4.2a | 495.3±9.1a | 497.3±7.6a | 488.0±7.5a |
| 35-43 | 550.0±11.9a | 557.6±9.9a | 543.5±4.7a | 561.4±6.6a |
| 0-22 | 583.7±2.3a | 493.2±2.5b | 447.0±7.1c | 366.1±4.0d |
| 22-43 | 1305.8±16.8a | 1326.0±7.8a | 1295.8±10.8a | 1315.9±18.2a |
| 0-43 | 1889.5±17.1a | 1819.2±9.0b | 1742.8±13.0c | 1682.0±18.7d |

a,b,c,d - means within a row not followed by the same letter are significantly different at $P<.05$.

1. See table 11 for explanation of treatments used.

2. Means ± standard error.

the control birds. Average period gains during the periods of feed restriction were significantly higher for the control birds (P<.05).

The average period gains of the feed restricted birds in the post restriction phase were generally equal to those of the control birds. The exception to this was from days 17-22 when the average gain of T3 was significantly (P<.05) less than T1 controls.

Due to the reduced gains during the feed restriction periods, starter period (days 0-22) gains showed a significant difference between all treatments. This difference was also reflected in the overall (days 0-43) gains.

Although variations in average gains existed in the post restriction phase (days 22-43), no significant (P>.05) differences could be detected.

b) **AVERAGE FEED CONSUMPTION AND FEED:GAIN**

Average feed consumption and feed:gain (F/G) ratios are presented in table 13 and 14 respectively. Mean squares from the analysis of variance tables are presented in appendices G-2 and H-2 respectively. Prior to feed restriction being imposed, no differences could be found between any of the treatment groups and the control birds. Subsequent to being returned to ad libitum feeding, T2 feed consumption remained significantly (P<.05) below that of the control birds until day 27. From day 27 to day 43, no difference in feed consumption was detected although T2 tended to be lower.

Except for the period of days 27-35, T3 feed consumption remained significantly (P<.05) below that of control birds subsequent to being

**TABLE 13. AVERAGE FEED CONSUMPTION OF MALE BROILERS FED AD LIBITUM OR VARIOUS RESTRICTION REGIMES (EXPERIMENT 2)**

| | TREATMENT[1] | | | |
|---|---|---|---|---|
| PERIOD | 1 | 2 | 3 | 4 |
| 0-7[2] | 111.7±1.28a | 115.0±0.97a | 115.1±1.07a | 115.2±1.22a |
| 7-12 | 182.5±0.97a | 63.4±0.36b | 185.1±2.11a | 182.8±3.81a |
| 12-17 | 262.1±2.25a | 241.0±1.28b | 80.7±0.33c | 260.2±3.16a |
| 17-22 | 390.4±2.75a | 352.9±2.14b | 354.3±6.74b | 87.3±5.92c |
| 22-27 | 519.6±9.52a | 485.7±1.64bc | 468.9±5.27c | 504.1±7.95ab |
| 27-35 | 1030.5±9.60a | 1022.3±9.27a | 1001.5±9.89a | 988.9±16.6a |
| 35-43 | 1282.5±13.7a | 1277.8±10.5a | 1191.8±17.7b | 1254.7±14.2a |
| 0-22 | 946.7±4.99a | 772.3±4.1b | 735.3±9.6c | 645.5±9.4d |
| 22-43 | 2832.1±19.7a | 2785.9±15.1ab | 2662.1±13.8c | 2747.7±18.7b |
| 0-43 | 3778.8±19.8a | 3558.1±14.4b | 3397.4±19.3c | 3393.2±23.6c |

a,b,c,d - means within a row not followed by the same letter are significantly different at P<.05.

1. See table 11 for explanation of treatments used.

2. Means ± standard error.

TABLE 14. AVERAGE FEED:GAIN OF MALE BROILERS FED AD LIBITUM OR VARIOUS RESTRICTION REGIMES (EXPERIMENT 2)

| AGE (DAYS) | TREATMENT[1] 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 0-7[2] | 1.46±.02a | 1.44±.02a | 1.47±.02a | 1.46±.01a |
| 7-12 | 1.62±.02a | 1.81±.13a | 1.65±.01a | 1.71±.03a |
| 12-17 | 1.58±.01a | 1.48±.01a | 1.73±.13a | 1.61±.01a |
| 17-22 | 1.71±.01a | 1.64±.01a | 1.71±.05a | 5.36±.82b |
| 22-27 | 1.90±.01a | 1.79±.06a | 1.84±.02a | 1.91±.08a |
| 27-35 | 2.14±.02a | 2.07±.04a | 2.02±.02a | 2.03±.05a |
| 35-43 | 2.34±.04b | 2.29±.03ab | 2.20±.05a | 2.24±.02ab |
| 0-22 | 1.62±.01b | 1.56±.01a | 1.64±.01b | 1.76±.02c |
| 22-43 | 2.17±.02b | 2.10±.01ab | 2.05±.02a | 2.09±.03ab |
| 0-43 | 1.99±.01ab | 1.95±.01a | 1.94±.01a | 2.01±.02b |

a,b,c - means within a row not followed by the same letter are significantly different at P<.05.

1. See table 11 for explanation of treatments used.

2. Means ± standard error.

returned to ad libitum feeding.

Feed consumption of T4 subsequent to being returned to ad libitum feeding remained less than control birds, although this difference was not significant (P>.05).

Overall, significant (P<.05) differences in feed consumption were found during the starter phase (days 0- 22) between all treatment groups. Feed consumption became progressively less as the age at which feed restriction was imposed increased from days 7-17. During the finisher phase (days 22-43), T1 and T2 were not significantly different while T3 and T4 were significantly different from T1.

For the first 35 days of the trial, no differences in feed:gain (F/G) were noted except for T4 in the period of day 17 to 22. The F/G was unusually high (5.36) and as a result was significantly different from the other treatment groups. During the final week, restricted birds tended to have a better F/G ratio than the control birds, yet only T3 was significantly better than T1 (2.20 vs. 2.34, P<.05).

During the starter phase (day 0 - 22), the F/G for T1 was significantly better (lower) than T4 (P<.05) and T3 (P>.05). The feed:gain ratio for T1 was significantly poorer (higher) than T2. During the starter phase, the F/G became progressively worse as the age at which restriction was imposed was increased (1.56, 1.64 and 1.76 for T2, T3 and T4 respectively).

During the finisher phase (day 22 - 43), F/G also tended to be better (lower) for T2, T3 and T4. However, except for T3, this difference was not significant.

c) **MORTALITY**

Mean percent total mortality and mean squares from the analysis of variance tables are presented in appendices D-2 and M-2 respectively.

No significant differences in total mortality could be determined between any treatment in any period. Also, no detectable trend could be ascertained. Mean mortalities for the experiment were 3.47, 2.86, 3.05 and 4.29 % for T1, T2, T3 and T4 respectively.

d) **SELECTED BLOOD SERUM PARAMETERS**

Least square means of selected blood serum parameters tested for in this trial are presented in table 15. Mean squares from the analysis of variance tables are presented in appendix L-2.

The effect of feed restriction appears to have had the greatest effect on birds restricted at an early age, as indicated by the greatest number of significant differences found on day 13.

The only parameter found to be significantly affected at all three ages of feed restriction was cholesterol. For each treatment, cholesterol was significantly greater for the restricted birds than for the control birds (P<.01). T1 aspartate amino transferase (AST) was significantly (P<.01) less than T3 on day 18 (136 vs 206 U) and T4 on day 23 (184 vs. 224 U).

TABLE 15. SELECTED[1] BLOOD SERUM PARAMETERS OF MALE BROILERS TAKEN 24 HOURS AFTER BEING RETURNED TO AD LIBITUM FEEDING (EXPERIMENT 2)

| PARAMETER | TREATMENT[2] | | |
|---|---|---|---|
| DAY 13 | 1 | 2 | PR>F |
| GLUCOSE (mmol/L) | 16.95±0.24 | 15.52±0.21 | .0031 |
| CHOLESTEROL(mmol/L) | 3.67±0.27 | 4.66±0.14 | .0035 |
| URIC ACID (mmol/L) | 799.5±49.9 | 631.5±31.7 | .0207 |
| ALP[3] (U/L) | 47188±6758 | 28162±2714 | .007 |

| | TREATMENT | | |
|---|---|---|---|
| DAY 18 | 1 | 3 | PR>F |
| AST[4] (U/L) | 135.75±46.2 | 206.0±6.16 | .0142 |
| CHOLESTEROL (mmol/L) | 3.46±0.20 | 4.25±0.11 | .0034 |

| | TREATMENT | | |
|---|---|---|---|
| DAY 23 | 1 | 4 | PR>F |
| AST (U/L) | 183.5±7.24 | 224.36±5.01 | .001 |
| CHOLESTEROL (mmol/L) | 3.73±0.14 | 4.45±0.11 | .0037 |

1. Although more parameters were tested for, only those deemed important or significant are included here.
2. See table 11 for explanation of treatments used.
3. Alkaline phosphatase
4. Aspartate aminotransferase

C. Effect of severe feed restriction at varying ages on compensatory weight gain and abdominal fat pad deposition of male broiler chickens (Experiment 3).

a) **MEAN BODY WEIGHTS AND WEIGHT GAINS**

Mean body weights and weight gains for the 58 day trial are presented in tables 16 and 17 respectively. Mean squares from the analysis of variance tables are presented in appendix E-3 and F-3 respectively.

Prior to feed restriction being imposed no significant (P>.05) differences in average body weights were detected between treatments. On day 12, the average weight of birds restricted from days 7-12 (T2) was significantly less than control birds (T1), and T3 and T4 birds (137 g vs 226 g, 226 g and 224 g respectively). Subsequent to being placed on ad libitum feeding on day 12, the body weights of T2 remained significantly below those of the control birds until day 42. By day 58, no significant (P>.05) differences in body weights could be ascertained between T1 and T2 indicating that compensatory gain had occurred.

The average weights of T3 and T4, from days 17 and 22 respectively, to the end of the experiment, remained significantly (P<.05) inferior to the weight of the ad libitum fed control (T1) birds.

Significant differences in body weight were also found between treatments restricted at varying ages. However, by day 42, T3 and T4 had gained sufficient weight that no differences in average weight among feed restricted birds remained.

**TABLE 16. MEAN BODY WEIGHTS OF MALE BROILERS FED AD LIBITUM OR VARIOUS RESTRICTED REGIMES (EXPERIMENT 3)**

| AGE (DAYS) | TREATMENT[1] 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 0[2] | 43.3±0.11a | 43.1±0.13a | 42.9±0.05a | 43.3±0.13a |
| 7 | 117.9±1.49a | 116.2±0.74a | 117.6±0.62a | 116.7±1.18a |
| 12 | 226.2±2.84a | 137.0±1.52b | 225.5±1.43a | 223.7±2.28a |
| 17 | 387.3±4.44a | 302.5±2.41b | 263.7±3.32c | 390.2±4.26a |
| 22 | 641.4±5.87a | 531.9±4.20b | 504.1±4.35c | 434.5±4.92d |
| 27 | 949.9±8.12a | 800.1±8.02b | 761.5±6.48c | 738.6±6.37c |
| 35 | 1462.2±12.7a | 1313.1±5.92b | 1233.3±12.4c | 1222.1±11.2c |
| 42 | 1959.4±19.0a | 1787.3±10.7b | 1739.5±11.1b | 1738.8±13.4b |
| 58 | 2988.2±17.3a | 2875.0±15.7ab | 2851.8±27.8b | 2864.8±48.4b |

a,b,c,d - Means within a row not followed by the same letter are significantly different at $P<.05$.

1. See table 11 for explanation of treatments used.

2. Means ± standard error.

**TABLE 17. AVERAGE WEIGHT GAINS OF MALE BROILERS FED AD LIBITUM OR VARIOUS RESTRICTION REGIMES (EXPERIMENT 3)**

| AGE (DAYS) | TREATMENT[1] 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 0-7[2] | 74.6±1.49a | 73.0±0.76a | 74.7±0.58a | 73.4±1.16a |
| 7-12 | 108.2±1.66a | 20.8±1.11b | 107.9±1.14a | 107.1±1.28a |
| 12-17 | 161.1±3.37a | 165.5±1.87a | 38.2±2.56b | 166.5±2.56a |
| 17-22 | 254.0±1.58a | 229.4±2.65b | 240.4±1.88c | 44.3±2.68d |
| 22-27 | 303.5±3.32a | 268.2±5.97b | 257.4±2.97b | 304.1±2.49a |
| 27-35 | 517.3±5.80a | 513.0±5.71a | 471.8±9.97b | 483.6±5.54b |
| 35-42 | 497.2±8.61ab | 474.1±6.01b | 506.2±9.12ab | 516.7±9.82a |
| 42-58 | 1028.8±15.6b | 1087.8±13.1ab | 1112.3±20.7ab | 1125.7±37.8a |
| 0-22 | 598.1±5.92a | 499.7±4.15b | 461.2±4.32c | 391.2±4.86d |
| 22-58 | 2346.9±14.0a | 2343.1±16.0a | 2347.7±26.5a | 2430.3±48.1a |
| 0-58 | 2944.9±17.3a | 2831.9±15.7ab | 2808.9±27.7b | 2821.5±48.4b |

a,b,c,d - means within a row not followed by the same letter are significantly different at P<.05.

1. See table 11 for explanation of treatments used.

2. Means ± standard error.

During the period in which feed restriction was imposed, the average weight gains for all restricted groups were significantly less than all other groups (Table 17).

In the five day period following the end of feed restriction for T2 (days 12-17), the average weight gain of T2 was numerically but not significantly greater than T1 (166 g vs. 161 g). Subsequently, the weight gains were significantly below T1 for days 17-27. For days 27-42, T2 weight gains were not different from T1.

From day 17-35, following the end of feed restriction for T3, average weight gains remained significantly ($P<.05$) below those of T1. From day 35 to 58, the average weight gain of T3 was only numerically greater than T1. In the first 5 day period following the end of feed restriction for T4, the average weight gain was not significantly different than T1 (304 g vs 304 g). During days 27-35, T4 gained significantly less ($P<.05$) than T1 birds. From day 35-58, the weight gain for T4 was greater than T1, but this was significant only for days 42 - 58 (1126 g vs. 1029 g; $P<.05$).

Starter phase (days 0-22) weight gains were progressively less as the age at which feed restriction was imposed increased (598, 500, 461 and 391 g for T1, T2, T3 and T4 respectively). During the period of days 35-58 there was a tendency for weight gains to increase as the age at which restriction was imposed was increased. Overall weight gains reflected final body weights, with no significant differences between T1 and T2 and no significant differences between any of the restricted groups ($P>.05$).

b) **AVERAGE FEED CONSUMPTION AND FEED:GAIN**

Average feed consumption and feed:gain data are presented in tables 18 and 19 respectively. Mean squares from the analysis of variance are presented in appendix G-3 and H-3 respectively.

Until birds were placed on feed restriction, no differences in average feed consumption were noted (Table 18). During the feed restriction period, feed consumption was always significantly (P<.05) less than all other treatments. Subsequent to T2 being returned to ad libitum feeding on day 12, feed consumption initially was not different from ad libitum fed controls.

As a result of the feed restriction, average feed consumption for the starter phase (days 0-22) was significantly (P<.05) different among all treatments. These differences however, were not evident in the finisher phase. However, feed restriction was severe enough such that all restricted birds had significantly (P<.05) lower overall feed consumption than ad libitum fed controls.

Up to day 17, no significant (P>.05) differences in feed:gain (F/G) were noted (Table 19). During the period of days 17-22 the F/G ratio of T4 (the period in which T4 was on feed restriction) was significantly greater than any of the other groups (P<.05).

From day 22-58 restricted birds generally had a lower F/G ratio than T1. While for the most part these differences were not significant, T3 and T4 were significantly (P<.05) lower than T1 for days 35-42 (2.15, 2.14 and 2.26 respectively) and T2 was significantly (P<.05) lower than T1 for days 42-58 (2.36 vs. 2.53). This resulted in a significantly (P<.05) lower F/G ratio for T3 and T4 during the overall

**TABLE 18. AVERAGE FEED CONSUMPTION OF MALE BROILERS FED AD LIBITUM OR VARIOUS RESTRICTION REGIMES (EXPERIMENT 3)**

| AGE | TREATMENT[1] | | | |
|---|---|---|---|---|
| (DAYS) | 1 | 2 | 3 | 4 |
| 0-7[2] | 118.1±1.56a | 118.6±1.69a | 119.0±1.51a | 117.7±0.86a |
| 7-12 | 184.1±1.16a | 37.7±0.14b | 182.4±1.71a | 182.5±1.96a |
| 12-17 | 256.9±4.99a | 248.9±3.54a | 58.4±0.25b | 247.0±3.64a |
| 17-22 | 382.4±4.07a | 336.1±1.33c | 362.8±2.47b | 84.2±0.62d |
| 22-27 | 559.0±4.95a | 509.9±3.87b | 469.1±4.48c | 544.1±10.5a |
| 27-35 | 1116.2±11.0a | 1070.0±8.43ab | 1033.1±31.7b | 1009.1±5.86b |
| 35-42 | 1122.7±11.9a | 1095.0±9.1a | 1085.7±14.0a | 1104.4±14.8a |
| 42-58 | 2600.1±44.7a | 2561.0±23.9a | 2655.8±56.9a | 2687.8±64.3a |
| 0-22 | 941.5±9.84a | 741.4±4.65b | 722.6±4.85c | 631.4±34.4d |
| 22-58 | 5397.9±62.5a | 5236.9±26.5a | 5243.7±50.6a | 5345.2±89.4a |
| 0-58 | 6339.5±67.5a | 5978.3±24.0b | 5966.4±52.3b | 5976.6±87.8b |

a,b,c,d - means within a row not followed by the same letter are significantly different at P<.05.

1. See table 11 for explanation of treatments used.

2. Means ± standard error.

**TABLE 19. AVERAGE FEED:GAIN OF MALE BROILERS FED AD LIBITUM OR VARIOUS RESTRICTION REGIMES (EXPERIMENT 3)**

| AGE (DAYS) | TREATMENT[1] 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 0-7[2] | 1.58±0.016a | 1.62±0.016a | 1.59±0.016a | 1.61±0.021a |
| 7-12 | 1.70±0.023a | 1.84±0.091a | 1.69±0.026a | 1.70±0.021a |
| 12-17 | 1.60±0.013a | 1.50±0.010a | 1.57±0.106a | 1.71±0.036a |
| 17-22 | 1.51±0.010a | 1.47±0.021a | 1.51±0.012a | 1.94±0.120b |
| 22-27 | 1.84±0.008a | 1.91±0.048a | 1.82±0.018a | 1.79±0.035a |
| 27-35 | 2.16±0.009a | 2.09±0.030a | 2.19±0.070a | 2.09±0.018a |
| 35-42 | 2.26±0.023b | 2.31±0.025b | 2.15±0.034a | 2.14±0.016a |
| 42-58 | 2.53±0.061b | 2.36±0.020a | 2.39±0.017ab | 2.39±0.035ab |
| 0-22 | 1.57±0.008a | 1.52±0.009a | 1.57±0.009a | 1.62±0.094a |
| 22-58 | 2.30±0.024b | 2.23±0.012ab | 2.23±0.014a | 2.20±0.014a |
| 0-58 | 2.15±0.020a | 2.11±0.009a | 2.12±0.011a | 2.12±0.012a |

a,b,c,d - means within a row not followed by the same letter are significantly different at $P<.05$.

