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Title : Studies of Managerial Variables on Broiler Performance and Abdominal Fat Levels

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Today's consumers have shown a greater concern in the relationship between dietary fat and human health. The demand for leaner meat is continuously on the rise. The reduction of fat deposits in the abdominal area of ready-to-cook fryers, considered a waste product in the poultry industry, has become a major opportunity for the researcher.

Experiments were conducted to evaluate the merit of managerial practices affecting abdominal fat (AF) levels in broiler chickens. Factors studied included seasons of the year, source of the commercial broiler strain crosses, stocking densities, lighting systems, types of housing, dietary salt (NaCl) levels and feed restriction.

Two housing types (open-sided and windowless) and different seasons were utilized to evaluate the influence on broiler performance and AF levels. Raising broilers from the same strain cross in an open-sided building did not affect performance and AF levels. Mean body weight (BW) were highest

in fall season (1929 g) and lowest in summer (1735 g) ($P<.05$) while highest and lowest % AF levels were observed in spring and winter (2.34, and 1.42% respectively).

The comparative effect of feeding regime, (full feed, FF), 95 and 90% FF), dietary salt levels (0, 0.25, and 0.5% of the finisher diet), stocking densities (0.06, 0.07, and 0.09 m^2 of floor space per bird) and type of housing (battery cages and litter pens) were examined on broiler performance and AF level. Ninety % FF resulted in significantly lower body weights and AF levels compared to *ad libitum* feeding. At 49 days of age, mean BW of broilers fed 0.5% salt were higher ($P<.05$) than the group not provided with salt. Altering stocking densities and rearing in battery cages failed to show any significant improvements performance and % AF.

Lighting regime 12 h light (L): 12 h dark (D), recycled during the rearing period resulted in lower ($P<.05$) mean BW than continuous lighting regime (CL) when applied from 5 days of age. Broilers raised on 16L:8D after 21 days had comparable performance to CL. Lighting regime of 12L:12D, recycled in combination with increasing stocking densities from 0.06 to 0.8 m^2 floor space/broiler and intermittent lighting of 1L:3D in combination with the addition of 0.5% salt to the diet resulted in improved ($P<.05$) BW with no corresponding increases in AF levels.

Factors such as season of the year, feeding of salt, and manipulation of light (up to 8 h dark) can be used as tools in reducing % AF and overall production costs.

Studies of Managerial Variables on Broiler Performance and Abdominal Fat Levels

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CHAPTER 1

INTRODUCTION

During the past few decades, abdominal fat (AF) levels in the broiler chicken have been the subject of extensive research. The modern commercial broiler has the potential for extremely rapid growth, achieving high market weights in a relatively short time span. As a consequence, the broiler has gained the ability to deposit excessive amounts of carcass abdominal fat (AF). This excessive increase in AF (leaf and gizzard fat) has contributed to major losses in the processing plants, indirectly affecting all segments of the industry, including the consumers.

More recently, consumers have been demanding leaner meats. Decreasing the carcass AF levels in broilers has thus become one of the principal aims of researchers as well as producers. However, since broiler producers are paid on the basis of live weight delivered to the processing plant, methods for lowering carcass fat in broilers will be of value only if they result in reduced production costs.

Several factors can influence fat deposition in the broilers. One of these factors is genetics. The genetic potentials of modern commercial broiler strain crosses are controlled and manipulated by the primary breeders. Genetics can be used as a tool for the long range approach to the problem, and progress in this area is forthcoming.

Another factor is nutrition which can have a significant effect on carcass AF in the commercial broiler. Nutritional studies have been successful in efforts to decrease carcass AF. However, nutritional solutions have not proven to be economically feasible due to a resultant decrease in live body weight (BW) and the increased cost of raising broilers.

Managerial practices in rearing broilers are controlled by the producer. The manipulation of elements over which the grower has control in order to minimize AF levels can also prove beneficial in reducing overall production costs. Though research in this area has to date shown few positive results in terms of carcass AF reduction, there is still reason to believe that additional research in the area will contribute to beneficial results.

The primary objective of this study was to determine whether differences in managerial practices for rearing broilers influence carcass AF levels. Managerial factors such as lighting systems, broiler stocking densities, level of dietary salt, rearing season, broiler strain crosses, and types of housing were investigated.