1. See table 11 for explanation of treatments used.

2. Means ± standard error.

finisher phase (days 22-58). Since no significant differences in F/G were found in the starter phase and only marginal differences ($P<.05$) in the finisher phase were found, overall F/G ratios were not found to be significantly different from each other ($P>.05$).

c) **MORTALITY**

Mean percent total mortality and mean squares from the analysis of variance are found in appendices D-3 and M-3 respectively.

At no time during the trial were any significant differences in mortality noted. The overall mortality rate from day 0-58 was 5.71%, 5.31%, 4.49% and 4.69% for T1, T2, T3 and T4 respectively.

d) **CARCASS ANALYSIS**

Carcass analysis data are presented in table 20. Mean squares from the analysis of variance tables are found in appendix J-2.

Dressing percents of T3 and T4 were found to be significantly ($P<.05$) less than T1. This reflects an overall trend for dressing percent to decrease as the age at which feed restriction was imposed increased.

However, percent liver increased significantly ($P<.05$) as the age at which feed restriction was imposed was increased. This resulted in the percent liver of T4 to be significantly greater than T1 (1.50% vs. 1.39%; $P<.05$).

No significant treatment differences in abdominal fat or gastrointestinal tract weight were found, regardless of whether expressed as total weight or as a percent of live weight.

**TABLE 20. CARCASS DATA OF 64 AND 65 DAY OLD MALE BROILERS FED AD LIBITUM OR VARIOUS RESTRICTION REGIMES (EXPERIMENT 3)**

| PARAMETER | TREATMENT[1] | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| | g | | | |
| LIVE WT | 3353±38.4a[2] | 3214±50.6ab | 3155±28.6b | 3261±54.2ab |
| DRESS WT | 2379±26.9a | 2258±38.6b | 2204±21.5b | 2273±37.8ab |
| LIVER WT | 46.6±.75a | 46.8±.83ab | 46.9±1.1ab | 49.6±1.1b |
| FAT WT[3] | 117.6±5.08a | 111.8±6.86a | 105.1±4.53a | 111.6±6.06a |
| GI[4] WT | 172.3±2.80a | 169.4±3.95a | 167.1±3.06a | 175.9±3.92a |
| LEG SCORE | 1.59±0.03a | 1.59±0.03a | 1.56±0.03a | 1.62±0.03a |
| | %[5] | | | |
| FAT | 3.50±.143a | 3.43±.174a | 3.32±.128a | 3.41±.186a |
| GI | 5.15±.076a | 5.27±.092a | 5.30±.099a | 5.40±.090a |
| LIVER | 1.39±.021a | 1.46±.028ab | 1.49±.030ab | 1.50±.024b |
| DRESS WT | 71.0±.35a | 70.4±.37ab | 69.9±.21b | 69.7±.22b |

1. See table 11 for explanation of treatments used.
2. Mean ± standard error
3. Refers to the abdominal fat pad as described in table 10.
4. GI - gastro-intestinal tract refers to that located between the cloaca and the gizzard, but not including the proventriculus.
5. Expressed as a percent of live weight.

Legscore analysis did not reveal any significant differences between treatments, nor any consistent trends.

D. Effect of severe feed restriction at varying ages on dry matter digestibility of male broiler chickens raised in battery brooders (Experiment 4).

a) **MEAN BODY WEIGHTS AND WEIGHT GAINS**

Mean body weight and weight gain data are presented in tables 21 and 22 respectively. Mean squares from the analysis of variance tables are found in appendices E-4 and F-4 respectively. No significant differences in body weight were noted among treatments on day 0 or 7. As a result of the imposed feed restriction, the weights of T2, T3 and T4 became significantly ($P<.05$) inferior to those of the control birds and remained inferior to the end of the experiment. By day 22, the weights of T2 and T3 had become similar to each other as had the weights of T3 and T4.

No significant differences in weight gain were noted until the various treatment groups were placed on feed restriction on day 7, 12 or 17 for T2, T3 and T4 respectively.

During the periods of feed restriction, birds experienced weight losses and subsequent to being returned to ad libitum feeding, T2 weight gains remained significantly ($P<.05$) below T1 up to day 17. For days 17-22 weight gain was non-significantly lower than T1 (193 vs. 212 g; $P>.05$).

The weight gains of T3 and T4 subsequent to being returned to ad libitum feeding were not significantly ($P>.05$) different than those of control birds.

**TABLE 21. MEAN BODY WEIGHTS OF CAGE REARED MALE BROILERS FED AD LIBITUM OR VARIOUS RESTRICTION REGIMES (EXPERIMENT 4)**

| AGE (DAYS) | TREATMENT[1] 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 0 | 39.59±0.40a[2] | 39.74±0.28a | 39.72±0.42a | 39.82±0.64a |
| 7 | 90.15±2.60a | 90.91±2.88a | 90.15±2.68a | 92.17±0.89a |
| 12 | 184.14±5.16a | 88.74±3.18b | 182.86±5.33a | 190.15±0.95a |
| 17 | 340.31±7.40a | 223.30±6.93b | 172.33±4.04c | 347.26±2.86a |
| 22i | 552.45±25.3a | 416.27±11.3b | 374.62±8.39bc | 325.56±3.52c |
| 22ii | 543.13±38.6a | ---[3] | --- | 325.56±3.5b |
| 27 | 846.22±13.8a | --- | --- | 601.72±6.83b |

a,b,c - means within a row not followed by the same letter are significantly different at P<.05.

i,ii - On day 22 average weights were initially (i) calculated for all the birds in the pen. Subsequent to this, 2 birds were removed from all treatment 1 pens to equalize weights between reamining treatments. This resulted in different average weights (22ii).

1. See table 11 for explanation of treatments used.

2. Means ± standard error.

3. --- refers to periods during which no measurements were taken.

**TABLE 22. MEAN WEIGHT GAINS OF CAGE REARED MALE BROILERS FED AD LIBITUM OR VARIOUS RESTRICTION REGIMES (EXPERIMENT 4)**

| AGE (DAYS) | TREATMENT[1] 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 0-7 | 50.56±2.71a[2] | 51.24±2.73a | 50.43±2.34a | 52.35±0.90a |
| 7-12 | 93.99±2.97a | -2.23±0.47b | 92.71±2.89a | 97.99±0.33a |
| 12-17 | 156.17±2.99a | 134.56±3.87b | -10.53±1.77c | 157.11±2.31a |
| 17-22 | 212.15±19.5a | 192.97±4.37a | 202.29±4.69a | -21.70±1.27b |
| 22-27 | 303.09±30.5a | ---[3] | --- | 276.16±4.50a |

a,b,c - means within a row not followed by the same letter are significantly different at P<.05.

1. See table 11 for explanation of treatments used.

2. Means ± standard error.

3. --- refers to periods during which no measurements were taken.

b) **AVERAGE FEED CONSUMPTION AND FEED:GAIN**

Average feed consumption and feed:gain data are presented in tables 23 and 24 respectively. Mean squares from the analysis of variance tables are found in appendices G-4 and H-4.

Prior to being placed on feed restriction, no differences were noted in average feed consumption between any of the treatment groups. During the period of their respective feed restriction, average feed consumption was significantly (P<.05) less than all other treatments. Except for the 5 day period following feed restriction for T2 (days 12-17) when average feed consumption was significantly below that of T1 and T4 no differences in average feed consumption were noted for any treatment in the post-restriction period.

Feed efficiency was significantly (P<.05) poorer, when compared against T1, for each treatment group during their respective feed restriction periods. No significant differences in feed efficiency were noted in the post-restriction phase when compared to T1.

c) **PERCENT DRY MATTER DIGESTIBILITY**

Percent dry matter digestibility )PDMD) data are presented in table 25. Mean squares from the analysis of variance tables are presented in appendix K.

On day 7, no differences in PDMD were noted for any treatment group. Following 5 days of restricted feeding, (restricted from day 7-12) PDMD of T2 was significantly (P<.05) higher than either control (T1) or T3 and T4 (66.5 vs. 56.8, 58.7 and 57.9 % respectively). In the five days following the return of T2 to ad libitum feeding PDMD

**TABLE 23. AVERAGE FEED CONSUMPTION OF CAGE REARED MALE BROILERS FED AD LIBITUM OR VARIOUS RESTRICTION REGIMES (EXPERIMENT 4)**

| AGE (DAYS) | TREATMENT[1] 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 0-7 | 77.01±4.44a[2] | 77.93±4.11a | 77.75±2.36a | 83.17±3.83a |
| 7-12 | 160.92±6.26a | 30.42±0.64b | 155.96±4.69a | 164.97±3.99a |
| 12-17 | 252.98±2.68a | 184.41±5.40b | 49.06±0.94c | 248.36±7.10a |
| 17-22 | 317.23±3.79a | 296.33±6.21a | 291.12±6.53a | 79.49±0.42b |
| 22-27 | 478.95±9.05a | ---[3] | --- | 479.23±8.5a |

a,b,c - means within a row not followed by the same letter are significantly different at P<.05.

1. See table 11 for explanation of treatments used.

2. Means ± standard error.

3. --- refers to periods during which no measurements were taken.

**TABLE 24. AVERAGE FEED:GAIN RATIOS OF CAGE REARED MALE BROILERS FED AD LIBITUM OR VARIOUS RESTRICTION REGIMES (EXPERIMENT 4)**

| AGE (DAYS) | TREATMENT[1] 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 0-7 | 1.52±0.04a[2] | 1.52±0.04a | 1.55±0.04a | 1.59±0.07a |
| 7-12 | 1.72±0.08a | -19.34±6.22b | 1.68±0.03a | 1.68±0.04a |
| 12-17 | 1.62±0.04a | 1.37±0.01a | -6.03±1.76b | 1.58±0.03a |
| 17-22 | 1.19±0.23a | 1.28±0.02a | 1.20±0.01a | -3.12±0.28b |
| 22-27 | 1.64±0.13a | ---[3] | --- | 1.74±0.05a |

a,b - means within a row not followed by the same letter are significantly different at P<.05.

1. See table 11 for explanation of treatments used.

2. Means ± standard error.

3. --- refers to periods during which no measurements were taken.

increased the first day and then gradually decreased until by day17, it was no longer different from T1. On day 22, PDMD for T2 was somewhat reduced below the level of T1 although this was not significant.

On day 7, 12, 17 and 22, no significant differences in PDMD were found between T3 and T1. Subsequent to being returned to ad libitum feeding, PDMD improved on day 18 and then decreased gradually. This resulted in PDMD for T3 being significantly ($P<.05$) less than T1 on days 20 and 21.

On day 7, 12, 17 and 22, no significant differences in PDMD were found between T4 and T1. However, subsequent to being returned to ad libitum feeding on day 22, PDMD initially was significantly ($P<.05$) better than T1 on day 23 (75.8 vs. 71.4) whereas on day 24 no significant difference was found and from day 25-27, PDMD was significantly ($P<.05$) less than T1.

A general trend towards improved PDMD with age was also evident. The PDMD increased for 1 day and then declined immediately following the end of feed restriction. This increase in PDMD was significant ($P<.05$) only for T3. The decline in PDMD following the temporary 1 day increase, was significant for all restricted birds however, it was most evident for T4. Towards the end of the trial, there was an indication that PDMD was again improving in the feed-restricted birds.

**TABLE 25. AVERAGE PERCENT DRY MATTER DIGESTIBILITY[1,5] OF CAGE REARED MALE BROILERS FED AD LIBITUM OR VARIOUS RESTRICTION REGIMES (EXPERIMENT 4)**

| DAY | TREATMENT[2] 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 7 | 55.0±2.08aC[3] | 54.2±1.77aD | 56.1±1.45aC | 53.2±3.37aCD |
| 12 | 56.8±1.78bC | 66.5±1.23aABC | 58.7±0.61bC | 57.9±2.16bBCD |
| 13 | ---[4] | 70.6±0.29A | --- | --- |
| 14 | --- | 67.7±1.10AB | --- | --- |
| 15 | --- | 64.5±0.36BC | --- | --- |
| 16 | --- | 61.9±0.53C | --- | --- |
| 17 | 63.9±0.66aB | 62.5±0.68aC | 65.4±1.53aB | 64.3±0.03aABC |
| 18 | --- | --- | 72.51±0.7A | --- |
| 19 | --- | --- | 66.29±0.8B | --- |
| 20 | 68.1±1.19aAB | --- | 62.81±0.5bB | --- |
| 21 | 67.0±0.80aAB | --- | 63.3±0.68bB | --- |
| 22 | 68.2±0.60abAB | 64.3±1.01bBC | 66.5±0.99abB | 69.3±1.25aAB |
| 23 | 71.4±0.63bA | --- | --- | 75.8±0.40aA |
| 24 | 69.8±0.62aA | --- | --- | 68.9±1.18aAB |
| 25 | 70.8±0.98aA | --- | --- | 46.5±4.65bD |
| 26 | 70.9±0.54aA | --- | --- | 48.8±3.95bD |
| 27 | 71.0±0.53aA | --- | --- | 57.3±3.57bBCD |

a,b,c,d - means within a row not followed by the same letter are significantly different at P<.05.

A,B,C,D - means within a column not followed by the same letter are significantly different at P<.05.

1. Dry matter digestibility as determined by chromic oxide analysis of feed and excreta.

2. See table 11 for explanation of treatments used.

3. Means ± standard error.

4. --- refers to periods during which no measurements were taken.

5. Each value represents the average over the preceding period since the last excreta sample was taken.

d) **EXCRETA MOISTURE**

Excreta moisture data are presented in table 26. Means squares from the analysis of variance tables are presented in appendix M.

The data on percent excreta dry matter showed that the excreta from control birds was significantly ($P<.05$) drier than the excreta taken from feed restricted birds on both days that measurements were taken.

**TABLE 26. MEAN PERCENT EXCRETA DRY MATTER ON DAYS 26 AND 27 OF MALE BRAOILER CHICKENS FED AD LIBITUM OR VARIOUS RESTRICTION REGIMES (EXPERIMENT 4)**

| DAY | TREATMENT[1] | |
|---|---|---|
| | 1 | 4 |
| 26 | 46.3±1.78a[2] | 39.6±1.82b |
| 27 | 49.9±2.59a | 40.5±0.82b |
| average | 48.1±1.59a | 40.2±0.96b |

1. See table 11 for explanation of treatments used.

2. Means ± standard error.

# V. Discussion

## A. Effect of feed restriction imposed for 3, 6 or 9 days of age on compensatory weight gain, percent abdominal fat and blood serum parameters of male broiler chickens (Experiment 1).

### a) LEAST SQUARES MEAN WEIGHTS AND WEIGHT GAINS

The mean treatment weights at the end of the starter phase (day 20) were found to be significantly less as the number of days the birds were subjected to feed restriction increased from 0 (control) to 9 days (treatment 4). This difference in weights is directly related to the feed consumption during this period with those birds being restricted for the longest period of time (T4) consuming the least amount of feed and consequently having the lowest weights.

The average weight gain that was obtained during the starter phase was considerably greater than what had been anticipated for the feed restricted birds. Although feed allotments during the restriction period had been calculated to maintain body weight, considerable gains were recorded during every restriction period. Gains were also recorded by Plavnik and Hurwitz (1985) for birds restricted to maintenance energy intakes. The gains observed in experiment 1 were however, considerably greater than the 4 g/day reported by Plavnik and Hurwitz (1985) and ranged from 8.1 g/day (T2, day 8-11) to 15.8 g/day (T4, day 14-17). It was because of these large average daily gains during the restriction periods, that major changes were deemed necessary for subsequent experiments.

The daily gains of T3 and T4, which had the equivalent of 2 and 3 restriction periods of 3 days respectively, became progressively larger in each successive restriction period. Thus, for T3, the average gain increased from 9.3 g/day during the first restriction period to 11.3 g/day during the second period. Likewise, the average gains for T4 were 8.4, 10.7 and 15.8 g/day for the three successive restriction periods. This occurred despite the fact that the formula utilized to determine maintenance energy requirements was not changed and the feed allotment/g of body weight remained the same. It therefore appears that either the feed efficiency is improved with increasing length of feed restriction or that the maintenance energy coefficient (MEC) is reduced with prolonged feed restriction.

The MEC equation used was: $$MEC = \frac{EI - (C \times G)}{ABW^{2/3}}$$

where EI is the energy intake (kcal/day), C is the energetic cost of gaining 1 g of weight, G is the average weight gain (g/day) and ABW is the average body weight for the period (Plavnik and Hurwitz, 1985). A slight modification was made to this formula. Rather than assigning a value of 2 kcal/g (C) of gain regardless of age as Plavnik and Hurwitz (1985) had calculated, values of 1.5, 2.0 and 2.5 kcal/g were assigned for gains occurring during the periods of day 0-20, 20-35 and 35-42 respectively. This was based on values reported by Scott et al. (1982) who suggest that the cost of gain varies from 1.5 to 3 kcal/g depending on age. Results of this calculation are tabulated in appendix C-1. Means squares for the maintenance energy coefficents are found in appendix I-1.

During the periods of feed restriction, the MEC of the restricted birds was always significantly (P<.05) less than for control birds. It was also shown for T3 and T4, that the MEC continued to decrease as the feed restriction regime was extended to 6 and 9 days respectively. During the respective restriction periods, Plavnik and Hurwitz (1985) also found that the MEC of restricted birds was considerably lower than for the control birds. The MEC of restricted birds was found to decrease as the length of restriction increased. Results of experiment 1, confirm these findings. It thus appears that part of the reason that gains continued during periods of restricted feeding to maintenance energy requirements, is the lowering of the MEC.

In the overall post-restriction period (day 20-42), the weights of all the feed restricted birds were significantly (P<.05) less than for control birds except for T2, which on day 42 was not significantly (P>.05) different in weight from T1. Except for the period of day 20-28 when the gains of T3 and T4 were significantly (P<.05) less than T1, the post-restriction gains of all feed restricted birds was not different from T1.

Even though weight gains of feed-restricted birds generally were not different from T1, it was possible to demonstrate significant compensatory growth during several periods in the post-restriction phase of each restricted group of birds[1]. (Means of percent period gains are tabulated in appendix B-1 and least squares means from the analysis of variance are found in appendix F-9). The number of periods in which compensatory gain occurred however, seems to be related to the severity

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1. Compensatory gain is taken here to mean that the rate or percent body weight gain in a period is greater for the feed restricted birds than for control ad libitum fed birds in the same period.

of feed-restriction imposed. Thus, for T2, which was restricted for only 3 days, significant compensatory gain occurred only in the periods of day 11-14 and 20-28. For T3, significant compensatory gain was observed for the period of day 14-35 and for T4, for day 17-42. For T3 and possibly for T4, it appears that significant compensatory gain occurs for approximately 3 weeks following the end of feed restriction. This is similar to the results of Moran (1979) who, when feeding various protein restriction diets to broiler chicks, reported that compensatory growth was evident only for the first 2 weeks post-restriction.

In the present experiment, the overall percent weight gain from day 20-42 was significantly ($P<.05$) greater for T3 and T4 when compared against T1. Because of the short duration of the feed restriction for T2, it appears that although a significant weight set back occurs initially, that final weight is not significantly different from control birds. However, examining the percent weight gain between day 20 and 42 (appendix B-1) shows that no significant ($P>.05$) compensatory growth occurs.

A certain severity of feed restriction therefore appears to be required before the compensatory growth mechanism is activated.

b) **LEAST SQUARES MEAN FEED CONSUMPTION**

The formula used to calculate the daily energy requirements was based on that used by Plavnik and Hurwitz (1985) who suggested that daily energy requirements were 1.5 kcal/BW(g)$^{2/3}$. Since the birds used to estimate this equation were raised in cages, some allowance was to be made for the increased activity of floor raised birds. Based on values reported by Kendeigh (1970) an allowance of 26% was added to offset the expected increase in energy demand.

The experimental results indicated however, that this assumption was not entirely correct. Daily gains of 8.1 to 15.8 g/day during the restriction periods were considerably greater than the 4 g/day reported by Plavnik and Hurwitz (1985) and are due primarily to the 26% extra feed allotment.

Analysing the cumulative feed consumption by starter (d 0-20), finisher (d 20-42) or overall periods, revealed that there was a trend for feed consumption to decrease as the length of feed restriction was increased. Thus, the difference in cumulative feed consumption for the respective treatments diverged in the post-restriction phase. 49-58% of the differences in cumulative feed consumption between the restricted and control birds was due to the decreased feed consumption occurring during their respective restriction periods. The fact that these birds were not able to consume more than control birds in the post-restriction periods is in agreement with the work of Nir et al. (1978) and Marks and Brody (1984). These authors showed that it was not possible to force feed selected fast growing broiler strains much above normal feed intake values while non-selected slower growing broiler strain could be.

Considering that feed restricted birds in the post-restriction period were significantly lighter than control birds, expressing feed consumption as a percent of body weight (Appendix table A-1) would give a better indication of the differences in feed consumption. The percent feed intake (PFI) for T2 was significantly ($P<.05$) greater than T1 for days 11-17, while PFI for T3 and T4 was significantly greater than T1 in every post restriction period.

This comparison was further refined by comparing the PFI of feed-restricted birds with that of control birds at similar body weights by using linear interpolation of the control bird results tabulated in appendix A-1. This resulted in a reduction in the difference in PFI. Although statistical analysis was not possible across varying weights, periods and treatments, it appeared as if compensatory feed consumption for T2 remained the same as previously, while for T3 and T4 it was reduced to days 14-20 and 17-20 respectively.

Thus, birds in this experiment were not able to compensate for the feed consumption that was sacrificed during the feed-restriction pepriod by significantly altering their feed consumption patterns in the post-restriction phase . One can conclude that birds were at all times eating near the maximum feed that normally would be eaten by birds at similar stages of physiological developement.

c) **LEAST SQUARES MEAN FEED:GAIN RATIOS**

Except for T2, the feed:gain of birds during the initial 3 days of feed restriction was not significantly different from control birds. Even though all three restriction groups were treated equally, a significant ($P<.05$) difference was found between T3, and T2 or T4 (1.7 vs. 1.99 and 1.91). No satisfactory explanation for this could be found.

The feed:gain of restricted birds generally was less than for controls for the entire restriction period. The exception to this was T2 and T4 which were higher than the controls during the initial 3 days of restriction. This is generally in disagreement with the work of Moran (1979), Marks (1979), Beane et al. (1979), Leclercq and Saadoun (1982) and Mollison (1983) who found that feed:gain was higher during a variety of different restriction periods. The general improvement in the feed:gain of restricted birds continued through to the end of the experiment resulting in starter (day 0-20), finisher (day 20-42) and overall feed:gain ratios being progressively better as the length of the feed restriction was increased from 0 to 9 days.

This improvement in feed:gain ratios is most likely due to one of two reasons. Firstly, the calculated maintenance energy coefficients (appendix C-1) were reduced as the length of feed restriction was increased. This made it possible for broilers to more efficiently convert feed nutrients to gain. Secondly, and probably more importantly, the improved feed:gain ratios observed in the restricted birds is a reflection of the lower body weights. It is generally recognized, and becomes evident when the data of the control birds are analyzed, that feed:gain ratios become progressively worse as the birds gain weight. Therefore, it is probable that the feed:gain ratios of the restricted birds, which were lighter than the controls, would not have been different from the control birds if they had been marketed at the same body weight. That this may be the case is supported by the fact that overall feed:gain and final body weight for T1 and T2 were not significantly different.

d) **CARCASS DATA**

The liveweights of birds selected for slaughter analysis were not entirely indicative of the overall mean treatment weights. Thus, while treatment mean weights showed T1 and T2 not being significantly different, the liveweights of the birds selected for slaughter were. Therefore, since the actual weight of the carcass, liver and fat are linked to body weight, these parameters will be discussed only as a percent of final weight. This assertion is supported by the work of Deaton et al. (1981) who found that the percent abdominal fat did not change significantly between day 40 and 53. Sreemannarayana et al. (1986)[2] also showed that the liver, as a percent of body weight, decreased with age. However, when male and female Leghorns of the same age were compared, no differences were noted. Since age was common to all birds in experiment 1, it was deemed appropriate to compare these parameters on a percent of body weight basis.

Dressing percent tended to decrease as the length of feed restriction was increased. However, only T4 had a significantly lower dressing percentage than controls. This reduction in dressing percent for feed restricted birds was also found by Beane et al. (1979) and Mollison (1983).

Even though all treatment groups were of the same chronological age, feed restriction may have delayed the physiological developement of these birds. This would result in the relationship between various organ weights and body weight not being the same for all treatments.

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2. Sreemannarayana, O., A.A. Frohlich, R.R. Marquardt and W. Guenter. 1986. Department of Animal Science, University of Manitoba. Personal communications.

Sreemannarayana et al. (1986)[3] showed that the relative weights of heart, kidney, pancreas, liver and parts of the gastro-intestinal tract declined with age in female Leghorn chicks between the ages of 2 and 20 weeks. Since these organs are all removed prior to weighing the carcass, significant differences in dressing percent could arise if birds slaughtered were at different stages of physiological developement.

The percent liver weight was not significantly different between any of the treatments when expressed as a percent of live weight. However, there was a trend for the percent liver to increase as the length of feed restriction was increased. Pokniak and Cornejo (1982) also found a non-significant increase in the percent liver weight for birds that had been feed restricted from day 8 to 23. It appears therefore, that birds in a compensatory growth phase may have enlarged livers to facilitate the increased demand for protein and fat synthesis. Additional research detailing the rate of protein and fat synthesis in the liver of restricted compensating broilers needs to be conducted to further investigate this premise.

The percent abdominal fat was not signifcantly different between any of the treatment groups. The results of other experimenters are controversial with some showing a significant decrease in the percent abdominal fat (Mollison, 1983) while others showed a significant increase in the percent abdominal fat of restricted birds (Beane et al., 1979; Pokniak and Cornejo, 1982). The effect of feed restriction on the

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[3]. Sreemannarayana, O., A.A. Frohlich, R.R. Marquardt and W. Guenter. 1986. Department of Animal Science, University of Manitoba. Personal communication.

percent abdominal fat is related to the age at which feed restriction is imposed and on the severity of the restriction regime. Griffiths et al. (1977a), by restricting the caloric intake of broilers from 0 to 3 weeks of age could not demonstrate a significant difference in percent abdominal fat at 56 days of age. Arafa et al. (1983), restricting the caloric intake for the 10 days prior to marketing, achieved a significant reduction in the percent abdominal fat. The early caloric restriction of Griffiths et al. (1977a) could not produce a significant reduction in the percent abdominal fat at 56 days primarily because the degree of restriction was not severe enough. Pokniak and Cornejo (1982) required a reduction in feed intake of 45% from day 8 to 23 in order to effect a significant reduction in the 56 day abdominal fat pad weight. The degree of energy restriction in the first 20 days of experiment 1 ranged from 9% for T2 to 37% for T4. Thus, the severity of energy restriction resulting from feeding birds maintenance energy requirement only was not severe, or long enough to effect a significant reduction in the percent abdominal fat at market age.

e) **MORTALITY**

No significant differences in mortality were found between any of the treatments for either the starter, grower or overall periods. Although the percent mortality for T2 and T4 was lower than for the control and could thus suggest a possible link between mortality and feed restriction, the results of T3, which was intermediate in degree of restriction, did not support an overall trend.

f) **LEGSCORE**

Significant differences (P<.05) in final legscore were found between treatments. While the results of T2 and T4 might indicate a trend towards a reduced incidence of leg problems in feed restricted birds, the results of T3 did not fall into this pattern. This is contrary to what would be expected if there was indeed a trend in this direction. Therefore, based on these data, no conclusion can be made.

There are however, some experimental results that support the concept of reduced leg abnormalities in birds that have been fasted or fed a reduced energy diet. Edwards and Sorensen (1987) reduced the incidence of tibia dyschondroplasia (TD) significantly by fasting birds for 8 hours daily up to 20 days of age. Regression analysis revealed a significant decrease in TD with increasing number of days that birds were fasted. It is not clear however, whether these results would have remained to market age, since this experiment was terminated at 20 days of age.

g) **SELECTED BLOOD SERUM PARAMETERS**

Little information on the response of blood serum parameters to feed restriction could be found. Therefore, it was not possible to determine the age at which blood serum samples should be taken to maximize treatment differences, or for how long these differences would remain. An arbitrary age of 5 weeks was chosen. This appeared however, to be too long after the end of feed restriction to detect many differences if they had existed, since retrospectively, changes that occurred would likely be maximized shortly after the end of feed restriction.

It was expected at the outset however, that some differences in the levels of enzymes associated with protein and lipid metabolism and their associated metabolites would be affected by feed restriction. The theory was that feed restriction would for some period, alter the relative rates of protein and fat metabolism resulting in either decreased abdominal fat pad deposition, or increased rates of protein deposition.

The results of this experiment however, showed no differences in the serum parameters associated with lipid metabolism. Since it is known that percent carcass and abdominal fat is significantly reduced immediately following feed restriction and that this difference is often eliminated at the end of a trial following a compensatory phase (e.g. Pokniak and Cornejo, 1982), the lack of a significant response here may be due to the long interval between ending feed restriction and blood sampling.

Parameters associated with protein metabolism (total protein and uric acid) were significantly ($P<.05$) reduced in the feed restricted birds. The reduction in total protein of feed restricted birds is possibly due to one of two factors: either the rate of protein deposition was increased, or the amount of protein absorbed from the digestive tract was decreased. Although uric acid synthesis is known to correspond to protein intake (Skadhauge, 1983), the decrease found here was likely linked to the compensatory gain demonstrated by feed restricted birds. As a result, less nitrogen from deaminated proteins was being excreted as uric acid.

B. Effect of severe feed restriction at varying ages on compensatory weight gain and blood serum parameters of male broiler chickens (Experiment 2).

Although experiment 2 was not conducted in an absolutely uniform fashion, with the degree of feed restriction being increased with progressive treatments, the discussion will deal wherever possible with the trends that might be inferred from the data.

a) **MEAN WEIGHTS AND WEIGHT GAINS**

Although T2, T3 and T4 were all restricted for 5 days, the degree of feed restriction during these respective periods was increased for T3 and T4 to offset the excessive gains that were observed for T2 during its restriction period. The percent weight gain occuring for T2 during the restriction period was 29% or 7.2 g/day average daily gain. Although this was considerably less than the 47% gain of comparably restricted birds in experiment 1, it was still greater than the 4 g/day reported by Plavnik and Hurwitz (1985). Restricting the energy intake by another 13% for T3 resulted in average daily gains increasing to 9.7 g/day. However, the percent gain during this restriction period was reduced to 21 %. Since this was still unacceptably high, energy intake was reduced by another 23% for T4. This effectively reduced the average daily gain during the restriction period to 3.7 g/day which was in the acceptable range. As a result, the percent weight gain during the restriction period for T4 was only 5%.

During the finisher phase (day 22-43), mean weights of feed restricted birds remained significantly ($P<.05$) less than control birds for all periods so that at the end of the experiment, final weights between all treatments were significantly ($P<.05$) different.

The differences in final body weights between treatments was a reflection of not only the age at which feed restriction was imposed (with weight differences being larger for birds restricted at an older age), but also because the degree of feed restriction was increased for each successive age. Therefore, final weights can not be compared unequivocally.

No difference in weight gains were observed in any of the finisher periods. This resulted in overall grower gains not being different for any of the treatments.

The difference in weight between the control and restricted birds at the end of the feed restriction period were 73.2, 116.3 and 217.8 g for T2, T3 and T4 respectively. At the end of the trial, these differences were 70.4, 146.9 and 207.6 g for T2, T3 and T4 respectively. Thus, if compensatory weight gain is defined as the converging of growth curves to a common end weight, then none appears to have occurred here.

The age at which feed restriction is imposed is an important factor in determining whether complete compensation will occur. Birds restricted at a younger age should be more capable of compensating since they have a greater time in which compensation can take place. Wilson and Osborn (1960) state that restricting feed near the point of inflection for growth results in a more severe setback and consequently the animal is less likely to completely compensate. In this experiment, even T2 birds which were mildly restricted in comparison to T3 and T4, were not able to recover the gains sacrificed during the early restriction period. It is also possible, that a certain degree of feed restriction is required before compensatory mechanisms are triggered.

b) **AVERAGE FEED CONSUMPTION**

The calculated maintenance energy requirement during the restriction periods was progressively reduced in an effort to more closely define the requirements of practical, floor fed broilers. The formulae used for calculating the daily energy requirements were 1.5 $Kcal/kg^{2/3}$, 1.3 $Kcal/kg^{2/3}$ and 1.0 $Kcal/kg^{2/3}$ for T2, T3 and T4 respectively.

The formula used by Plavnik and Hurwitz (1985) for cage reared birds overestimated the requirements of the floor fed birds. Even though floor-fed birds are expected to be more active and thus have a greater existence energy requirement, the T2 birds in this experiment gained considerably more than intended. Some possible explanations for the greater gains exhibited by these birds is that some strain differences in metabolic energy requirements may exist. Although no experiments detailing differences in strain requirements could be found, Kuenzel and Kuenzel (1977) did find that Leghorn and broiler chicks had different basal metabolic requirements to 3 weeks of age. Also, birds on feed restriction in this experiment were found to be voraciously scratching in the litter for feed that had been spilled in previous periods. Thus, birds may have been conuming more feed than was intended. Since no quantification was made of this amount, it can not be stated conclusively whether this in fact represented a significant amount.

The overall feed consumption of restricted birds remained below control birds through to the end of the trial. The decrease in cummulative feed consumption as age of feed restriction increased was partly due to the increasing severity of feed restriction imposed on older birds. There is some indication that selected fast growing broilers are not as capable of overconsuming feed as are slower growing non-selected birds following periods of feed restriction (Marks and Broody, 1984). Therefore, some of the differences here may be related to this factor. Since birds were not able to consume significantly more feed than control birds, no compensatory gain could be expected unless the efficiency with which the birds utilized the feed was enhanced.

c) **FEED:GAIN RATIOS**

In the starter phase, significant differences in feed:gain were found. Although the degree of feed restriction was not the same for all treatments, feed:gain appeared to be numerically worse during periods of feed restriction. This poorer feed:gain during periods of feed restriction is similar to that found by Marks (1979), Beane et al. (1979) and Moran (1979). Subsequent to being returned to ad libitum feeding, the feed:gain ratios returned to levels similar to control.

d) **MORTALITY**

No significant differences in mortality rate were evident in the starter, finisher or overall periods.

One of the possible causative factors involved in mortality rate of chickens cited in Riddell and Springer (1985) is a fast growth rate. Therefore, if feed restriction stimulates the compensatory growth mechanism of broilers, then it might be suspected that mortality rate may be increased. However, since mortality rate and average daily gain in the post restriction phase were not affected by feed restriction, no conclusion can be made.

e) **SELECTED BLOOD SERUM PARAMETERS**

The results of the blood parameters analyzed for (table 16) show that only cholesterol was significantly affected by feed restriction for all treatments. The values found here of approximately 3.5 mMol/l for control birds are comparable to the values of Sreemannarayana et al. (1986)[4] for Leghorn chicks.

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4. Sreemannarayana, O., A.A. Frohlich, R.R. Marqurdt and W. Guenter. 1986. Department of Animal Science, University of Manitoba. Personal communication.

C. Effect of severe feed restriction at varying ages on compensatory weight gain and percent abdominal fat of male broiler chickens (Experiment 3).

a) **MEAN WEIGHTS AND WEIGHT GAINS**

Mean weights prior to feed restriction being imposed for each treatment were not significantly different from the ad libitum fed control birds. The mean weights at the end of the starter phase (day 22) were significantly different between all treatments. Even though T2, T3 and T4 were all restricted for 5 days, the effect of this feed restriction became more severe as the age at which feed restriction was imposed increased.

Since birds were restricted to maintenance energy intakes (which are calculated to support 0 weight gain), the birds restricted at an older age sacrifice a greater gain since the normal average daily gain is greater in older heavier birds.

When compared against the control birds during the respective restriction periods, T2, T3 and T4 gained 87.4, 122.9 and 209.7 g less respectively. Thus, at 22 days of age, 80-100% of the difference in weight between the restricted and control birds is accounted for by the weight sacrificed during the restriction period.

The average daily gains during the restriction periods ranged from 4.2 g/day for T2, to 8.9 g/day for T4. The results indicate that for T2, feed intake was closely regulated so that average gains were similar to the 4 g/day reported by Plavnik and Hurwitz (1985). However, the gains of T3 and T4 were considerably greater than for T2. This was not expected, since the formula utilized to calculate daily feed requirements was the same that had resulted in only 3.7 g/day gain (T4) in experiment 2. Although some differences in average daily gain were recorded, the % weight gain during the restriction periods were similar for all restricted birds (18, 17 and 11% for T2, T3 and T4 respectively).

That the gains in experiment 3 are somewhat greater than during experiment 2 could be related to one of two factors. Firstly, there was a slightly better feed efficiency observed possibly due to the difference in strain of birds used. Secondly, it is probable that the nutritional benefit derived from the feed was enhanced because of increasing the tallow and energy levels of the feed. The associative dynamic action of fats has been previously reported (Scott et al., 1982) where 10-15% more energy was deposited in chickens receiving higher levels of fat in the diet even though the metabolizable energy intake of the birds was not different.

This sparing of energy requirements during the restriction period seems to be lost in the post-restriction period. Immediately following each restriction period, the MEC of restricted broilers is significantly higher than for the control birds (appendix C-2). This trend towards increased MEC levels appears to continue to the end of the trial.

Since birds in the post-restriction period are in a compensatory phase, the increased MEC found could be related to an increased activity of metabolic tissues. As these tissues increase their metabolic rate (e.g. muscle tissues are increasing at a greater rate in feed restricted birds compared to controls as evidenced by the greater percentage period gains being exhibited), the associated maintenance costs will also be increased to support the increased metabolic turnover rate.

At the end of the experiment there were significant (P<.05) differences in body weight between T3 and T4, and T1. T2 and T1 were not significantly different, indicating that some compensatory gain must have taken place.