CHAPTER 2

REVIEW OF LITERATURE

A. General Aspects of Fat Deposition

The term fat is generally used to denote visible deposits in the body (Evans, 1977). The principal biological purpose of fat deposition in poultry is the storage of excess energy in times of abundant feed supply against times when the feed supply is limited (Leenstra, 1986). Fats are stored as triglycerides in fat cells. In contrast to mammals, avian fat cells cannot synthesize triglycerides, and have only a storage function (Evans, 1977).

Surplus energy from the diet is invariably stored as fat after body maintenance and muscle growth requirements are satisfied. At the same time, the biological mechanism favors the deposition of fats by converting excess carbohydrates and proteins to fats; however, the reverse does not occur. Fats can constitute as much as 15-20% of the total live BW of broilers (Scheele *et al.*, 1981; Griffin *et al.*, 1982; Leenstra, 1982). Evans (1977) stated that more than 85% of total body fat is stored in the adipose tissues mainly as subcutaneous, intermuscular, and abdominal fat (AF). Thus, from 2 to 2.5% of the total body fat that is present in the blood and other tissues is necessary for the physiological functions of the bird. Yoshida and Morimoto (1970) reported that fats in the amount of 0.9% of total BW constitute the minimum amounts necessary to continue normal functions.

The amount of fat stored is dependent upon the energy intake and the amount of energy required for maintenance, including growth activity in non-fat tissues. Fat deposition often occur when the energy intake exceeds the energy requirements for growth and maintenance (Lin, 1981). According to Evans (1977), three main factors contribute to the growth of adipose tissue. First, an increase in size (hypertrophy) or number (hyperplasia) of cells; second the accumulation of fat in adipocytes as a part of animal growth, and third, food consumption, which is related to the substrate available to the fat cells.

During the early growth period of the bird, (up to about 14 wk of age in pullets) the number of fat cells increases rapidly then levels off (Pffaf and Austic, 1976; March and Hansen, 1977). The cells which expand in size, are then steadily and rapidly filled with lipid once their numbers have stabilized (Hood, 1982). Cherry *et al*. (1984) reported that from day-old up to about 28 days of age the increase in fat deposition are associated primarily with hyperplasia, while at later stages of growth, adipocyte hypertrophy becomes the primary influence.

In general, fat tissues grow at a faster rate than total BW (Taylor, 1982; Fisher, 1984) as measured by an allometric coefficient > 1.0 with AF as the highest coefficient (Simon and Leclerq ,1982; Fisher, 1984). Griffiths *et al.* (1978) found an increase of 12% in body fat content between the ages of four and eight wk, while at the same time there was a 40% increase in AF. Growth of lean tissue is accompanied by an increase in the percentage of body fats and a concomitant increase in the mass of abdominal as well as visceral fat.

B. Genetic Influence on Fat Deposition

Genetics play important roles in fat deposition in broiler chickens. Intensive selection for BW at a fixed age under *ad libitum* feeding conditions is the principal contributor to the increase in AF in broilers (Lin, 1981). The capacity of the gastro-intestinal tract constitutes the main limiting factor in the process (McCarthy and Siegel, 1983). This system of selection favors birds with a large appetite capable of overeating to such an extent that feed intake exceeds the bird's capacity for lean tissue growth, and thus the excess intake is converted to fat (Summers and Leeson, 1979).

1. Selection against fat

AF deposition in the chicken constitute a highly variable characteristic. Some of this variability is seemingly of genetic origin, and researchers have been able to find quite high heritability values (Ricard and Rouvier, 1967; Ricard, 1975; Becker *et al.*, 1979; Leclerq *et al.*, 1980; Chambers *et al.*, 1981). Heritability estimates for AF have been reported to range from 0.3 to 0.79 based on sire variance component (Ricard and Rouvier, 1967 and 1969; Becker 1978). Such high heritability suggests that the amount of fat can be reduced by breeding. Consequently, several researchers have developed broiler strains with fat and lean lines by selection process.