The differences between the body weights of restricted and control birds immediately after the restriction ended were 89.2, 123.6 and 206.9 g respectively for T2, T3 and T4. At the end of the experiment, the differences between control and feed restricted birds were 113.2, 123.6 and 123.4 g for T2, T3 and T4 respectively. Thus, even though T2 and T1 were not significantly different in body weight on day 58, the actual difference between their weights was 27% greater than it had been immediately post-restriction. A similar pattern of growth was also evident for T3, although the increase of the difference between their body weights was only 10%. The difference in the body weights between T4 and T1 immediately post-restriction and on day 58 is remarkably different. The difference in weight decreased from 206.9 to 123.4 g. Thus, the pattern of growth for T4 indicates that compensatory growth had occurred, while those of T2 and T3 were less clear.

Alternatively, comparing gains as a percent of initial period body weight (appendix B-3), reveals that feed restricted birds had significantly larger increases during all periods except day 35-42 when the % gain of T2 was the same as T1. As a result, the percent gain during the finisher phase was found to be significantly (P<.05) better for all the restricted birds (366, 441, 466 and 560 % for T1, T2, T3 and

T4 respectively).

Although finisher phase (day 22-58) average weights for restricted birds remained inferior to those of the ad libitum fed control birds, average treatment gains were not significantly different. The gain of T4 during this period was approximately 85 g greater than the other treatments, but due to the large standard error associated with this mean, it was not found to be different.

b) **AVERAGE FEED CONSUMPTION**

The formula for estimating the daily energy requirements was established in experiment 2 to approximate 1.0 kcal/$g^{2/3}$. Thus, birds in this experiment received only 66% of the daily energy allowed by Plavnik and Hurwitz (1985) and 53% of the energy allowed at the beginning of experiment 2.

The cumulative feed consumption during the starter phase reflected the age at which feed restriction had occurred, and the amount of time birds had to readjust to normal feed intakes. Thus, T2 which had been restricted the earliest and had the most time to readjust, had a starter feed consumption that was 21% less than control ($P<.05$). T4, which had just come off feed restriction on day 22, had a starter feed consumption 33% less than the control ($P<.05$).

Cumulating the feed consumption for days 0-58, shows that no significant ($P>.05$) difference exist between feed restricted birds, and that all feed-restricted birds had a significantly ($P<.05$) lower feed consumption than the control birds. Graphing the data (Appendix A-4), shows that although the cumulative feed consumption curves of feed-restricted birds converged, they did not converge with the curve of the control birds. In the feeding period immediately following the 5 day restriction period, feed consumption was 96.9, 94.9 and 97.3 % of ad libitum fed control birds for T2, T3 and T4 respectively. This is in agreement with Marks and Brody (1984), who found that selected fast growing birds do not have as great an ability to consume more feed than ad libitum fed control birds as do birds of non-selected broiler lines. They found that broilers on a skip-a-day feeding program, only consumed 95% as much feed on feeding days as the control birds.

Except for the last feeding period for T3 and T4 (day 42-58), feed consumption of all restricted birds remained below that of control birds. During the last period, feed consumption of T3 and T4 was numerically greater than control birds and may suggest, as did Marks and Brody (1984), that birds subjected to feed restriction at an older age may be more capable of compensating during the refeeding period.

Considering that restricted birds were lighter in the post-restriction period, it may be more appropriate to compare feed intake as a percent of average period body weight (PFI). These values are tabulated in appendix A-2. Expressing feed intake in this manner shows that feed restricted birds consumed significantly (P<.05) greater amounts of feed in every post-restriction period except for days 42-58 when the PFI of T2 was not different from T1.

c) **FEED:GAIN RATIOS**

During the starter phase (day 0-22), no significant differences in feed:gain could be found. There was a trend however, for the feed:gain to be worse during the periods of feed restriction. This increased feed:gain during periods of feed restriction is in agreement with the results of Marks (1979), Bean et al. (1979), Moran (1979), Leclercq and Saadoun (1982) and Mollison (1983). This poorer feed:gain during periods of nutrient restriction was due to a larger portion of feed intake going to meet maintenance requirements (Titus, 1949). Subsequent to being returned to ad libitum feeding, the feed:gain of restricted birds became better than control birds. As a result, starter feed:gain ratios reflect the length of time the birds had to recover from feed restriction. Therefore, T2, which had the greatest time to recover by day 22, showed a reduction on overall feed:gain. T4, however, since it had not had time to recover from the feed restriction that had just ended on day 22, showed a feed:gain that was poorer than T1.

The post-restriction improvement in feed:gain was also found by Marks (1979) who reported a numerically, but not significant, improvement in feed:gain following an 85% feed restriction regime.

This general improvement in feed:gain continued through the finisher phase resulting in a significantly ($P<.05$) lower ratio for T3 and T4 compared to T1. The improved feed:gain found in the finisher and overall periods, was similar to that found by Marks (1979) following 2 weeks of protein restriction. Marks states however, that this apparent improvement in feed:gain quite likely is due to a reduced body weight at marketing. The reasoning for this is that the feed:gain ratio generally becomes poorer with increasing age and therefore would correlate well with weight. Thus, looking at the feed:gain pattern of the control birds, it becomes obvious that the feed:gain ratio in the starter phase is much better than in the finisher phase. In the present experiment, the improvement in feed:gain for feed restricted birds was accompanied by a slight reduction in final body weight. Therefore, the beneficial effect of reduced feed:gain may not be the direct result of feed restriction altering feed efficiency, but rather it may be a secondary effect of delayed physiological growth.

d) **MORTALITY**

No significant differences or trends in mortality could be found in either the starter, finisher or overall periods.

e) **LEGSCORE**

At the end of the trial, a legscore determination was made for each bird. Although a large number of birds were analysed, no significant differnces or trends could be determined. The legscores for the different treatments were 1.59, 1.59, 1.56 and 1.62 for T1, T2, T3 and T4 respectively.

A scoring system of 1-3 was used, based in part on the work of Stevens et al. (1984). The assessment of which score should be given each bird was often difficult owing to the fact that only 3 values could be assigned. A scoring system with more scoring values may be more descriptive, but the time involved to score 1900 broilers would be prohibitive.

f) **CARCASS DATA**

The weights of birds used for the slaughter analysis closely reflected the weight differences observed for all the birds at the end of the trial. However T4, was slightly heavier in the slaughtered birds resulting in these birds not being different (P>.05) in weight from T1. Half of the birds kept for carcass analysis were slaughtered 6 and 7 days after the end of the trial. It is possible therfore, that the significantly (P<.05) superior gains exhibited by T4 for the period of day 42-58 continued, resulting in the slaughtered T4 birds no longer being different from T1.

Dressing percent of restricted birds became progressively poorer as the age at which feed restriction was imposed increased. This resulted in T3 and T4 having a significantly (P<.05) lower dressing percent than the control birds.

Similar results were obtained by Mollison (1983) and Beane et al. (1979). It might be suspected that these differences in dressing percent are a result of differences in the weight of the eviscerated parts since the proportions of these in relation to overall body weight change with increasing age. Sreemannarayan et al. (1986)[5] found a reduction in the relative weights of heart, kidney, pancreas, liver and parts of the gastro-intestinal tract in female Leghorn chicks between 2 and 20 weeks of age. If birds were significantly delayed in their physiological developement by feed restriction, then differences in dressing percent could be expected since these organs are all removed

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[5]. Sreemannaryana, O., A.A. Frohlich, R.R. Marquardt and W. Guenter. 1986. Department of Animal Science, University of Manitoba. Personal communication.

prior to weighing the carcass. However, the results from the present experiment show that no significant differences exist in the weight of the gastro-intestinal tract and that the significant differences in liver weight accounted for only a very small portion of the difference in the body weights. Since significant differences in dressing percentages were found, it must be concluded that even though large differences in the gastro-intestinal tract weight, liver weight and abdominal fat weight were not found, that differences in these and other eviscerated tissues were sufficiently large enough in combination so that a significant difference in dressing percent was found.

Significant ($P<.05$) differences in the percent liver were found, with the percent liver increasing progressively as the age at which feed restriction was imposed increased. Birds in a compensating phase appear to increase the size of the liver to facilitate the increased demand for protein and fat synthesis. However, Lilburn et al. (1982), could not find a significant difference in percent liver between a lean and obese line of broilers. Thus, increased fat synthesis associated with fat broilers did not require an increased liver size.

No significant differences in the percent gastro-intestinal weight could be found between any of the treatments. Pokniak and Cornejo (1982) restricted broilers from day 8-23 and found that immediately after the end of feed restriction the percent gastro-intestinal tract weight was significantly ($P<.05$) less for the feed restricted birds. This is directly related to the fact that reduced feed intake does not require the same gut capacity. Therefore, if significant changes in feed consumption are found, then it could be expected that significant changes in the weight of the gastro-intestinal tract would occur as well. However, by the end of the experiment on day 58, no differences remained. This lack of difference in the weight of the gastro-intestinal tract is most likely a reflection of the fact that no significant differences in feed consumption were found. In the present experiment, no significant differences in feed consumption were found in the post-restriction phase (day 22-58). McCartney and Brown (1977) used a limited time feed restriction regime (15 minutes feed/4 hours to market) for male broilers and found that the percent gastro-intestinal tract was significantly (P<.05) greater for those birds on this feed restriction regime. No feed consumption data was presented however, so it is not known if this increased percent gastro-intestinal weight was the result of increased feed consumption which is known to increase gut capacity and weight.

No significant (P>.05) differences or trends in percent abdominal fat (PAF) could be found between any of the treatment groups even though research supporting the concept of reduced fat in feed restricted broilers was found by Arafa et al. (1983), Simon and Brisson (1972) and Plavnik and Hurwitz (1985). Arafa et al. (1983) restricting the caloric intake 10 days prior to market found a significant (P<.05) reduction in the PAF. However, Griffiths et al. (1977a), restricting the caloric intake of young broilers (0-3 weeks) could not find any significant effect on abdominal fat pad at market age.

Pfaff and Austic (1976), working with pullets, determined that feed restriction limited adipose tissue accumulation but did not permanently alter the cellularity of the abdominal fat pad. Hood (1982) reported that both hyperplastic and hypertrophic growth of fat cells occurs up to 14 weeks of age in broiler-type chickens. Hyperplastic growth is of greater importance in younger birds while hypertrophic growth of fat cells becomes more important as the bird ages. Thus, while feed restriction may have arrested hypertrophic growth temporarily in the experiments of Griffiths et al. (1977a), hyperplastic growth continued. It appears that sufficient time was allowed after the end of feed restriction for hpypertrophic growth to elicit normal adiposity at market age. Therefore the age at which feed restriction is imposed plays an important role in determining the effect that feed restriction has on abdominal fat pad deposition since the relative rates of hyerplasia and hypertrophy change with age. According to Hood (1982), cell numbers increase linearly to approximately 12 weeks of age and cell size similarily, exhibits a linear increase to about 15 weeks. Hood and Allen (1977) state that adiposity is positively correlated with cell volume and not the number of cells present. Thus, although it was surmised that restricting broilers from day 17-22 (T4) may have reduce the PAF because of the greater importance of hypertrophy at this age than in birds restricted at a younger age, this was not found to be the case.

Thus, the question of age and severity of feed restriction needs to be investigated further before any conclusive statements can be made.

D. Effect of severe feed restriction at varying ages on dry matter digestibility of male broiler chickens raised in battery brooders (Experiment 4).

The experiment was designed to evaluate the percent dry matter digestiblity (PDMD) (by chromic oxide indicator method) of male broilers prior to, during and after being subjected to severe feed restriction.

a) **MEAN WEIGHTS AND WEIGHT GAINS**

Prior to feed restriction, all birds had equal weights. As a result of feed restriction, weights at the end of the starter period (day 22) were significantly less for restricted (T2, T3 and T4) than for control birds (T1).

The gains during the starter phase were significantly less during the periods of feed restriction. The formula that had been used in experiment 3 to estimate the maintenance energy requirements (1.0 $Kcal/g^{2/3}$) was found here to result in weight loss. Average daily gains were -0.45, -2.11 and -4.34 g/day for T2, T3 and T4 respectively during the periods of feed restriction. This weight loss was very different from the modest 4 g/day gain obtained by Plavnik and Hurwitz (1985) who had used the formula of 1.5 $Kcal/g^{2/3}$ for cage-reared broilers. The losses in weight occurring here are in contrast to the large positive gains made in experiment 3. T4 in experiment 3 gained 8.9 g/day during the restriction period. The reason for this large difference in response to the same level of feed restriction is not entirely clear. However, since caged birds do not have access to litter, spilled feed or excreta as do floor raised birds, it is possible that the inability to recycle these, may have accounted for part of the large reduction in gains seen during the feed restriction periods of this experiment.

The possibility exists that the caloric value of the diet was overestimated, therby supplying less energy than expected. However, the calculated MEC values during the restriction periods (1.01, 1.12 and 1.22 for T2, T3 and T4 respectively) agree well with the value of 1.00 obtained by Plavnik and Hurwitz (1985), and thus supports the caloric value calculated for the feed.

Subsequent to being returned to ad libitum feeding, the average weight of resticted birds remained significantly ($P<.05$) below that of control birds. Except for the period of day 12-17 for T2, post-restriction weight gains were not significantly different between restricted and control birds. Weight gains of T2 in the period immediately following restriction was significantly less than control, indicating that, contrary to the results of T3 and T4, the degree of restriction was severe enough to significantly set back average gains temporarily.

## b) **AVERAGE FEED CONSUMPTION**

Average feed consumption patterns were similar to those of average gains. Except for the period of day 12-17 when the feed consumption of T2 was significantly ($P<.05$) less than control, post-restriction feed consumption of previously feed-restricted broilers was not significantly different from controls. The ability of birds in the post-restriction phase to consume as much feed as control birds even though body weights had been retarded, is an indication of compensatory feed consumption.

c) **FEED:GAIN RATIOS**

Due to the weight losses occurring during the feed restriction periods meaningful feed:gain ratios could not be calculated. In the post-restriction phase, feed:gain ratios were not significantly different from control birds except for T4 which had a significantly worse feed:gain ratio immediately following the period of feed restriction. The poor feed:gain ratios found during periods of feed restriction have been reported by numerous researchers (Moran, 1979; Marks, 1979; Mollison, 1983). The significantly worse feed:gain of T4 following feed restriction is possibly due to the large weight loss that occured during the feed restriction period.

Nutrient restriction may have been of such a severity that the intestinal integrity and the ability to absorb nutrients were adversely affected. There is some controversy as to the effect that feed restriction has on intestinal integrity. Bayer et al. (1981) found significant increases in the amount of epithelial damage resulting from feed restriction. Peer et al. (1984) however, could not find any significant effect and attributed part of the differences in results on the post mortem degeneration that occurs if samples are not taken immediately. The results of the current experiment could indicate that T4 birds were less able to utilize the feed. A possible reason for this is that nutrients in the post-restriction period may have been diverted to regenerating damaged epithelial tissues at the expense of growth.

Thus, although total gains for this period were not significantly different, the marginally lower gains and marginally greater feed consumption combined to significantly ($P<.05$) affect the feed:gain during this period.

d) **EXCRETA MOISTURE**

During the course of the experiment, it became evident that the moisture content of excreta from restricted birds appeared to be increased during and following feed restriction. Marks and Washburn (1983) found that water consumption of broilers remained the same as for control birds even though several forms of feed restriction were employed. As a result, the water:feed ratio was increased. However, when feed restriction was removed, the water:feed ratios returned to normal. Although Marks and Washburn (1983) did not report any values for excreta moisture in their experiment, it is conceivable that the increased water:feed ratios would have increased the moisture content of the excreta.

Although excreta moisture was measured only on days 26 and 27, the indications are that excreta dry matter for T4, was significantly ($P<.05$) less than control birds on days 4 and 5 after the feed restriction period. The reasons for these results are not clear at this time.

e) **PERCENT DRY MATTER DIGESTIBILITY (PDMD)**

No significant differences in PDMD were found between control and any treatment groups prior to being placed on feed restiction.

Excreta collections during the restriction period were not possible on a daily basis due to the small amount of excreta voided. Therefore, pooling the excreta material for the entire period and analysing for PDMD revealed that PDMD was numerically greater during the feed restriction periods. This difference was significant (P<.05) for T2.

Teeter and Smith (1985) similarly found that increasing the feed intake from 75 to 160% resulted in a significant decrease in ration digestibility. The digesta passage rate was not affected over this range. Therefore, reducing the feed intake from 100% (T1, control) to approximately 20% (restricted intake) in this experiment, may have increased the ration PDMD to a similar or greater extent than the significant increase found by Teeter and Smith (1985) when they reduced the intake from 100 to 75%.

There was a significant trend for PDMD to improve with age in the control birds. The initially poor PDMD is the result of the digestion capabilities of the newly hatched chick not being fully developed or activated. Initially, the nutriture is still being supplied by the vestiges of the yolk sac. As increasing amounts of carbohydrates, proteins and lipids are consumed, the enzymes required for their digestion adapt and increase in activity to approximately 5-8 days post hatch. Adaptation to lipids in the diet may continue up to 8 weeks of age (Moran, 1985; Krogdahl, 1985; Austic, 1985).

Overall, this trend towards improved PDMD was also evident for the restricted birds. Immediately following feed restriction, the PDMD was numerically increased for all restricted groups. This increase was significant (P<.05) only for T3. The reason for this increase in PDMD upon refeeding is not clear, but could be related to the passage rate of feed. With the gut not being stimulated as much during the previous 5 days of feed restriction, it is possible that gut mot*lity was slowed down in an effort to enhance nutrient absorption. If this is the case, then the initial increase in PDMD seen in the first day post restriction could be a vestige of this state, and that the declines seen subsequent to this are a result of an overly increased passage rate or a temporary or permanent reduction in the ability of the intestinal tract to absorb feed. That this is a temporary effect is supported by the results of T2 and T3, where the PDMD increased again after an initial decline. However, the results of T4 indicate that the reduced PDMD was much more severe and longer lasting and may have been a primary reson for the inferior F/G seen in the post-restriction phase.

Further trials using a non-soluble colorimetric indicator would be required to better define this response.

# VI. GENERAL DISCUSSION

In reviewing the literature on the effects that feed restriction has on compensatory gain and abdominal fat pad deposition, it appears that no clear consensus exists. The concept of compensatory gain seems to be ill defined and controversial. Likewise for abdominal fat pad deposition, there are conflicting reports as to whether feed restriction plays an important role.

## A. COMPENSATORY GAIN

The results of experiment 1 were not in agreement with those of Plavnik and Hurwitz (1985) who reported that birds restricted for 6 or 10 days to maintenance energy levels still attained the same final body weights at 8 weeks of age as control birds. Using linear interpolation of percent gains for birds in experiment 1, indicated that if birds had been restricted for between 3 and 6 days they would have exhibited sufficient compensatory gain to attain the same final body weights as control birds. However, the degree of feed restriction was not as severe as desired and thus gains during the periods of restriction were larger than desired. The reasons for these larger gains are possibly related to 3 factors. Firstly, an increased energy allowance was made due to the expected increase in requirements of floor raised birds in comparison to the cage-reared birds that Plavnik and Hurwitz (1985) used. This allowance was too generous. To correct this, the feed allowed for each successive restriction group in experiment 2 was fed less feed until an acceptable level was determined that would result in weight maintenance only. This was then used in experiment 3.

A second reason for the greater than expected gains in restricted birds is related to the fact that floor fed birds have access to spilled feed and excreta that can be recycled. The results of experiment 4, where birds maintained in cages lost weight on the same formula used in experiment 3 confirm this.

A third reason may be that an error in calculating the energy value of the feed had occured also resulting in greater weight gains than expected. If in experiment 3 the energy value of the feed had been underestimated, then birds would in actual fact be consuming greater amounts of energy than calculated. This would have resulted in greater gains than anticipated. The calculated energy value of the feed, and hence the average energy consumption were, however, correct. This is based on the maintenance energy coefficients (MEC) calculated during the restriction periods of experiment 4 (1.00, 1.16 and 1.22 for T2, T3 and T4 respectively). These are almost identical to the values of Plavnik and Hurwitz (1985) who reported a calculated MEC of 1.04 for birds restricted for days 7-14. This compares favourably with the 1.00 of birds in experiment 4 that were restricted for days 7-12. That the values of the MEC increases with age was also expected since Kuenzel and Kuenzel (1977) report that the basal metabolic rate of broiler chickens increases to 3 weeks of age.

The weight of birds per se is not an absolute guage by which to measure compensatory gain.

Compensatory gain has usually been defined as having occurred when birds, subsequent to a period of undernutrition, achieve or exceede the body weights of non-restricted control birds (e.g. Auckland and Morris, 1971a,b). The overcompensation that has been found in turkeys has not been found with broilers. This is due mostly to the earlier age at which broilers are marketed. A second method of expressing compensatory gain was used by Pokniak and Cornejo (1982) and Pokniak et al. (1984). They expressed compensatory gain as the relative percent increase in body weight of feed restricted birds compared to control birds over the entire post-restriction period. A third way of describing compensatory gain was used by Auckland et al. (1969). They described compensatory gain (or percentage relative growth rate per day) for the entire post restriction period as being

$$\frac{\log_e \text{(final weight)} - \log_e \text{(weight at end of restriction)}}{\text{number of days between weights}}$$

As mentioned in the literature review, in order for compensatory gain to be significant, daily gain, or percent gain must be greater for all or a portion of the post restriction phase.

In the current experiments, the average gains in the various post restriction periods were generally not of sufficient magnitude to result in restricted birds achieving the same final body weight as control birds. Only for birds restricted at an early age were final weights the same as for control birds.

The results of experiment 1 and 3 indicate that two important factors determine whether final weight of restricted birds will be the same as for control birds. Firstly, the degree of feed restriction in experiments 1 and 3 are quite different. Feed consumption was on average reduced to 40.2 and 21.7% of ad libitum fed broilers during the respective feed-restriction periods of experiments 1 and 3 respectively. As a result, the absolute differences in weight between control and restricted birds in the post-restriction period were larger in experiment 3 than for experiment 1. In experiment 3 feed restricted birds required a longer period of time to achieve the same final weights as control birds than in experiment 1 because the feed restriction was more severe.

The second factor that determines whether final weights will be similar for restricted and ad libitum fed birds, is the length of time allowed for re-alimentation following feed restriction. Thus, if birds in experiment 1 had been grown to 58 days, final weight of restricted birds would have more closely resembled those of control birds. This becomes even more probable when it is considered that the degree of feed restriction in experiment 1 was considerably less severe than in experiment 3.

Although the gains in experiments 1 and 3 generally were not different from control birds, the percent gains during the post restriction periods were. This is in agreement with the work of Pokniak and Cornejo (1982) and Pokniak et al. (1984). Whereas these researchers reported the percent gain only for the overall post-restriction period, the results of experiments 1 and 2 were calculated for each individual period in the post restriction phase. Thus, it was possible to examine the patterns of compensatory gain in the post-restriction periods. This pattern showed that the percent gain was most pronounced in the initial post-restriction period and that subsequently, the percent gains were reduced as the time after feed restriction increased.

If the percent gains for restricted birds are compared to the percent gains exhibited by control birds at similar weights, then the differences between the two are reduced. Although no statistical analysis was done across periods, lighter birds generally exhibited larger percentage gains.

## B. ABDOMINAL FAT PAD

Numerous researchers have found that feed restriction reduces the percent abdominal fat (Plavnik and Hurwitz, 1985; Arafa et al., 1885; Mollison, 1983).

No significant differences in abdominal fat were found in either experiment 1 or 3. In experiment 1, this lack of response was probably due to the fact that feed restriction was not as severe as desired. Therefore, unlike Plavnik and Hurwitz (1985), no differences were found. Although no differences in abdominal fat were found for experiment 3, the results indirectly support those of Pfaff and Austic (1976) who showed that feed restriction did not permanently reduce the number of fat cells. Since hypertrophy is the major means of fat accretion after about 28 days of age, these birds had sufficient time in the post restriction period to equalize the abdominal fat weight as evidenced by the lack of significant differences between treatments. Therefore, while significant differences in abdominal fat likely were evident at the end of feed restriction, these differences had disappeared at market age as was the case for Pokniak and Cornejo (1982).

The physiological basis for the effect that feed restriction has on abdominal fat pad deposition is far from clear. Factors that may affect the magnitude of changes in abdominal fat in response to feed restriction include age at which it is imposed, severity, duration and possibly a difference in response due to the strain of bird used.

Thus, while significant differences in abdominal fat have been reported by various researchers, it remains to be determined why greater unanimity in response to feed restriction is not found.

# VII. SUMMARY AND CONCLUSIONS

Four experiments were conducted to evaluate the phenomenon of compensatory gain and how it is affected by age at which feed restriction is imposed and its severity. The effect that feed restriction has on abdominal fat pad deposition, serum blood parameters and dry matter digestibility were also investigated.

## A. COMPENSATORY GAIN

1. Significant compensatory gain was demonstrated by all feed restricted birds. Compensatory gains appeared to be more intense immediately following the end of feed restriction.

2. Birds restricted at a younger age appeared more capable of demonstrating enough compensatory gain so that final weights were not different from control birds.

3. The negative effect that severe feed restriction at an older age has on final weight, preclude its use as a practical management tool at this time.

## B. ABDOMINAL FAT PAD

1. Under the conditions that these experiments were conducted, abdominal fat was found not to differ between treatments at market age.

## C. BLOOD SERUM PARAMETERS

1. Alkaline phosphatse was significantly ($P<.05$) reduced for birds restricted from day 7 while aspartate aminotransferase was was significantly ($P<.05$) increased for birds restricted from days 12 and

17 in experiment 2. Although the results are not conclusive at this time they may aid in elucidating the physiological basis of any changes in the pattern of abdominal fat pad deposition that may occur.

2. Serum uric acid was significantly ($P<.05$) reduced in experiment 1, and for birds restricted from day 7 in experiment 2.

3. Cholesterol was significantly ($P<.05$) reduced for all restricted birds in experiment 3.

D. **DRY MATTER DIGESTIBILITY**

1. Results show that feed restriction has a significant effect on percent dry matter digestibility during and after feed restriction.

2. This effect seems to be most dramatic in birds restricted from day 17. A significant depression in PDMD following feed restriction was found.

E. **AREAS FOR RESEARCH IMPLICATED BY THESE EXPERIMENTS**

1. There seems to be a lack of uniformity in describing the phenomenon of compensatory gain. A concerted effort needs to be made to develope a fair and equitable measure by which compensatory gain can be evaluated.

2. The results of these experiments indicate that changes in dry matter digestibility occur during and after feed restriction. Further research into this phenomenon needs to be made to determine under what conditions and in response to what factors these changes occurred.

3. There does not appear to be much data on the effect of feed restriction on blood parameters. If the physiological basis for the

response to feed restriction is to be determined, more studies in this area need to be made. Specifically, a) in what time framework these changes occur b) whether these changes are important in altering the protein or lipid metabolism and c) whether these changes are permanent or temporary.

4. The effect of varying the length of feed restriction at different ages needs to be determined so that the importance of age of restriction can be better understood.

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## APPENDIX TABLES - GENERAL INFORMATION

List of treatments and abbreviations used in the appendix tables.

### A. TREATMENTS USED:

a) Experiment 1. Treatment 1 (T1) - ad libitum fed control birds; treatment 2 (T2) - restricted for days 8-11; treatment 3 (T3) - restricted for days 8-14; treatment 4 (T4) - restricted for days 8-17.

b) Experiments 2, 3 and 4. Treatment 1 (T1) - ad libitum fed control birds; treatment 2 (T2) - restricted for days 7-12; treatment 3 (T3) - restricted for days 12-17; treatment 4 (T4) - restricted for days 17-22.

### B. ABBREVIATIONS USED:

AFC - average feed consumption

AGN - average period gain

AVWT - average weight

GI - gastrointestinal tract

LEG SC - leg score

MEC - maintenance energy coefficients

M - refers to the statistical model used in experiment 4 and includes treatment, block and treatment*block interaction.

PCG - weight gain as a percent of average period weight

PFI - feed intake as a percent of average period weight

T = treatment

E - error

22i - refers to the average prior to 2 birds/pen from T1 being removed for the final period (day 22ii - 27)

APPENDIX A. FEED INTAKE AS A PERCENT OF AVERAGE PERIOD BODY WEIGHT OF MALE BROILERS FED AD LIBITUM OR RESTRICTED FOR VARIOUS PERIODS (PFI).

TABLE A-1. AVERAGE PFI OF MALE BROILERS FOR EXPERIMENT 1.

| | TREATMENT | | | |
|---|---|---|---|---|
| PERIOD | 1 | 2 | 3 | 4 |
| 8-11 | 21.7±0.30a[1] | 10.8±0.37b | 10.9±0.37a | 10.9±0.37a |
| 11-14 | 18.4±0.15b | 21.1±0.19a | 8.9±0.19c | 8.9±0.19c |
| 14-17 | 17.8±0.13c | 18.8±0.16b | 22.1±0.16a | 7.5±0.16d |
| 17-20 | 16.4±0.12c | 16.9±0.15c | 18.3±0.15b | 22.3±0.15a |
| 20-28 | 13.9±0.08c | 14.2±0.10c | 14.9±0.10b | 15.8±0.10a |
| 28-35 | 10.6±0.07c | 10.7±0.08c | 11.3±0.08b | 11.9±0.08a |
| 35-42 | 8.9±0.08c | 8.7±0.10bc | 9.0±0.10b | 9.5±0.10a |

a,b,c,d - means within a row not followed by the same letter are significantly different at $P<.05$.

1. Means ± standard error.

See page 134 for explanation of abbreviations and treatments used.

TABLE A-2. AVERAGE PFI OF MALE BROILERS FOR EXPERIMENT 3.

| | TREATMENT | | | |
|---|---|---|---|---|
| PERIOD | 1 | 2 | 3 | 4 |
| 7-12 | 21.4±0.23a[1] | 6.0±0.04b | 21.3±0.23a | 21.4±0.19a |
| 12-17 | 16.7±0.22c | 22.7±0.24a | 4.8±0.03d | 18.5±0.28b |
| 17-22 | 14.9±0.12c | 16.1±0.15b | 18.9±0.10a | 4.1±0.02d |
| 22-27 | 14.1±0.07c | 15.3±0.20b | 14.8±0.80bc | 18.6±0.34a |
| 27-35 | 11.6±0.05b | 12.7±0.11a | 13.0±0.43a | 12.9±0.09a |
| 35-42 | 9.4±0.07c | 10.1±0.05b | 10.4±0.14ab | 10.7±0.12a |
| 42-58 | 6.6±0.10c | 6.9±0.06bc | 7.2±0.11ab | 7.3±0.10a |

1. Means ± standard error.

a,b,c,d - means within a row not followed by the same letter are significantly different at P<.05.

See page 134 for explanation of treatments and abbreviations used.

TABLE A-3. AVERAGE PFI OF MALE BROILERS (EXPERIMENT 4).

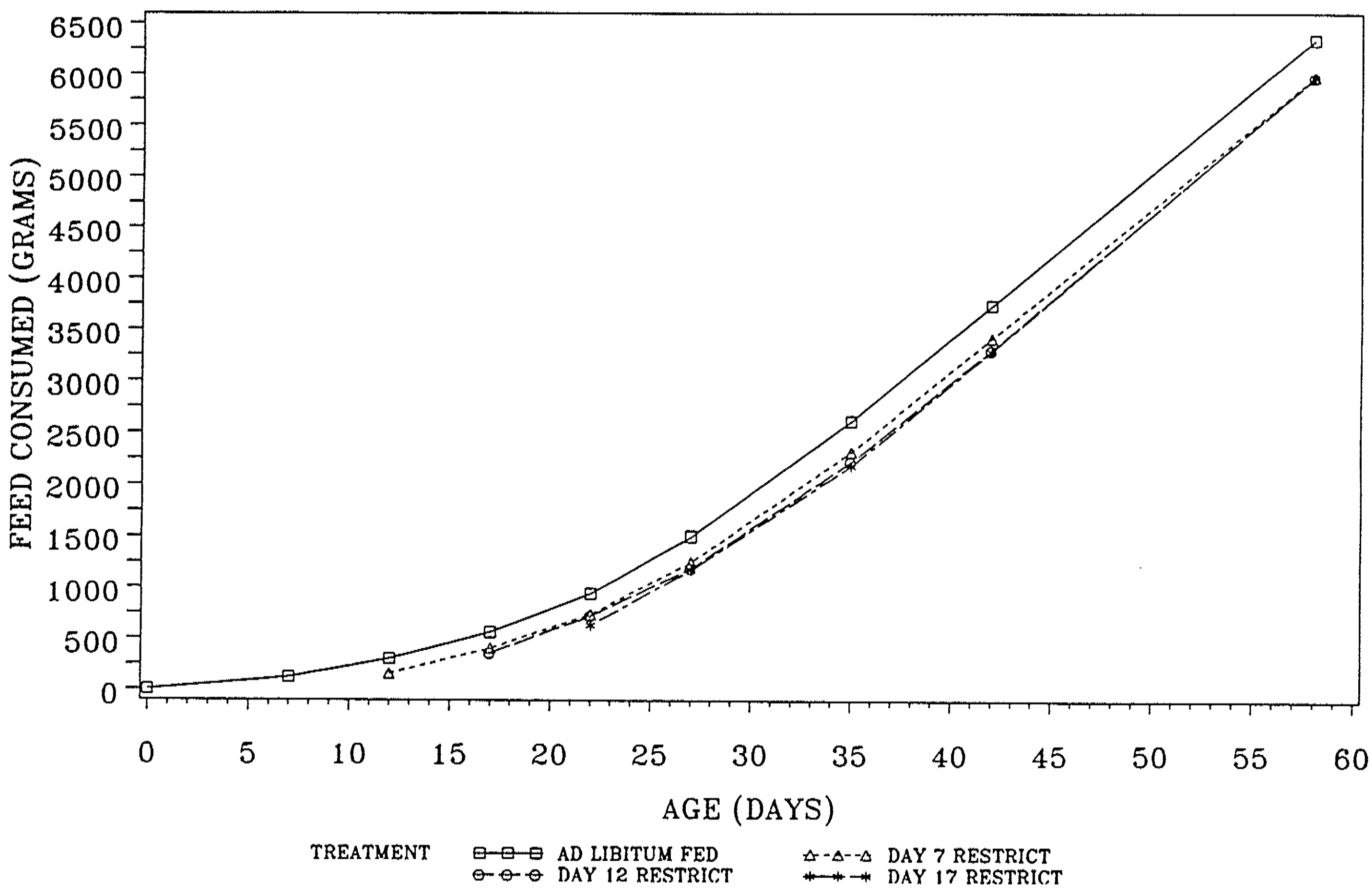
| | TREATMENT | | | |
|---|---|---|---|---|
| AGE (DAYS) | 1 | 2 | 3 | 4 |
| 7-12 | 23.5±0.89a[1] | 6.8±0.09b | 22.9±0.42a | 23.4±0.57a |
| 12-17 | 19.3±0.45b | 23.7±0.13a | 5.5±0.04c | 18.5±0.46b |
| 17-22 | 16.6±0.82c | 18.6±0.30b | 21.3±0.07a | 4.73±0.02d |
| 22-27 | 13.8±0.42b | | | 20.7±0.45a |

1. Means ± standard error.

a,b,c,d - means within a row not followed by the same letter are significantly different at P<.05.

See page 134 for explanation of treatments and abbreviations used.

APPENDIX A–4. CUMMULATIVE FEED CONSUMPTION OF MALE BROILERS FED AD LIBITUM OR VARIOUS RESTRICTION REGIMES (EXPERIMENT 3)



APPENDIX B. PERCENT PERIOD GAINS OF MALE BROILER CHICKENS FED AD LIBITUM OR VARIOUS RESTRICTION REGIMES

TABLE B-1. LEAST SQUARES MEAN PERCENT PERIOD GAINS FOR EXPERIMENT 1.

| PERIOD AGE (DAYS) | TREATMENT 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 8-11 | 44.2±0.95a[1] | 18.1±1.19b | 21.3±1.19b | 18.8±1.19b |
| 11-14 | 40.3±0.74a | 54.3±0.94b | 21.4±0.94c | 20.1±0.94c |
| 14-17 | 40.2±3.09a | 42.4±3.88a | 59.1±3.88b | 24.6±3.88c |
| 17-20 | 35.5±2.75b | 36.1±3.44b | 39.2±3.44ab | 52.1±3.44a |
| 20-28 | 91.8±0.89d | 98.8±1.12c | 106.0±1.12b | 114.9±1.12a |
| 28-35 | 45.1±0.43c | 46.6±0.54c | 51.5±0.54b | 56.7±0.54a |
| 35-42 | 33.8±0.73b | 34.2±0.90b | 35.3±0.90b | 39.7±0.90a |
| 20-42 | 272.5±3.87d | 291.2±4.86c | 322.0±4.86b | 370.7±4.86a |

1. Means ± standard error.

a,b,c,d - means within a row not followed by the same letter are significantly different at $P<.05$.

See page 134 for explanation of treatments and abbreviations used.

TABLE B-2 MEAN PERCENT PERIOD GAINS (EXPERIMENT 2).

| AGE (DAYS) | TREATMENT 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 7-12 | 94.9±0.84a[1] | 29.5±1.72b | 93.1±0.54ab | 88.5±1.80b |
| 12-17 | 71.9±1.20b | 103.0±2.71a | 21.1±2.38c | 71.0±1.29b |
| 17-22 | 57.5±0.30c | 67.0±0.32b | 74.1±2.63a | 4.7±0.63d |
| 22-27 | 43.7±1.08c | 51.0±2.06bc | 52.2±0.92b | 65.4±2.83a |
| 27-35 | 53.7±0.65d | 61.4±1.76c | 66.9±1.41b | 72.4±1.19a |
| 35-43 | 39.8±0.75c | 42.8±1.01b | 43.8±0.19b | 48.3±0.63a |
| 22-43 | 208.6±2.80d | 247.7±1.92c | 265.4±4.54b | 322.6±5.48a |

a,b,c,d - means within a row not followed by the same letter are significantly different at $P<.05$.

1. Means ± standard error.

See page 134 for explanation of treatments and abbreviations used.