Leclerq *et al.* (1980) in measuring responsiveness to selection, showed a difference of 0.47 and 0.79 in the heritability index among males and females, respectively, in relation to % AF between two lines following three generations of selection. They also noted that males were more responsive to selection than were females. Ricard *et al.* (1982) compared lines selected for a high and low amounts of AF relative to BW, and noted a favorable effect of selection for leanness on processing yields and meat content. Liburn *et al.* (1982) found that selection for and against AF resulted in differences in appetite. However, once the fat line was restricted in the feed intakes of the lean line, no differences were noted in BW or body composition. Similar results have also been noted by Proudman *et al.* (1970) who reported that fat depositions were higher in fast-growing lines. In similar experiments, this difference disappeared once food intakes were made equal for both lines (Summers and Leeson, 1979). Research conducted by Hood and Pym (1982) demonstrated that chickens in the faster growing lines had larger fat cells than the lines which grew at slower rates. Cahaner *et al.*, (1985) reported that one cycle of divergent sib selection for or against AF weight resulted in 60% more AF in the high fat line, with heritability estimates calculated at 0.73 with 1 to 5% lower BW. In a subsequent study, Cahaner *et al.*, (1986) reported that after two generations of divergent sib selection, a difference of approximately 100% in the weight of the abdominal adipose tissue was found between the high fat line and the low fat line at nine wk of age.

The importance of selection is the ability to reduce fatness without adversely affecting growth rates. The difficulty in selection against fat lies in the question of how to estimate the amount of fat without sacrificing the birds. Direct measurement of fats, after slaughtering the birds, requires the use of progeny or sib testing as the basis for the selection system. Since fat depositions are highly heritable and generation turnovers are rapid in commercial broilers, selection against fat on the basis of sib and progeny testing (Lin *et al.*, 1980, Leenstra, 1982; Leclerq *et al.* 1980) or by selection for feed efficiency (Pym and Solvyns, 1979) are seemingly feasible methods. At the same time, selection systems by progeny or sib testing are more costly and time consuming than individualized selection systems. Thus, extensive use of sib and progeny testing has been limited. Pym and Thompson (1980) have developed a caliper which is inserted into the cloaca to measure the thickness of the abdominal region as a predictor of AF levels. This method has shown some promise, with correlations between AF thickness and fat weights ranging from 0.3 to 0.9. Becker *et al.*, (1981) noted correlation coefficients between the % AF with BW to be 0.29 in males and 0.36 in females, respectively. The heritability coefficients for % AF were 0.51 in males and 0.36 in females. Mirosh and Becker (1984) reported correlation coefficients of AF thickness with leaf fat thickness as high as 0.65. Friars *et al.* (1983) noted that heritability estimates for AF, AF as a percentage of carcass weight and carcass fat percentage were, respectively, 0.51, 0.62, and 0.48, for 580 female progenies from 23 to 44 days of age. These parameters were higher than those for daily feed intake, feed/gain, or live weight. It was concluded that the heritability estimates suggest the possibility of simultaneous improvement in growth, lean carcass content, and feed efficiency in broilers. Chung *et al.* (1983) concluded that shank and keel lengths could be used as selection criteria to decrease % AF in 8 wk old broilers, based on estimated heritability values of 0.41 for BW and 0.52 for AF. Akiba *et al.* (1986) reported a significant correlation coefficient of 0.54 ($P<.05$) between BW and AF weights.

High correlations of AF depositions to total carcass lipids in broiler chicken have also been shown. Depending on the sample, correlation coefficients between 0.4 and 0.9 were established (Delpech and Ricard, 1965; Shigeno, 1973; Van Middlekoop *et al.*, 1977; Griffiths *et al.*, 1978; Becker *et al.*, 1979; Elwinger, 1980; Leclerq et al., 1980). During selection for growth rate, changes occurred in food intakes (Siegel and Wiseman 1966; Wilson 1969; Proudman *et al.*, 1970). Increased feed intakes resulted in greater fat deposition contributing to an indirect but positive correlation between growth rates and fat deposition.

Washburn *et al.* (1975), based upon high heritability estimates, suggested selecting for lower body fat content rather than growth rate as a means to decrease AF levels. The practical viewpoint suggests that selection against AF under *ad libitum* feeding would act to decrease appetite, gain, and overall efficiency (Sollier and Eitan, 1984). Preventing the development of excess fat cells by selection or by limiting the energy supplies in early life, as well as limiting the hypertrophy of fat cells by the restriction of feed intakes in the later stages of growth, may lead to the reduction of fat deposition (Van Es, 1981).

Selection for better feed conversion can result in less carcass fat when birds are compared at the same age or at the same BW (Washburn *et al.*, 1975; Pym and Solvyns, 1979). Research has indicated that broilers with better feed conversion have less fat than broilers with poor feed conversion, indicating a positive correlation within generations between relative amounts of AF and feed conversion, with some degree of variability (Eisen 1982; Dickerson 1982). Breeders who select for improved feed conversion are likely interested in selection for leaner birds which eat less feed. Conversely, selection against fat should result in decreased amounts of AF as well as total body lipids, thus providing for leaner birds (Becker, 1983). Lines selected for low fat depositions attain more favorable feed conversions than those selected for high fat depositions (Griffin *et al.*, 1982; Leclerq and Saadoun, 1982).

2. Differences in breeds

Significant differences in fat deposition exist among breeds. March and Hansen (1977) have found that the adipocytes of Single Comb White Leghorns are smaller in number and size than those of broilers. According to the literature, Cornish cross-breeds have been found to be good meat producers (Dawson *et al.* ,1958; Moran *et al.*, 1970). In this sense, Edwards and Denman (1975) concluded that among five breeds, the Dark Cornish breed had the lowest percent of total lipids (8.6%) at four wk of age.

3. Differences in broiler strains

Research indicates that differences in carcass fats exist among broiler strains (Hunt, 1965; Washburn *et al.*, 1975).

Significant differences in AF deposition have also been reported among commercial broiler strains (Littlefield, 1972; Farr *et al.*, 1977; Merkley *et al.*, 1973, Van Middlekoop *et al.*,1977; Griffiths *et al.*, 1978; Nordstrom *et al.*, 1978). In contrast, Becker *et al.*, (1981) observed no significant differences in AF levels between five broiler strains. However, the lack of significance could be attributed to the small size of the sample (10 birds/sex/strain). Since differences exist in AF levels among broiler strains, line or strain selection for lower AF levels could be used as an effective technique for leaner carcasses. The challenge of the current research efforts is to provide useful methods for selection against body fat deposition while at the same time increasing BW (Becker, 1983).

C. Internal Environment Influence on Fat Deposition

1. Differences by sex

Sexual differences exist in fat deposition. Current research indicates that there is a higher percentage of fat in females than in males at market weights (Thomas *et al.*, 1958; Ricard, 1964; Summers *et al.*, 1965; Ricard and Rouvier, 1969; Moran *et al.*, 1970; Edwards *et al.*, 1973; Rinehart *et al.*, 1975; Pym and Solvyns, 1979). In addition, increases in the percentages of total body fat in females exceed those for males (Edwards *et al.*, 1973; Fisher, 1980). Ehinger and Seemann (1982) slaughtered birds from 35 to 53 days of age and demonstrated the clear effect of sex and age on the percentages of body fat without significant differences between the sexes in the rate of change due to age. In females, the amounts of AF comprise a greater portion of total fat than in males (Hakansson *et al.*, 1978). Consistent differences in fat deposition between sexes can be an important consideration in rearing of the sexes separately. Standard methods of straight-run production are disadvantageous with respect to fat deposition since males are marketed at lower, and females at higher BW. The separate rearing of the sexes will be more beneficial. Increases in BW (growth) of males are faster than those for females, while increases in body fat as well as AF in females exceeds that in the males (Edwards *et al.*, 1973). These differences suggest that substitution of the parent lines in commercial broiler strain crosses may alter broiler fat content (Van Middlekoop *et al.*, 1977).

2. Differences in age

It is generally accepted that the fat content of birds increases with age (Edwards *et al.*, 1973; Deaton *et al.*, 1974; Becker, 1978). Kubena *et al.*, (1974a) reported that within each sex there were no significant differences in the quantities of AF at seven, eight, or nine wk of age when expressed as % of BW. Females had larger percentages of AF than did males. Leenstra (1982), studied the growth of total fats in 3 to 10 wk old broilers, and found an increase in total fat in females and males of, 10-19% and 10-13%, respectively. Only minor increases were noted past six wk of age. Since the percentage of carcass fat increases with age, the percentage of moisture, protein, and ash should simultaneously decrease given that these four body constituents must add up to 100% (Lin *et al.*, 1980). Age is thus an important factor in the determination of the relative proportions of body constituents. Current trend is to market broilers at younger ages (6 to 7 wk), offsetting any effect on the rate of fat depositions (Delpech and Ricard, 1965; Edwards *et al.*,1973). Therefore, it is evident that the fat content of broilers will not change noticeably if present breeding and marketing trends are continued.