TABLE B-3. MEAN PERCENT PERIOD GAINS (EXPERIMENT 3).

| AGE (DAYS) | TREATMENT 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 7-12 | 91.8±1.10a[1] | 17.9±0.92b | 91.7±0.95a | 91.8±0.80a |
| 12-17 | 71.3±1.76b | 120.9±1.90a | 16.9±1.10c | 74.4±0.96b |
| 17-22 | 65.6±0.45c | 75.8±0.87b | 91.2±1.11a | 11.4±0.70d |
| 22-27 | 47.3±0.47c | 50.4±1.11b | 51.1±0.50b | 70.0±0.76a |
| 27-35 | 54.8±0.47b | 64.2±1.28a | 62.0±1.37a | 65.5±0.47a |
| 35-42 | 34.0±0.48b | 36.1±0.38b | 41.1±1.01a | 42.3±0.99a |
| 42-58 | 52.6±1.16b | 60.9±0.87a | 63.9±1.07a | 64.7±1.86a |
| 22-58 | 366.1±3.20c | 440.7±4.95b | 465.8±6.01b | 559.8±12.98a |

a,b,c,d - means within a row not followed by the same letter are significantly different at $P<.05$.

1. Means ± standard error.

See page 134 for explanation of treatments and abbreviations used.

# APPENDIX C. MAINTENANCE ENERGY COEFFICIENTS OF MALE BROILERS FED AD LIBITUM OR VARIOUS RESTRICTION REGIMES

TABLE C-1. MAINTENANCE ENERGY COEFFICIENTS[2] (EXPERIMENT 1)

| AGE (DAYS) | TREATMENT 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 0-8 | 1.90±0.02a[1] | 1.90±0.03a | 1.91±0.02a | 1.89±0.02a |
| 8-11 | 2.63±0.06a | 1.31±0.03b | 1.24±0.02b | 1.31±0.03b |
| 11-14 | 2.42±0.03c | 2.54±0.04b | 0.97±0.01a | 1.00±0.02a |
| 14-17 | 2.58±0.02b | 2.67±0.03b | 2.81±0.02b | 0.70±0.22a |
| 17-20 | 2.67±0.02b | 2.70±0.04b | 2.82±0.04b | 3.11±0.13a |
| 20-28 | 2.44±0.02a | 2.43±0.01a | 2.49±0.01ab | 2.52±0.02b |
| 28-35 | 2.37±0.02a | 2.34±0.01a | 2.40±0.02a | 2.40±0.02a |
| 35-42 | 1.91±0.03a | 1.93±0.04a | 1.98±0.03a | 1.98±0.03a |

a,b,c - Means within a row not followed by the same letter are significantly different at $P<.05$.

1. Means ± standard error

2. Maintenance energy coefficients (MEC) were calculated by the following formula:

$$MEC = \frac{[(\text{Kcal/day intake}) - (C * ADG)]}{\text{average period body weight}^{.667}}$$

where C is the cost of each gram of average daily gain (ADG)

See page 134 for explanation of treatments and abbreviations used.

TABLE C-2. MAINTENANCE ENERGY COEFFICIENTS[2] (EXPERIMENT 3)

| AGE (DAYS) | TREATMENT 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 0-7 | 2.01±0.04a[1] | 2.05±0.03a | 2.03±0.03a | 2.02±0.02a |
| 7-12 | 2.72±0.03a | 0.70±0.01b | 2.69±0.04a | 2.72±0.03a |
| 12-17 | 2.51±0.04b | 2.97±0.04a | 0.65±0.02c | 2.86±0.06a |
| 17-22 | 2.19±0.03b | 2.17±0.04b | 2.53±0.02a | 0.64±0.02c |
| 22-27 | 2.75±0.01b | 2.86±0.06b | 2.67±0.03b | 3.22±0.09a |
| 27-35 | 2.51±0.01a | 2.57±0.04a | 2.65±0.13a | 2.55±0.02a |
| 35-42 | 2.51±0.01b | 2.47±0.02a | 2.41±0.04ab | 2.46±0.02a |
| 42-58 | 1.78±0.05a | 1.75±0.02a | 1.85±0.04a | 1.86±0.03a |

a,b,c - Means within a row not followed by the same letter are significantly different at P<.05.

1. Means ± standard error.

2. See table C-1 for explanation of formula used to calculate MEC.

See page 134 for explanation of treatments and abbreviations used.

APPENDIX D. MEAN PERCENT MORTALITY OF MALE BROILER CHICKENS FED AD LIBITUM OR VARIOUS RESTRICTION REGIMES

TABLE D-1. PERCENT TOTAL MORTALITY[1] FOR EXPERIMENT 1

| AGE (DAYS) | TREATMENT 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 0-20 | 4.90±0.77[2] | 2.42±1.00 | 5.06±0.80 | 3.52±0.80 |
| 20-42 | 3.36±0.47 | 1.76±0.98 | 3.30±0.98 | 2.42±0.74 |
| 0-42 | 8.25±1.18 | 4.18±1.95 | 8.35±1.57 | 5.93±1.48 |

1. Means for each period were analysed using the arc-sine transformation of the square root of the percent mortality in each period. Values reported in this table however, are actual percent mortalities with the associated means separation values obtained from the analysis of the arc-sin transformed data.

2. Means ± standard error. No significant (P>.05) differences in percent mortality were found.

See page 134 for explanation of treatments and abbreviations used.

TABLE D-2. PERCENT TOTAL MORTALITY FOR EXPERIMENT 2

| AGE (DAYS) | TREATMENT 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 0-22 | 1.63±.73[1] | 0.61±.29 | 1.83±.60 | 2.86±.54 |
| 22-43 | 1.84±.75 | 2.44±.21 | 1.22±.49 | 1.43±.54 |
| 0-43 | 3.47±.69 | 2.86±.83 | 3.05±.72 | 4.29±.88 |

1. Means ± standard error. No significant (P>.05) differences in percent mortality were found. Differences between means were determined as in Table D-1.

See page 133 for explanation of treatments used.

TABLE D-3. PERCENT TOTAL MORTALITY IN EXPERIMENT 3

| AGE (DAYS) | TREATMENT 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 0-22 | 1.02±0.408[1] | 0.82±0.289 | 0.61±0.289 | 1.43±0.312 |
| 22-58 | 4.69±0.866 | 4.49±0.656 | 3.88±0.600 | 3.27±0.866 |
| 0-58 | 5.71±0.882 | 5.31±0.808 | 4.49±0.660 | 4.69±0.972 |

1. Means ± standard error. No significant (P>.05) differences in percent mortality could be found. Differences between means were determined as in Table D-1.

See page 134 for explanation of treatments used.

# APPENDIX E. ANALYSIS OF VARIANCE FOR AVERAGE WEIGHT (AVWT)

TABLE E-1. ANALYSIS OF VARIANCE FOR AVWT (EXPERIMENT 1).

| AGE (DAY) | | DF | SS | MS | F | PR>F | C.V. |
|---|---|---|---|---|---|---|---|
| 0 | T | 3 | 0.064 | 0.021 | 0.17 | 0.917 | 0.869 |
| | E | 28 | 3.566 | 0.127 | | | |
| 8 | T | 3 | 88.1 | 29.4 | 1.88 | 0.0155 | 2.976 |
| | E | 28 | 437 | 15.6 | | | |
| 11 | T | 3 | 7279 | 2426 | 78.00 | 0.0001 | 3.288 |
| | E | 28 | 871 | 31 | | | |
| 14 | T | 3 | 36659 | 12220 | 306.22 | 0.0001 | 2.756 |
| | E | 28 | 1117 | 39.9 | | | |
| 17 | T | 3 | 83987 | 27996 | 62.88 | 0.0001 | 6.517 |
| | E | 28 | 12466 | 445 | | | |
| 20 | T | 3 | 104028 | 34676 | 406.10 | 0.0001 | 2.059 |
| | E | 28 | 2391 | 85.4 | | | |
| 28 | T | 3 | 195499 | 65166 | 591.72 | 0.0001 | 1.167 |
| | E | 28 | 3084 | 110 | | | |
| 35 | T | 3 | 197455 | 65818 | 194.42 | 0.0001 | 1.374 |
| | E | 28 | 9479 | 339 | | | |
| 42 | T | 3 | 194887 | 64962 | 47.90 | 0.0001 | 2.031 |
| | E | 28 | 37971 | 1356 | | | |

See page 134 for explanation of abbreviations used.

TABLE E-2. ANALYSIS OF VARIANCE FOR AVWT (EXPERIMENT 2).

| AGE (DAY) | | DF | SS | MS | F | PR>F | C.V. |
|---|---|---|---|---|---|---|---|
| 0 | T | 3 | 0.3202 | 0.1067 | 2.03 | 0.1369 | 0.545 |
| | E | 24 | 1.264 | 0.0527 | | | |
| 7 | T | 3 | 44.4 | 14.8 | 2.17 | 0.1179 | 2.166 |
| | E | 24 | 164 | 6.82 | | | |
| 12 | T | 3 | 27591 | 9197 | 237.58 | 0.0001 | 2.928 |
| | E | 24 | 929 | 38.7 | | | |
| 17 | T | 3 | 65811 | 21937 | 367.47 | 0.0001 | 2.225 |
| | E | 24 | 1433 | 59.7 | | | |
| 22 | T | 3 | 173683 | 424.62 | 424.62 | 0.0001 | 2.269 |
| | E | 24 | 3272 | 136 | | | |
| 27 | T | 3 | 191869 | 63956 | 103.98 | 0.0001 | 3.173 |
| | E | 24 | 14761 | 615 | | | |
| 35 | T | 3 | 181647 | 60549 | 79.33 | 0.0001 | 2.171 |
| | E | 24 | 18319 | 763 | | | |
| 43 | T | 3 | 171636 | 57212 | 37.48 | 0.0001 | 2.140 |
| | E | 24 | 36635 | 1526 | | | |

See page 134 for explanation of abbreviations used.

TABLE E-3. ANALYSIS OF VARIANCE FOR AVWT (EXPERIMENT 3).

| AGE (DAY) | | DF | SS | MS | F | PR>F | C.V. |
|---|---|---|---|---|---|---|---|
| 0 | T | 3 | 0.623 | 0.2077 | 2.47 | 0.0865 | 0.6722 |
| | E | 24 | 2.020 | 0.0842 | | | |
| 7 | T | 3 | 14.5 | 4.84 | 0.61 | 0.6158 | 2.409 |
| | E | 24 | 191 | 7.96 | | | |
| 12 | T | 3 | 40795 | 13598 | 441.09 | 0.0001 | 2.734 |
| | E | 24 | 740 | 30.8 | | | |
| 17 | T | 3 | 83438 | 27813 | 290.06 | 0.0001 | 2.913 |
| | E | 24 | 2297 | 95.7 | | | |
| 22 | T | 3 | 155291 | 51764 | 310.5 | 0.0001 | 2.446 |
| | E | 24 | 4001 | 167 | | | |
| 27 | T | 3 | 180148 | 60049 | 161.16 | 0.0001 | 2.379 |
| | E | 24 | 8943 | 373 | | | |
| 35 | T | 3 | 257215 | 85738 | 103.33 | 0.0001 | 2.203 |
| | E | 24 | 19915 | 830 | | | |
| 42 | T | 3 | 229743 | 76581 | 55.98 | 0.0001 | 2.048 |
| | E | 24 | 32831 | 1368 | | | |
| 58 | T | 3 | 83115 | 27705 | 4.32 | 0.0143 | 2.766 |
| | E | 24 | 153833 | 6410 | | | |

See page 134 for explanation of abbreviations used.

TABLE E-4. ANALYSIS OF VARIANCE FOR AVWT (EXPERIMENT 4).

| AGE (DAY) | | DF | SS | MS | F | PR>F | C.V. |
|---|---|---|---|---|---|---|---|
| 0 | M | 11 | 20.5 | 1.862 | 5.21 | 0.0042 | 1.506 |
| | E | 12 | 4.29 | 0.358 | | | |
| 7 | M | 11 | 424 | 38.6 | 1.63 | 0.2074 | 5.356 |
| | E | 12 | 284 | 23.7 | | | |
| 12 | M | 11 | 43942 | 3995 | 88.12 | 0.0001 | 4.170 |
| | E | 12 | 544 | 45.3 | | | |
| 17 | M | 11 | 137396 | 12491 | 68.04 | 0.0001 | 5.000 |
| | E | 12 | 2203 | 184 | | | |
| 22i | M | 11 | 183784 | 16708 | 15.67 | 0.0001 | 7.826 |
| | E | 12 | 12795 | 1066 | | | |
| 22ii | M | 5 | 160199 | 32040 | 7.14 | 0.0165 | 15.43 |
| | E | 6 | 26938 | 4490 | | | |
| 27 | M | 5 | 182810 | 36562 | 60.27 | 0.0001 | 3.402 |
| | E | 6 | 3640 | 607 | | | |

See page 134 for explanation of abbreviations used.

APPENDIX F. ANALYSIS OF VARIANCE FOR GAINS EXPRESSED AS AVERAGE PERIOD GAINS (AGN) OR AVERAGE GAINS AS A PERCENT OF AVERAGE BODY WEIGHT (PCG).

TABLE F-1. ANALYSIS OF VARIANCE FOR AGN (EXPERIMENT 1).

| PERIOD (DAYS) | | DF | SS | MS | F | PR>F | C.V. |
|---|---|---|---|---|---|---|---|
| 0-8 | T | 3 | 91.4 | 30.5 | 1.93 | 0.1476 | 4.336 |
| | E | 28 | 441 | 15.8 | | | |
| 8-11 | T | 3 | 7703 | 2568 | 155.35 | 0.0001 | 11.005 |
| | E | 28 | 463 | 16.5 | | | |
| 11-14 | T | 3 | 17967 | 5989 | 469.8 | 0.0001 | 5.996 |
| | E | 28 | 357 | 12.7 | | | |
| 14-17 | T | 3 | 20361 | 6787 | 17.24 | 0.0001 | 20.978 |
| | E | 28 | 11022 | 394 | | | |
| 17-20 | T | 3 | 1241 | 414 | 1.14 | 0.3493 | 15.231 |
| | E | 28 | 10142 | 362 | | | |
| 20-28 | T | 3 | 15476 | 5159 | 86.88 | 0.0001 | 1.711 |
| | E | 28 | 1662 | 59.4 | | | |
| 28-35 | T | 3 | 896 | 299 | 1.74 | 0.1818 | 2.978 |
| | E | 28 | 4809 | 172 | | | |
| 35-43 | T | 3 | 645 | 215 | 0.22 | 0.8784 | 6.529 |
| | E | 28 | 26784 | 957 | | | |
| 0-20 | T | 3 | 104047 | 34682 | 407.33 | 0.0001 | 2.2636 |
| | E | 28 | 2384 | 85.1 | | | |
| 20-43 | T | 3 | 15242 | 5081 | 3.31 | 0.0344 | 2.872 |
| | E | 28 | 42971 | 1535 | | | |
| 0-43 | T | 3 | 194893 | 64964 | 47.79 | 0.0001 | 2.081 |
| | E | 28 | 38059 | 1359 | | | |

See page 134 for explanation of abbreviations used.

TABLE F-2. ANALYSIS OF VARIANCE FOR AGN (EXPERIMENT 2).

| PERIOD (DAYS) | | DF | SS | MS | F | PR>F | C.V. |
|---|---|---|---|---|---|---|---|
| 0-7 | T | 3 | 46.20 | 15.4 | 2.22 | 0.1113 | 3.355 |
| | E | 24 | 166 | 6.92 | | | |
| 7-12 | T | 3 | 29353 | 9784 | 427.25 | 0 .0001 | 5.205 |
| | E | 24 | 550 | | | | |
| 12-17 | T | 3 | 68972 | 22991 | 362.67 | 0.0001 | 5.907 |
| | E | 24 | 1521 | 63.4 | | | |
| 17-22 | T | 3 | 208480 | 69493 | 797.84 | 0.0001 | 5.578 |
| | E | 24 | 2096 | 87.1 | | | |
| 22-27 | T | 3 | 1533 | 511 | 1.02 | 0.4012 | 8.383 |
| | E | 24 | 12025 | 501 | | | |
| 27-35 | T | 3 | 975 | 325 | 0.86 | 0.4733 | 3.951 |
| | E | 24 | 9025 | 376 | | | |
| 35-43 | T | 3 | 1340 | 447 | 0.84 | 0.4845 | 4.164 |
| | E | 24 | 12732 | 531 | | | |
| 0-22 | T | 3 | 173357 | 57786 | 424.61 | 0.0001 | 2.469 |
| | E | 24 | 3266 | 136 | | | |
| 22-43 | T | 3 | 3535 | 1178 | 0.85 | 0.4804 | 2.841 |
| | E | 24 | 33283 | 1387 | | | |
| 0-43 | T | 3 | 171276 | 57092 | 37.35 | 0.0001 | 2.192 |
| | E | 24 | 36684 | 1529 | | | |

See page 134 for explanation of abbreviations used.

TABLE F-3. ANALYSIS OF VARIANCE FOR AGN (EXPERIMENT 3).

| PERIOD (DAYS) | | DF | SS | MS | F | PR>F | C.V. |
|---|---|---|---|---|---|---|---|
| 0-7 | T | 3 | 15.9 | 5.30 | 0.67 | 0.5760 | 3.793 |
| | E | 24 | 188.8 | 7.87 | | | |
| 7-12 | T | 3 | 39631 | 13210 | 1089.93 | 0.0001 | 4.078 |
| | E | 24 | 291 | 12 | | | |
| 12-17 | T | 3 | 83695 | 27898 | 569.01 | 0.0001 | 5.272 |
| | E | 24 | 11767 | 49 | | | |
| 17-22 | T | 3 | 205940 | 68647 | 1936.34 | 0.0001 | 3.101 |
| | E | 24 | 851 | 35 | | | |
| 22-27 | T | 3 | 12181 | 4060 | 37.65 | 0.0001 | 3.665 |
| | E | 24 | 2588 | 108 | | | |
| 27-35 | T | 3 | 10389 | 3463 | 10.08 | 0.0002 | 3.733 |
| | E | 24 | 8242 | 343 | | | |
| 35-42 | T | 3 | 6896 | 2299 | 4.53 | 0.0118 | 4.518 |
| | E | 24 | 12179 | 507 | | | |
| 42-58 | T | 3 | 38702 | 12901 | 3.25 | 0.0394 | 5.786 |
| | E | 24 | 95242 | 3968 | | | |
| 0-22 | T | 3 | 155140 | 51713 | 312.29 | 0.0001 | 2.654 |
| | E | 24 | 3974 | 166 | | | |
| 22-58 | T | 3 | 37482 | 12494 | 2.06 | 0.1326 | 3.292 |
| | E | 24 | 145719 | 6072 | | | |
| 0-58 | T | 3 | 82834 | 27611 | 4.31 | 0.0144 | 2.805 |
| | E | 24 | 153575 | 6399 | | | |

See page 134 for explanation of abbreviations used.

TABLE F-4. ANALYSIS OF VARIANCE FOR AGN (EXPERIMENT 4).

| PERIOD (DAYS) | | DF | SS | MS | F | PR>F | C.V. |
|---|---|---|---|---|---|---|---|
| 0-7 | M | 11 | 368 | 33.5 | 1.45 | 0.2677 | 9.407 |
| | E | 12 | 278 | 23.1 | | | |
| 7-12 | M | 11 | 42916 | 3901 | 308.94 | 0.0001 | 5.033 |
| | E | 12 | 152 | 12.6 | | | |
| 12-17 | M | 11 | 117053 | 10641 | 161.04 | 0.0001 | 7.436 |
| | E | 12 | 793 | 66.1 | | | |
| 17-22i | M | 11 | 233084 | 21190 | 37.16 | 0.0001 | 16.307 |
| | E | 12 | 6842 | 570 | | | |
| 22ii-27 | M | 5 | 10064 | 2013 | 5.11 | 0.0359 | 6.967 |
| | E | 6 | 2365 | 394 | | | |

See page 134 for explanation of abbreviations used.