D. External Environmental Influences on Fat Deposition

1. Nutrition

Among the different factors which affect fat deposition, nutritional considerations have been studied extensively. Through alterations in the feed consumption and nutritional composition of the diet significant effects on body composition of broilers have resulted (Lin *et al.*, 1980; McLeod, 1982; Fisher, 1984). Mabray and Waldroup (1981) recognized four general nutritional concepts that influence the degree of fatness in broilers: 1) narrowing the calorie-protein ratio (C:P) to prevent excessive depositions of body fat; 2) conditions which lead to an imbalance of amino acids cause increased body fat levels; 3) existence of a specific effect of dietary fat on carcass composition; and 4) the effects of dietary energy levels can be related to the degree of fatness. Other factors known to influence carcass fat depositions include, crude fiber and the salt content of the diet (Have and Scheele, 1981; Marks and Washburn, 1983).

Calorie to protein ratio (C:P) of the ration has a significant effect on the AF content of the broiler chicken. Two underlying principles that can influence the growth of body fat are: first, diets containing sub-optimal amounts of protein will cause birds to consume excessive amounts of energy to optimize protein intake for non-fat growth (Combs, 1962). This excess energy can in turn result in the deposition of AF. Broilers fed low protein diets have overconsumed feed to satisfy protein requirements for optimum growth. Hence, they have deposited more fat as a result of this increased feed intake (Hill and Dansky, 1954; Donaldson *et al.*, 1956; Adams *et al.*, 1962, Griffiths *et al.*, 1977a). Second, high protein diets with optimum energy intake involve excessive consumption of protein. As a result, fat deposition is decreased due to a depressing effect on lipid synthesis as well as the energy cost of the excretion of surplus nitrogen (Whitehead, 1986). Thus, according to Fraps (1943), any change in a positive direction which serves to increases C:P will in turn decrease fat content. Conversely, a decrease in C:P will enhance fat deposition. Donaldson *et al.* (1956, 1957) demonstrated a highly significant correlation ($P<.01$) between the C:P and the amount of carcass fat in chickens. Spring and Wilkinson (1957) found that increases in dietary energy resulted in increased weight gains and body fat while increases in dietary protein levels had no effects upon weight gain, but did decrease body fat. Subsequently, Yoshida *et al.* (1962) demonstrated that feeding low energy, high protein diets reduced the amounts of carcass fat. Bartov *et al.* (1974) noted that protein levels slightly above or below the accepted optimum levels had no effects upon either growth rate or fatness of broilers. Jackson *et al.* (1982) indicated a growth depression whenever dietary energy or protein became inadequate. Minimizing body fat content at an optimum rate of growth was achieved by increasing dietary protein levels, rather than by decreasing dietary energy levels. Therefore, well balanced diets can have an important effect upon reduction of fat deposition.

Kubena *et al.* (1974b), in relating to the effect of age and dietary energy levels to quantities of broiler AF, noted that dietary energy levels of a starter diet fed during the first four wk of age appeared to influence the quantity of AF at seven or eight wk of age, but by the ninth wk this influence was no longer present. Following up on conclusions first reached by Deaton *et al.* (1973) and Moran (1979), Pesti and Fletcher (1984) fed male broilers diets containing 175 to 220 g protein/kg (17.5 to 22% crude protein) from 21 to 42 days of age with same metabolizable energy (ME) and found increased BW gains and lower feed conversions with to increased protein amounts, while there were decreases in AF weights and total carcass fat content. From 42 to 49 days of age, feed conversion decreased with increased protein content, while there was no effect on BW gains or AF content. Compensatory growth was more evident with broilers fed lower protein diets during the growth phase due to increased efficiency in the utilization of the feed. Prior to this study, Twining *et al.* (1978), in an evaluation of the effect of high and low protein diets on broiler body composition at 28, 49, and 59 days of age noted that broilers receiving low protein diets had more carcass fat than those receiving high protein diets. Thus, an effective approach to decreasing body fat content involves feeding normal starter diets up to 21 days of age, accompanied by finisher diet from 21 days of age up to market with a higher than normal protein to energy ratio. This can be achieved either by decreasing the energy content resulting in lowered growth or by increasing the protein content, resulting in more expensive diets. Therefore, these diets are not commercially viable (Holsheimer, 1975). Consideration of economic factors is the final determinant in the manipulation of fatness via the use of dietary C:P.

In general, modern high energy diets can be advantageous from the viewpoints of BW gain and feed conversion. However, when carcass quality is also a consideration, the benefits gained from high energy diets are less pronounced (Freeman, 1983). When chickens are fed diets containing sufficient energy to cause fat depositions, a considerable portion of this fat is deposited in the abdominal area (Essary *et al.*, 1960).

Deficiencies of amino acids can have an effect similar to low C:P on lean tissues as well as on fat growth. Velu *et al.* (1971) showed that body fat increased as the amino acid mixture was changed from 0 to 60% of a previously determined reference standard and in turn decreased when changing from 80 to 160%. In a subsequent report, Velu *et al.* (1972) fed balanced *ad libitum* diets devoid of either lysine, or isoleucine, and noted an increase in body fats with each increment in the levels of the limiting amino acids. Lipstein *et al.* (1975) reported that in three of four cases, an increase in fat deposition due to a lowered protein content in a well-balanced finisher diet could be reversed by supplementation with methionine and lysine. Mabray and Waldroup (1981) also concluded that the degree of fatness could be significantly reduced ($P<.05$) by increasing dietary amino acid levels within given energy levels. It was also noted in most cases, that when the amino acid levels were increased to the levels of the control group, the results were increases in gains with reduction in the size of the AF pad. Marks and Pesti (1984), in an experiment in which male broilers from day-old up to 19 days of age were fed diets containing 17,22, and 26% protein, noted that the chicks fed the 26% diet consumed more water, had higher water/feed ratios, and had less AF than chicks fed the lower protein diets.

Studies concerning the effect of dietary energy levels on the degree of fatness in broilers have shown conflicting results. Hill and Dansky (1954) reported that carcass fat content increased with increased energy levels and constant protein diets. Mabray and Waldroup (1981) associated a similar increase with broader C:P and not specifically with energy levels. Farrell (1974) noted progressive fattening of the birds with increases in the energy value of the diet when essential nutrients were held in a constant ratio to energy levels. Kubena *et al.* (1974a) reported the highest % AF were achieved with starter-finisher of 3306/3372 kcal ME/kg and the lowest were achieved with 3141/3042 kcal ME/kg at seven and eight wk of age. Griffiths *et al.* (1977a) detected no differences in AF weights between the sexes in eight wk old broilers reared either on 2970 or 3190 kcal ME/kg diets.

The specific effects of dietary fat supplementation on carcass composition are not clear, but a large body of evidence suggests that addition of fat to the diet, without changing the total dietary energy content, has little influence upon body fat deposition. Diets with higher fat contents depress lipogenesis in the broiler, but only to the extent that the fat is provided within the diet. Nevertheless, improvements in energy efficiency have been noted as a possible result of increases in body fat deposition (Whitehead, 1986).

Edwards and Hart (1971) found no changes in the carcass fat content of Single Comb White Leghorn chicks up to 8 wk of age when total energy was derived from various dietary oil, such as lard, corn oil, and linseed oil. It was also reported that the fatty acid compositions of the total carcass lipids reflected the fatty acid composition of the oils fed in the diet.

Bartov *et al.* (1974), Bartov and Bornstein (1977), Bartov (1977), Fuller and Rendon (1977), Mabray and Waldroup (1981) and Deaton *et al.* (1981) have all noted that the addition of dietary fats, of both animal and vegetable origin without a change in the total dietary energy, could result in increased body or carcass fat content. Griffiths *et al.* (1977b), however, noted that increasing the content of dietary fat (i.e. 0 to 9%) in diets formulated to be isocaloric with equivalent levels of lysine and methionine had no significant influence on % AF in eight wk old broilers.

Research has also indicated that additional amounts of dietary fats accompanied by increases in feed energy can cause increases in carcass fat (Donaldson *et al.*, 1956; Newell *et al.*, 1956; Essary *et al.*, 1960; Carew and Hill, 1964). Since body fat in poultry is derived from dietary fat as well as from liver lipogenesis, dietary constituents have been found to have a significant effect on the composition of body fats in broiler chickens (Marion and Woodroof, 1966; Edwards *et al.*, 1973; Edwards and Denman, 1975; Bartov and Bornstein, 1977). Deaton *et al.* (1981) reported that when dietary fat was increased up to 10% of the diet, the amount of broiler body fat increased regardless of rearing temperatures. It was suggested when dietary fat were added that the benefits of increased BW gains could outweigh the disadvantages of an increases in AF. In turn, the feeding of unsaturated fats has served to increase unsaturated fat depositions in poultry carcasses. Unsaturated fatty acids were more readily oxidized, thus reducing the keeping quality of the meat (Klose *et al.*, 1951; Marion and Woodroof, 1966).