TABLE F-5. ANALYSIS OF VARIANCE FOR PCG (EXPERIMENT 1).

| PERIOD (DAYS) | | DF | SS | MS | F | PR>F | C.V. |
|---|---|---|---|---|---|---|---|
| 8-11 | T | 3 | 0.446 | 0.149 | 149.06 | 0.0001 | 11.31 |
| | E | 28 | 0.028 | 0.001 | | | |
| 11-14 | T | 3 | 0.577 | 0.192 | 313.41 | 0.0001 | 7.11 |
| | E | 28 | 0.017 | 0.0006 | | | |
| 14-17 | T | 3 | 0.651 | 0.217 | 631.11 | 0.0001 | 4.69 |
| | E | 28 | 0.010 | 0.0003 | | | |
| 17-20 | T | 3 | 0.298 | 0.099 | 584.74 | 0.0001 | 3.12 |
| | E | 28 | 0.005 | 0.0002 | | | |
| 20-28 | T | 3 | 0.248 | 0.0827 | 94.66 | 0.0001 | 2.91 |
| | E | 28 | 0.024 | 0.0009 | | | |
| 28-35 | T | 3 | 0.0664 | 0.022 | 110.36 | 0.0001 | 2.87 |
| | E | 28 | 0.0056 | 0.0002 | | | |
| 35-42 | T | 3 | 0.0168 | 0.0056 | 9.92 | 0.0001 | 6.69 |
| | E | 28 | 0.0158 | 0.00057 | | | |
| 20-42 | T | 3 | 4.47 | 1.492 | 90.36 | 0.0001 | 4.16 |
| | E | 28 | 0.46 | 0.0165 | | | |

See page 134 for explanation of abbreviations used.

TABLE F-6. ANALYSIS OF VARIANCE FOR PCG (EXPERIMENT 3).

| PERIOD (DAYS) | | DF | SS | MS | F | PR>F | C.V. |
|---|---|---|---|---|---|---|---|
| 7-12 | T | 3 | 2.86 | 0.954 | 1506.6 | 0.0001 | 3.43 |
| | E | 24 | 0.015 | 0.0006 | | | |
| 12-17 | T | 3 | 3.80 | 1.265 | 817.25 | 0.0001 | 5.55 |
| | E | 24 | 0.037 | 0.002 | | | |
| 17-22 | T | 3 | 2.535 | 0.845 | 1796.8 | 0.0001 | 3.55 |
| | E | 24 | 0.011 | 0.0005 | | | |
| 22-27 | T | 3 | 0.225 | 0.0749 | 187.89 | 0.0001 | 3.65 |
| | E | 24 | 0.010 | 0.0004 | | | |
| 27-35 | T | 3 | 0.048 | 0.016 | 23.3 | 0.0001 | 4.26 |
| | E | 24 | 0.017 | 0.0007 | | | |
| 35-42 | T | 3 | 0.033 | 0.011 | 26.38 | 0.0001 | 5.32 |
| | E | 24 | 0.010 | 0.0004 | | | |
| 42-58 | T | 3 | 0.010 | 0.0034 | 19.57 | 0.0001 | 3.52 |
| | E | 24 | 0.004 | 0.0002 | | | |

See page 134 for explanation of abbreviations used.

# APPENDIX G. ANALYSIS OF VARIANCE FOR AVERAGE FEED CONSUMPTION (AFC) AND FEED INTAKE AS A PERCENT OF BODY WEIGHT (PFI).

TABLE G-1. ANALYSIS OF VARIANCE FOR AFC (EXPERIMENT 1)

| PERIOD (DAYS) | | DF | SS | MS | F | PR>F | C.V. |
|---|---|---|---|---|---|---|---|
| 0-8 | T | 3 | 34.6 | 11.5 | 0.62 | 0.6101 | 3.037 |
| | E | 28 | 524 | 18.7 | | | |
| 8-11 | T | 3 | 23988 | 7996 | 231.10 | 0.0001 | 8.737 |
| | E | 28 | 969 | 34.6 | | | |
| 11-14 | T | 3 | 50906 | 16969 | 1522.27 | 0.0001 | 3.640 |
| | E | 24 | 312 | 11.1 | | | |
| 14-17 | T | 3 | 80800 | 26933 | 2748.54 | 0.0001 | 2.214 |
| | E | 24 | 274 | 9.8 | | | |
| 17-20 | T | 3 | 2526 | 842 | 23.42 | 0.0001 | 2.906 |
| | E | 24 | 1007 | 36 | | | |
| 20-28 | T | 3 | 53648 | 17883 | 131.91 | 0.0001 | 1.488 |
| | E | 24 | 3796 | 136 | | | |
| 28-35 | T | 3 | 19936 | 6645 | 16.76 | 0.0001 | 2.302 |
| | E | 24 | 11105 | 397 | | | |
| 35-42 | T | 3 | 4781 | 1594 | 1.27 | 0.3032 | 3.606 |
| | E | 24 | 35087 | 1253 | | | |
| 0-20 | T | 3 | 372721 | 124240 | 600.09 | 0.0001 | 2.216 |
| | E | 24 | 5797 | 207 | | | |
| 20-42 | T | 3 | 192737 | 64246 | 21.61 | 0.0001 | 2.074 |
| | E | 24 | 83256 | 2973 | | | |
| 0-42 | T | 3 | 1080650 | 362017 | 106.34 | 0.0001 | 1.780 |
| | E | 24 | 95323 | 3404 | | | |

See page 134 for explanation of abbreviations used.

TABLE G-2. ANALYSIS OF VARIANCE FOR AFC (EXPERIMENT 2).

| PERIOD (DAYS) | | DF | SS | MS | F | PR>F | C.V. |
|---|---|---|---|---|---|---|---|
| 0-7 | T | 3 | 60.89 | 20.3 | 2.22 | 0.1119 | 2.647 |
| | E | 24 | 219.5 | 9.15 | | | |
| 7-12 | T | 3 | 75755 | 25252 | 719.00 | 0.0001 | 3.862 |
| | E | 24 | 843 | 35.12 | | | |
| 12-17 | T | 3 | 160346 | 53449 | 1821.37 | 0.0001 | 2.567 |
| | E | 24 | 704 | 29.3 | | | |
| 17-22 | T | 3 | 41832 | 137944 | 850.79 | 0.0001 | 4.299 |
| | E | 24 | 3891 | 162 | | | |
| 22-27 | T | 3 | 10212 | 3404 | 10.56 | 0.0001 | 3.631 |
| | E | 24 | 7738 | 322 | | | |
| 27-35 | T | 3 | 7493 | 2498 | 2.59 | 0.0764 | 3.074 |
| | E | 24 | 23159 | 965 | | | |
| 35-42 | T | 3 | 36608 | 12203 | 8.58 | 0.0005 | 3.012 |
| | E | 24 | 34114 | 1421 | | | |
| 0-22 | T | 3 | 334855 | 111618 | 288.37 | 0.0001 | 2.539 |
| | E | 24 | 9296 | 387 | | | |
| 22-42 | T | 3 | 108959 | 36320 | 17.95 | 0.0001 | 1.632 |
| | E | 24 | 48573 | 2024 | | | |
| 0-42 | T | 3 | 692983 | 230994 | 86.35 | 0.0001 | 1.464 |
| | E | 24 | 64206 | 2675 | | | |

See page 134 for explanation of abbreviations used.

TABLE G-3. ANALYSIS OF VARIANCE FOR AFC (EXPERIMENT 3).

| PERIOD (DAYS) | | DF | SS | MS | F | PR>F | C.V. |
|---|---|---|---|---|---|---|---|
| 0-7 | T | 3 | 6.25 | 2.08 | 0.14 | 0.9328 | 3.220 |
| | E | 24 | 349 | 14.5 | | | |
| 7-12 | T | 3 | 110836 | 36945 | 2601.35 | 0.0001 | 2.570 |
| | E | 24 | 341 | 14.2 | | | |
| 12-17 | T | 3 | 225134 | 75045 | 1031.58 | 0.0001 | 4.021 |
| | E | 24 | 1746 | 72.7 | | | |
| 17-22 | T | 3 | 408096 | 136032 | 3132.13 | 0.0001 | 2.262 |
| | E | 24 | 1042 | 43.4 | | | |
| 22-27 | T | 3 | 33470 | 11157 | 37.44 | 0.0001 | 3.316 |
| | E | 24 | 7151 | 298 | | | |
| 27-35 | T | 3 | 45771 | 15257 | 7.09 | 0.0014 | 4.389 |
| | E | 24 | 51658 | 2152 | | | |
| 35-42 | T | 3 | 5149 | 1716 | 1.54 | 0.2306 | 3.032 |
| | E | 24 | 26804 | 1117 | | | |
| 42-58 | T | 3 | 67018 | 22339 | 1.28 | 0.3025 | 5.023 |
| | E | 24 | 417614 | 17401 | | | |
| 0-22 | T | 3 | 299451 | 99817 | 363.83 | 0.0001 | 2.155 |
| | E | 24 | 6584 | 274 | | | |
| 22-58 | T | 3 | 130501 | 43500 | 1.64 | 0.2065 | 3.070 |
| | E | 24 | 636671 | 26528 | | | |
| 0-58 | T | 3 | 664007 | 221336 | 7.84 | 0.0008 | 2.766 |
| | E | 24 | 677496 | 28229 | | | |

See page 134 for explanation of abbreviations used.

TABLE G-4. ANALYSIS OF VARIANCE FOR AFC (EXPERIMENT 4).

| PERIOD (DAYS) | | DF | SS | MS | F | PR>F | C.V. |
|---|---|---|---|---|---|---|---|
| 0-7 | M | 11 | 1065 | 96.8 | 1.48 | 0.2546 | 10.237 |
| | E | 12 | 784 | 65.3 | | | |
| 7-12 | M | 11 | 77694 | 7063 | 73.06 | 0.0001 | 7.677 |
| | E | 12 | 1160 | 96.7 | | | |
| 12-17 | M | 11 | 163511 | 14865 | 100.18 | 0.0001 | 6.631 |
| | E | 12 | 1781 | 148 | | | |
| 17-22i | M | 11 | 252055 | 22914 | 6.17 | 0.0020 | 24.771 |
| | E | 12 | 44575 | 3715 | | | |
| 22ii-27 | M | 5 | 83659 | 16732 | 29.27 | 0.0004 | 6.030 |
| | E | 6 | 3430 | 572 | | | |

See page 134 for explanation of abbreviations used.

TABLE G-5. ANALYSIS OF VARIANCE FOR PFI (EXPERIMENT 1).

| PERIOD (DAYS) | | DF | SS | MS | F | PR>F | C.V. |
|---|---|---|---|---|---|---|---|
| 8-11 | T | 3 | 850 | 283 | 288.69 | 0.0001 | 6.788 |
| | E | 28 | 27.5 | 0.98 | | | |
| 11-14 | T | 3 | 927 | 309 | 1279.11 | 0.0001 | 3.314 |
| | E | 28 | 6.76 | 0.24 | | | |
| 14-17 | T | 3 | 842 | 281 | 1534.05 | 0.0001 | 2.560 |
| | E | 28 | 5.12 | 0.183 | | | |
| 17-20 | T | 3 | 166 | 55.4 | 333.12 | 0.0001 | 2.237 |
| | E | 28 | 4.65 | 0.17 | | | |
| 20-28 | T | 3 | 18.2 | 6.07 | 93.16 | 0.0001 | 1.750 |
| | E | 28 | 1.83 | 0.065 | | | |
| 28-35 | T | 3 | 8.02 | 2.67 | 55.41 | 0.0001 | 1.982 |
| | E | 28 | 1.35 | 0.048 | | | |
| 35-42 | T | 3 | 33.89 | 1.30 | 18.70 | 0.0001 | 2.955 |
| | E | 28 | 1.94 | 0.069 | | | |

See page 134 for explanation of abbreviations used.

TABLE G-6. ANALYSIS OF VARIANCE FOR PFI (EXPERIMENT 3).

| PERIOD (DAYS) | | DF | SS | MS | F | PR>F | C.V. |
|---|---|---|---|---|---|---|---|
| 7-12 | T | 3 | 1248 | 416 | 1670.09 | 0.0001 | 2.849 |
| | E | 24 | 5.98 | 0.249 | | | |
| 12-17 | T | 3 | 1237 | 412 | 1261.45 | 0.0001 | 3.647 |
| | E | 24 | 7.85 | 0.327 | | | |
| 17-22 | T | 3 | 886 | 295 | 3551.89 | 0.0001 | 2.137 |
| | E | 24 | 2.0 | 0.083 | | | |
| 22-27 | T | 3 | 81.5 | 27.2 | 92.15 | 0.0001 | 3.459 |
| | E | 24 | 7.08 | 0.295 | | | |
| 27-35 | T | 3 | 8.34 | 2.78 | 7.58 | 0.0010 | 4.837 |
| | E | 24 | 8.80 | 0.367 | | | |
| 35-42 | T | 3 | 6.59 | 2.20 | 29.32 | 0.0001 | 2.698 |
| | E | 24 | 1.80 | 0.075 | | | |
| 42-58 | T | 3 | 2.38 | 0.794 | 12.44 | 0.0001 | 3.615 |
| | E | 24 | 1.53 | 0.064 | | | |

See page 134 for explanation of abreviations used.

TABLE G-7. ANALYSIS OF VARIANCE FOR PFI (EXPERIMENT 4).

| PERIOD (DAYS) | | DF | SS | MS | F | PR>F | C.V. |
|---|---|---|---|---|---|---|---|
| 7-12 | M | 11 | 1234 | 112 | 51.66 | 0.0001 | 7.702 |
| | E | 12 | 26 | 2.18 | | | |
| 12-17 | M | 11 | 1105 | 100.4 | 150.64 | 0.0001 | 4.874 |
| | E | 12 | 8.00 | 0.667 | | | |
| 17-22i | M | 11 | 972 | 88.4 | 94.86 | 0.0001 | 6.308 |
| | E | 12 | 11.18 | 0.93 | | | |
| 22ii-27 | M | 5 | 148.5 | 29.7 | 48.04 | 0.0001 | 4.555 |
| | E | 6 | 3.71 | 0.62 | | | |

See page 134 for explanation of abbreviations used.

# APPENDIX H. ANALYSIS OF VARIANCE FOR FEED:GAIN

TABLE H-1. ANALYSIS OF VARIANCE FOR FEED:GAIN (EXPERIMENT 1).

| PERIOD (DAYS) | | DF | SS | MS | F | PR>F | C.V. |
|---|---|---|---|---|---|---|---|
| 0-8 | T | 3 | 0.0106 | 0.0035 | 1.23 | 0.3165 | 3.439 |
| | E | 28 | 0.0802 | 0.0029 | | | |
| 8-11 | T | 3 | 0.3510 | 0.1170 | 6.29 | 0.0021 | 7.39 |
| | E | 28 | 0.5207 | 0.0186 | | | |
| 11-14 | T | 3 | 0.3497 | 0.1166 | 11.57 | 0.0001 | 6.621 |
| | E | 28 | 0.2820 | 0.0101 | | | |
| 14-17 | T | 3 | 0.3589 | 0.1196 | 2.06 | 0.1284 | 15.916 |
| | E | 28 | 1.6274 | 0.0581 | | | |
| 17-20 | T | 3 | 2.584 | 0.8613 | 0.73 | 0.5440 | 60.292 |
| | E | 28 | 33.093 | 1.1819 | | | |
| 20-28 | T | 3 | 0.0108 | 0.0036 | 9.26 | 0.0002 | 1.137 |
| | E | 28 | 0.0109 | 0.0004 | | | |
| 28-35 | T | 3 | 0.0950 | 0.0317 | 26.33 | 0.0001 | 1.764 |
| | E | 28 | 0.0337 | 0.0012 | | | |
| 35-42 | T | 3 | 0.0365 | 0.0122 | 0.96 | 0.4247 | 5.416 |
| | E | 28 | 0.3547 | 0.0127 | | | |
| 0-20 | T | 3 | 0.0692 | 0.0231 | 30.15 | 0.0001 | 1.747 |
| | E | 28 | 0.0214 | 0.0008 | | | |
| 20-28 | T | 3 | 0.0277 | 0.0076 | 4.51 | 0.0105 | 2.124 |
| | E | 28 | 0.0469 | 0.0017 | | | |
| 0-42 | T | 3 | 0.0169 | 0.0056 | 6.95 | 0.0012 | 1.542 |
| | E | 28 | 0.0227 | 0.0008 | | | |

See page 134 for explanation of abbreviations used.

TABLE H-2. ANALYSIS OF VARIANCE FOR FEED:GAIN (EXPERIMENT 2).

| PERIOD (DAYS) | | DF | SS | MS | F | PR>F | C.V. |
|---|---|---|---|---|---|---|---|
| 0-7 | T | 3 | 0.0039 | 0.0013 | 0.670 | 0.5761 | 3.003 |
| | E | 24 | 0.0460 | 0.0019 | | | |
| 7-12 | T | 3 | 0.1374 | 0.0458 | 1.37 | 0.2771 | 10.790 |
| | E | 24 | 0.8048 | 0.0335 | | | |
| 12-17 | T | 3 | 0.2220 | 0.0740 | 2.41 | 0.0922 | 10.953 |
| | E | 24 | 0.7382 | 0.0308 | | | |
| 17-22 | T | 3 | 70.87 | 23.62 | 20.16 | 0.0001 | 41.528 |
| | E | 24 | 28.13 | 1.172 | | | |
| 22-27 | T | 3 | 0.0624 | 0.0208 | 1.20 | 0.3324 | 7.090 |
| | E | 24 | 0.4176 | 0.0174 | | | |
| 27-35 | T | 3 | 0.0603 | 0.0200 | 2.35 | 0.0974 | 4.483 |
| | E | 24 | 0.205 | 0.0085 | | | |
| 35-43 | T | 3 | 0.0819 | 0.0273 | 3.23 | 0.0403 | 4.061 |
| | E | 24 | 0.2032 | 0.0085 | | | |
| 0-22 | T | 3 | 0.1454 | 0.0485 | 53.75 | 0.0001 | 1.822 |
| | E | 24 | 0.0216 | 0.0009 | | | |
| 22-43 | T | 3 | 0.0488 | 0.0163 | 4.94 | 0.0082 | 2.727 |
| | E | 24 | 0.0790 | 0.0033 | | | |
| 0-43 | T | 3 | 0.0231 | 0.0077 | 5.61 | 0.0046 | 1.876 |
| | E | 24 | 0.0329 | 0.0014 | | | |

See page 134 for explanation of abbreviations used.