However, it is not possible to accurately predict carcass composition from current knowledge of dietary factors. This is because any number of interacting factors can influence carcass composition (Leenstra, 1986). One other complicating factor in the relationship of nutrition and fat depositions is that most dietary factors do not have the same effect on AF deposition. The effects of diet on AF are greater than their effects on the total amount of carcass fat (Elwinger, 1980; Jackson *et al.*, 1982; Ehinger and Seeman, 1982).

It has also been established that the lipid and the moisture content of the carcass are inversely correlated (Donaldson *et al.*, 1956; Twining *et al.*, 1978) and moisture content has been used to estimate the fat content of chicken carcasses. McNally (1955), as well as Taylor and Shaffner (1975), reported correlation coefficients of, r = -0.99 and r = -0.98, between the fat and moisture contents of the total edible carcass of broilers, respectively. Verstrate *et al.* (1980) also reported highly negative coefficients, from r = -0.87 to -0.9, between moisture and the ether extractable solids of the ground broiler carcass. This relationship suggests that increased broiler water consumption may in turn inhibit fat depositions. Feed restriction and salt levels are among the factors which have been demonstrated to influence the water/feed intake ratios (Marks, 1980; Marks and Washburn, 1983).

Feed restrictions can help reduce AF content by decreasing caloric intake. Restriction of caloric intake during the early growth stage tends to decrease fat depositions in chickens (Pffaf and Austic, 1974; Moran, 1976; March and Hansen, 1977). In contrast, Griffiths *et al.*, (1977a) noted that caloric restriction from day-old up to three wk of age had no significant effect on AF pad when they reached 56 wk of age. Cherry *et al.*, (1978), found that early growth restrictions increased AF weight in some strains while decreasing AF weights in others, suggesting a possible interaction between genotype and feed restriction. Boone *et al*. (1980) noted that approximately 25% reduction in fat pad weight may be expected with a 75% reduction in feed intake. Nitsan *et al*. (1984) observed that restrictions of less than 75% of the normal feed intake were necessary to depress body fat content in chicks between 2 and 4 wk of age. As a consequence depressions in non-body fat weights have resulted from feed restrictions during the final wk of growth (Auckland and Fulton, 1972; Arafa *et al*., 1983). A study by Plavnik (1987) noted that a feed restriction for 6 to 12 days, starting at 5 days of age, resulted in 30% AF reduction. The final BW at 54 days of age for the restricted males and females were, slightly higher and smaller, respectively, when compared to the controls. It appears that caloric restriction during early growth stages could have a relationship to reduced fat depositions.

Feed restrictions can also serve to prevent excessive fat birds kept in groups by increasing their physical activity (Wenk, 1980). It can also have a slight negative effect on protein deposition, prolonging the growth period and thus resulting in increased feed efficiency (Van Es, 1981). However, feed restriction, in comparison to *ad libitum* feeding, increases requirements for both labor and equipment (Pym and Nichols, 1979; Boone *et al*. 1980). Feed restriction can only be developed as a useful approach once economic feasibility is demonstrated through increased demand for leaner meats.

In experiments with salt, Maurice and Deodato (1982) demonstrated a significant decrease ($P<.05$) in the AF levels among males 5 to 7 wk of age when they were given 50-100 mM solutions of sodium chloride (NaCl) in their drinking water, without significantly affecting BW. Lightsey *et al.* (1983) noted that either the addition of NaCl at levels of 0.8% or greater to the diet, or a 25 mM solution to the drinking water, resulted in a reduction of AF in broilers. Marks and Washburn (1983) observed that with the addition of 2.4% dietary salt, a significant reduction of AF in a range from 17 to 28% was obtained. Thus, experiments with salt, have shown some promising results. However, associated disadvantages of increased salt levels include more water consumption, excessively wet litter and possible salt toxicity. Additional research in this area will be required to demonstrate commercial feasibility.