TABLE H-3. ANALYSIS OF VARIANCE FOR FEED:GAIN (EXPERIMENT 3).

| PERIOD (DAYS) | | DF | SS | MS | F | PR>F | C.V. |
|---|---|---|---|---|---|---|---|
| 0-7 | T | 3 | 0.0065 | 0.0022 | 0.99 | 0.4139 | 2.917 |
| | E | 24 | 0.0524 | 0.0022 | | | |
| 7-12 | T | 3 | 0.0987 | 0.0329 | 1.90 | 0.1573 | 7.598 |
| | E | 24 | 0.4166 | 0.0174 | | | |
| 12-17 | T | 3 | 0.1537 | 0.0512 | 2.30 | 0.1029 | 9.352 |
| | E | 24 | 0.5344 | 0.0223 | | | |
| 17-22 | T | 3 | 1.0498 | 0.3499 | 17.88 | 0.0001 | 8.716 |
| | E | 24 | 0.4698 | 0.0196 | | | |
| 22-27 | T | 3 | 0.0513 | 0.0171 | 2.53 | 0.0814 | 4.470 |
| | E | 24 | 0.1624 | 0.0068 | | | |
| 27-35 | T | 3 | 0.0589 | 0.0196 | 1.80 | 0.1750 | 4.904 |
| | E | 24 | 0.2623 | 0.0109 | | | |
| 35-42 | T | 3 | 0.1538 | 0.0513 | 11.43 | 0.0001 | 3.024 |
| | E | 24 | 0.1076 | 0.0045 | | | |
| 42-58 | T | 3 | 0.1281 | 0.0427 | 4.34 | 0.014 | 4.105 |
| | E | 24 | 0.236 | 0.0698 | | | |
| 0-22 | T | 3 | 0.143 | 0.0477 | 42.08 | 0.0001 | 2.115 |
| | E | 24 | 0.0272 | 0.0011 | | | |
| 22-58 | T | 3 | 0.0353 | 0.0118 | 5.98 | 0.0034 | 1.980 |
| | E | 24 | 0.0472 | 0.002 | | | |
| 0-58 | T | 3 | 0.0058 | 0.0019 | 1.51 | 0.2371 | 1.690 |
| | E | 24 | 0.0310 | 0.0013 | | | |

See page 134 for explanation of abbreviations used.

TABLE H-4. ANALYSIS OF VARIANCE FOR FEED:GAIN (EXPERIMENT 4).

| PERIOD (DAYS) | | DF | SS | MS | F | PR>F | C.V. |
|---|---|---|---|---|---|---|---|
| 0-7 | M | 11 | 0.1544 | 0.0140 | 0.91 | 0.5582 | 8.027 |
| | E | 12 | 0.1849 | 0.0154 | | | |
| 7-12 | M | 11 | 2346 | 213 | 3.18 | 0.0293 | 229.97 |
| | E | 12 | 805 | 67.1 | | | |
| 12-17 | M | 11 | 307 | 27.9 | 7.75 | 0.0007 | 520.54 |
| | E | 12 | 43.2 | 3.60 | | | |
| 17-22i | M | 11 | 3.418 | 0.3107 | 57.5 | 0.0001 | 268.07 |
| | E | 12 | 0.0649 | 0.0054 | | | |
| 22ii-27 | M | 5 | 1.447 | 0.2890 | 24.10 | 0.0007 | 7.740 |
| | E | 6 | 0.0721 | 0.012 | | | |

22i - refers to the feed:gain occuring prior to 2 birds/pen from treatment 1 being removed for the day 22ii-27 period.

See page 134 for explanation of abbreviations used.

APPENDIX I. ANALYSIS OF VARIANCE FOR MAINTENANCE ENERGY COEFFICIENT[1] (MEC).

TABLE I-1. ANALYSIS OF VARIANCE FOR MEC (EXPERIMENT 1).

| PERIOD (DAYS) | | DF | SS | MS | F | PR>F | C.V. |
|---|---|---|---|---|---|---|---|
| 0-8 | T | 3 | 0.0022 | 0.0007 | 0.16 | 0.9223 | 3.56 |
| | E | 28 | 0.1283 | 0.0046 | | | |
| 8-11 | T | 3 | 13.2 | 4.385 | 229.2 | 0.0001 | 7.915 |
| | E | 28 | 0.536 | 0.0191 | | | |
| 11-14 | T | 3 | 17.4 | 5.785 | 1002.2 | 0.0001 | 4.174 |
| | E | 28 | 0.162 | 0.0058 | | | |
| 14-17 | T | 3 | 21.5 | 7.169 | 96.34 | 0.0001 | 12.20 |
| | E | 28 | 2.084 | 0.0744 | | | |
| 17-20 | T | 3 | 0.916 | 0.305 | 9.07 | 0.0002 | 6.530 |
| | E | 28 | 0.942 | 0.0336 | | | |
| 20-28 | T | 3 | 0.0408 | 0.0136 | 7.00 | 0.0012 | 1.788 |
| | E | 28 | 0.0544 | 0.0019 | | | |
| 28-35 | T | 3 | 0.0152 | 0.0051 | 1.69 | 0.1914 | 2.303 |
| | E | 28 | 0.0837 | 0.0030 | | | |
| 35-42 | T | 3 | 0.0259 | 0.0086 | 0.95 | 0.4304 | 4.901 |
| | E | 28 | 0.2552 | 0.0091 | | | |

See pages 134 and 145 for explanation of abbreviations used.

TABLE I-2. ANALYSIS OF VARIANCE FOR MEC (EXPERIMENT 3).

| PERIOD (DAYS) | | DF | SS | MS | F | PR>F | C.V. |
|---|---|---|---|---|---|---|---|
| 0-7 | T | 3 | 0.0078 | 0.0026 | 0.57 | 0.6426 | 3.342 |
| | E | 24 | 0.1103 | 0.0046 | | | |
| 7-12 | T | 3 | 21.2 | 7.076 | 980.5 | 0.0001 | 3.849 |
| | E | 24 | 0.173 | 0.0072 | | | |
| 12-17 | T | 3 | 24.5 | 8.16 | 728.5 | 0.0001 | 4.710 |
| | E | 24 | 0.269 | 0.0112 | | | |
| 17-22 | T | 3 | 14.9 | 4.97 | 866.5 | 0.0001 | 4.023 |
| | E | 24 | 0.138 | 0.0057 | | | |
| 22-27 | T | 3 | 1.26 | 0.421 | 19.59 | 0.0001 | 5.096 |
| | E | 24 | 0.515 | 0.0215 | | | |
| 27-35 | T | 3 | 0.0800 | 0.0267 | 0.81 | 0.4989 | 7.044 |
| | E | 24 | 0.7869 | 0.0328 | | | |
| 35-42 | T | 3 | 0.0723 | 0.0241 | 4.52 | 0.012 | 3.020 |
| | E | 24 | 0.1280 | 0.0053 | | | |
| 42-58 | T | 3 | 0.0639 | 0.0213 | 2.38 | 0.095 | 5.231 |
| | E | 24 | 0.2149 | 0.0090 | | | |

See pages 134 and 145 for explanation of abbreviations used.

# APPENDIX J. ANALYSIS OF VARIANCE FOR CARCASS DATA (CD)

TABLE J-1. ANALYSIS OF VARIANCE FOR CD (EXPERIMENT 1).

| PARAMETER | | DF | SS | MS | F | PR>F | C.V. |
|---|---|---|---|---|---|---|---|
| WEIGHT | T | 3 | 1143089 | 38103 | 14.14 | .0001 | 7.214 |
| | E | 124 | 3341573 | 26948 | | | |
| DRESSED WEIGHT | T | 3 | 840854 | 280285 | 20.05 | .0001 | 7.666 |
| | E | 124 | 1733168 | 13977 | | | |
| LIVER WEIGHT | T | 3 | 262 | 87.4 | 1.74 | .1603 | 16.716 |
| | E | 124 | 6224 | 50.2 | | | |
| FAT WEIGHT | T | 3 | 2571 | 857 | 5.57 | .0014 | 23.219 |
| | E | 124 | 19063 | 154 | | | |
| % DRESS | T | 3 | 90.1 | 30.04 | 4.48 | .0052 | 3.823 |
| | E | 124 | 832 | 6.71 | | | |
| % LIVER | T | 3 | 0.0005 | 0.00016 | 2.05 | .1100 | 6.369 |
| | E | 124 | 0.0098 | 0.00008 | | | |
| % FAT | T | 3 | 0.0014 | 0.00048 | 1.89 | .1344 | 10.381 |
| | E | 124 | 0.0311 | 0.00025 | | | |
| LEG SC | T | 3 | 5.88 | 1.96 | 8.66 | .0001 | 37.889 |
| | E | 1968 | 445 | 0.226 | | | |

See page 134 for expanation of abbreviations used.

TABLE J-2. ANALYSIS OF VARIANCE FOR CD (EXPERIMENT 3).

| PARAMETER | | DF | SS | MS | F | PR>F | C.V. |
|---|---|---|---|---|---|---|---|
| WEIGHT | T | 3 | 587438 | 195813 | 3.60 | 0.0159 | 7.190 |
| | E | 108 | 5881927 | 54462 | | | |
| DRESS | T | 3 | 446136 | 148712 | 5.36 | 0.0019 | 7.312 |
| WEIGHT | E | 106 | 2942856 | 27763 | | | |
| LIVER | T | 3 | 105 | 35.0 | 1.38 | 0.2523 | 10.632 |
| WEIGHT | E | 107 | 2713 | 25.4 | | | |
| FAT | T | 3 | 2186 | 729 | 0.76 | 0.5241 | 27.835 |
| WEIGHT | E | 108 | 104045 | 963 | | | |
| GI | T | 3 | 1220 | 407 | 1.21 | 0.3110 | 10.731 |
| WEIGHT | E | 108 | 36434 | 337 | | | |
| % DRESS | T | 3 | 27.9 | 9.29 | 3.91 | 0.0109 | 2.195 |
| | E | 106 | 252 | 2.38 | | | |
| % LIVER | T | 3 | 0.0004 | 0.0001 | 3.63 | 0.0153 | 4.679 |
| | E | 107 | 0.0034 | 0.000032 | | | |
| % FAT | T | 3 | 0.003 | 0.0001 | 0.20 | 0.8990 | 13.110 |
| | E | 108 | 0.0631 | 0.00058 | | | |
| % GI | T | 3 | 0.0005 | 0.00015 | 1.32 | 0.2718 | 4.586 |
| | E | 108 | 0.0122 | 0.00011 | | | |
| LEG SC | T | 3 | 0.681 | 0.227 | 0.72 | 0.5382 | 35.245 |
| | E | 1858 | 584 | 0.314 | | | |

See page 134 for explanation of abbreviations used.

APPENDIX K. ANALYSIS OF VARIANCE FOR PERCENT DRY MATTER DIGESTIBILITY.

Table K-1. ANALYSIS OF VARIANCE FOR PERCENT DRY MATTER DIGESTIBILITY (EXPERIMENT 4).

| DAY | | DF | SS | MS | F | PR>F | C.V. |
|---|---|---|---|---|---|---|---|
| 7 | M | 11 | 298 | 27.1 | 0.91 | 0.5585 | 9.993 |
| | E | 12 | 357 | 29.8 | | | |
| 12 | M | 11 | 491 | 44.6 | 3.57 | 0.0192 | 5.90 |
| | E | 12 | 150 | 12.5 | | | |
| 17 | M | 11 | 57.1 | 5.19 | 1.32 | 0.3352 | 3.106 |
| | E | 10 | 39.4 | 3.94 | | | |
| 20 | M | 5 | 122 | 24.3 | 14.26 | 0.0028 | 1.995 |
| | E | 6 | 10.2 | 1.70 | | | |
| 21 | M | 5 | 51.5 | 10.3 | 2.64 | 0.1343 | 3.032 |
| | E | 6 | 23.4 | 3.90 | | | |
| 22 | M | 11 | 115 | 10.5 | 1.41 | 0.2805 | 4.062 |
| | E | 12 | 89.1 | 7.42 | | | |
| 23 | M | 5 | 67.4 | 13.5 | 10.60 | 0.0061 | 1.533 |
| | E | 6 | 7.64 | 1.27 | | | |
| 24 | M | 5 | 21.0 | 4.20 | 0.73 | 0.6251 | 3.453 |
| | E | 6 | 34.4 | 5.74 | | | |
| 25 | M | 5 | 2236 | 447 | 12.47 | 0.0040 | 10.207 |
| | E | 6 | 215 | 35.9 | | | |
| 26 | M | 5 | 1758 | 352 | 12.14 | 0.0043 | 8.995 |
| | E | 6 | 174 | 29.0 | | | |
| 27 | M | 5 | 842 | 168 | 9.22 | 0.0088 | 6.668 |
| | E | 6 | 110 | 18.3 | | | |

See page 134 for explanation of abbreviations used.

APPENDIX L. ANALYSIS OF VARIANCE FOR SELECTED BLOOD PARAMETERS OF MALE BROILERS FOLLOWING FEED RESTRICTION

TABLE L-1. ANALYSIS OF VARIANCE OF 5 WEEK OLD MALE BROILERS (EXPERIMENT 1)

| PARAMETER | | DF | SS | MS | F | PR>F | C.V. |
|---|---|---|---|---|---|---|---|
| AST[1] | T | 1 | 0.346 | 0.346 | 0.00 | 0.970 | 7.370 |
| | E | 24 | 5760 | 240 | | | |
| AMYLASE | T | 1 | 29534 | 29534 | 1.28 | 0.2687 | 20.980 |
| | E | 24 | 552966 | 23040 | | | |
| CK[2] | T | 1 | 1049813 | 1049813 | 1.34 | 0.2625 | 24.917 |
| | E | 18 | 14120347 | 784464 | | | |
| TOTBIL[3] | T | 1 | 0.0097 | 0.0097 | 0.01 | 0.9289 | 36.514 |
| | E | 25 | 29.78 | 1.19 | | | |
| ALBUMIN | T | 1 | 3.562 | 3.562 | 7.02 | 0.0137 | 6.035 |
| | E | 25 | 12.678 | 0.507 | | | |
| TPROT[4] | T | 1 | 16.879 | 16.879 | 6.90 | 0.0145 | 4.787 |
| | E | 25 | 61.121 | 2.44 | | | |
| URIC[5] | T | 1 | 37435 | 37437 | 6.31 | 0.0189 | 18.504 |
| | E | 25 | 148379 | 5935 | | | |
| TRIGLY[6] | T | 1 | 0.063 | 0.063 | 2.24 | 0.1471 | 16.351 |
| | E | 25 | 0.704 | 0.0282 | | | |
| ALP[7] | T | 1 | 6261103 | 6261103 | 1.50 | 0.2376 | 43.99 |
| | E | 17 | 71028878 | 4578169 | | | |
| ALT[8] | T | 1 | 3.495 | 3.495 | 0.16 | 0.6907 | 80.546 |
| | E | 23 | 495.1 | 21.5 | | | |
| CHOLES[9] | T | 1 | $2*10^{-5}$ | $2*10^{-5}$ | 0.00 | 0.9903 | 10.128 |
| | E | 25 | 3.263 | 0.1305 | | | |

1. Aspartate aminotransferase 2. creatine kinase 3. total bilirubin 4. total protein 5. uric acid 6. triglycerides 7. alkaline phosphatase 8. alanine aminotransferase 9. cholesterol

See page 134 for abbreviations used.

TABLE L-2. ANALYSIS OF VARIANCE FOR SELECTED BLOOD PARAMETERS OF MALE BROILERS AT THREE DIFFERENT AGES FOLLOWING FEED RESTRICTION (EXPERIMENT 2)

| PARAMETER | | DF | SS | MS | F | PR>F | C.V. |
|---|---|---|---|---|---|---|---|
| **DAY 13** | | | | | | | |
| GLUCOSE | T | 1 | 6.349 | 6.349 | 12.07 | 0.0031 | 4.578 |
| | E | 16 | 8.414 | 0.526 | | | |
| CHOLES[1] | T | 1 | 3.051 | 3.051 | 11.68 | 0.0035 | 11.519 |
| | E | 16 | 4.181 | 0.261 | | | |
| URIC[2] | T | 1 | 87808 | 87808 | 6.59 | 0.0207 | 17.261 |
| | E | 16 | 213243 | 13328 | | | |
| ALP[3] | T | 1 | $1x10^9$ | $1x10^9$ | 9.54 | 0.007 | 33.523 |
| | E | 16 | $1.9x10^9$ | $1.9x10^9$ | | | |
| **DAY 18** | | | | | | | |
| AST[4] | T | 1 | 15353 | 15353 | 7.57 | 0.0142 | 23.601 |
| | E | 16 | 42369 | 2029 | | | |
| CHOLES | T | 1 | 1.949 | 1.949 | 11.81 | 0.0034 | 9.965 |
| | E | 16 | 2.639 | 0.165 | | | |
| **DAY 23** | | | | | | | |
| AST | T | 1 | 5193 | 5193 | 15.97 | 0.001 | 8.378 |
| | E | 16 | 5204 | 325 | | | |
| CHOLES | T | 1 | 1.648 | 1.648 | 11.55 | 0.0037 | 8.805 |
| | E | 16 | 2.284 | 0.123 | | | |

1. cholesterol 2. uric acid 3. alkaline phosphatse
4. aspartate aminotransferase

See page 134 for explanation of abbreviations used.

# APPENDIX M. ANALYSIS OF VARIANCE FOR PERCENT TOTAL MORTALITY

The analysis of variance is based on the arc-sine square root of the percent mortality.

TABLE M-1. ANALYSIS OF VARIANCE FOR PERCENT TOTAL MORTALITY (EXPERIMENT 1).

| PERIOD | | DF | SS | MS | F | PR>F | C.V. |
|---|---|---|---|---|---|---|---|
| 0-20 | T | 3 | 0.045 | 0.015 | 3.16 | 0.0402 | 36.362 |
| | E | 28 | 0.134 | 0.005 | | | |
| 20-42 | T | 3 | 0.046 | 0.015 | 2.45 | 0.0841 | 53.807 |
| | E | 28 | 0.219 | 0.006 | | | |
| 0-42 | T | 3 | 0.081 | 0.027 | 2.95 | 0.0496 | 38.817 |
| | E | 28 | 0.336 | 0.009 | | | |

TABLE M-2. ANALYSIS OF VARIANCE FOR PERCENT TOTAL MORTALITY (EXPERIMENT 2).

| PERIOD | | DF | SS | MS | F | PR>F | C.V. |
|---|---|---|---|---|---|---|---|
| 0-22 | T | 3 | 0.040 | 0.013 | 2.13 | 0.1228 | 76.419 |
| | E | 24 | 0.150 | 0.006 | | | |
| 22-43 | T | 3 | 0.007 | 0.002 | 0.36 | 0.7843 | 78.961 |
| | E | 24 | 0.163 | 0.007 | | | |
| 0-43 | T | 3 | 0.010 | 0.003 | 0.49 | 0.6892 | 48.972 |
| | E | 24 | 0.164 | 0.007 | | | |

TABLE M-3. ANALYSIS OF VARIANCE FOR PERCENT TOTAL MORTALITY (EXPERIMENT 3).

| PERIOD | | DF | SS | MS | F | PR>F | C.V. |
|---|---|---|---|---|---|---|---|
| 0-22 | T | 3 | 0.013 | 0.004 | 1.24 | 0.3920 | 83.420 |
| | E | 24 | 0.097 | 0.004 | | | |
| 22-58 | T | 3 | 0.011 | 0.004 | 1.00 | 0.4079 | 30.415 |
| | E | 24 | 0.095 | 0.004 | | | |
| 0-58 | T | 3 | 0.004 | 0.001 | 0.44 | 0.7235 | 24.132 |
| | E | 24 | 0.068 | 0.003 | | | |

See page 134 for explanation of abreviations used.