2. Environmental Temperature

Kubena *et al.* (1972) in a study on the effects of environmental temperatures from 7.2 to 32.2 C reported a significant decrease in carcass ether extract with a concomitant increase in moisture content as temperatures were decreased. In a subsequent study, Kubena *et al.* (1974a), noted a positive trend between AF and rearing temperatures among both males and females at eight and nine wk of age. In a series of experiments, Fisher (1984) calculated a 0.19% linear increase in total body fats per degree increase in temperature between 10 and 30 C. In turn, lower environmental temperatures can stimulate appetite, resulting in higher heat production. When high heat production cannot be easily lost, poultry tend to lower their feed intake and thus their heat production. At the same time, physical activity tends to decrease (Van Kampen, 1973,1980). Among growing animals, low feed intake depresses fat deposition to a greater degree than lean tissue growth or live weight gain (Van Es, 1981). In fitting regression equations from data obtained from 17 published and one unpublished report, Howlider and Rose (1987) noted that AF increases by 1.6% for each degree of rise in temperature. In a study of the seasonal effect of temperature on AF and performance, Yamane *et al.*, (1979) concluded that broilers reared on litter in windowless houses during summer months had higher percentages of AF than groups raised during other seasons. Merkley *et al.*, (1980), in trials conducted during four different seasons of the year, reported that the leaf fat of five different strain crosses were significantly affected by crosses and sex. Broilers processed in December had the lowest %AF (e.g., 2.76% males; 3.51% females), while broilers processed in September had the highest %AF (e.g., 3.4% males; 4.23% females).

3. Type of housing

Considerable interest has been shown in housing broilers in battery cages. Cage management allows for rearing more broilers in a given area, helps in the reduction of housing costs, and eliminates the purchase of litter materials. Balint (1978) reported that broilers placed in battery cages had higher carcass yields (i.e., 79.2 vs 74.8%) and higher percentages of grade A carcass (i.e., 82.8 vs. 73.1%) than counterparts raised on deep litter. Evans *et al.* (1976) found that the fat content of the meat from cage reared broilers was lower than that obtained from floor reared broilers. Deaton *et al.* (1974) noted that at seven wk of age, males and females produced higher percentages of AF when raised in cages (i.e.,1.99 and 2.06%, respectively) than broilers raised on litter floor (i.e., 1.8 and 1.99%, respectively). This could have been attributed to decreased activity of caged broilers, as reported by Haye and Simmons (1978).

Yamane *et al.* (1979), in a study on the influence of age, season and type of housing on AF deposition in broilers, noted that males and females placed in cages in windowless housing had lower percentages of AF (2.73 and 3.5% respectively) than counterparts raised on a litter floor in windowless housing (3.86 and 5.16%, respectively) and broilers raised on a litter floor in open-sided facilities (3.18 and 4.35%, respectively).

4. Lighting programs

Lighting programs have also been used as a tool in the improvement of poultry production. Most studies which have examined the effect of intermittent lighting (IL) on performance have indicated favorable results, based on BW gains and feed conversion ratios. This improvement in growth has been associated with alterations of feeding behavior (Cohn and Joseph, 1960), and increased feed efficiency has been obtained through reduction of physical activity and heat production (Clegg and Sanford, 1951; Ota, 1967). Buckland (1975), following review of the literature on IL noted that IL, in comparison to continuous lighting (CL), resulted in improved performance of marketable chickens and suggested that a ratio of 1 h light (L): 3 h dark (D), recycled over a 24 h period, was the most satisfactory approach to fat reductions among broilers. Cholocinka (1985) reported that 6 h of lighting did not reduce performance when compared to 12 h of lighting per day. However due to the intricate relationships among diverse factors such as photoperiod, light intensity, and the nutritional status of the experimental birds, the results of the effect of light upon broilers have not been consistent. This inconsistency, could be due to the use of different broiler strains and managerial conditions such as temperature or broiler rearing density.

To date, there has been little research interest in the issue of the influence of IL on the meat quality of the broiler carcass. Cherry and Barwick (1962) and Cain (1973) reported higher carcass grades from broilers reared under the 1L:3D light regime. However, Buckland *et al*. (1971) found IL increased % undergrades when compared with CL in one of the two strains tested. Beane *et al*. (1979) noted that female broilers reared under IL deposited more AF than those reared under CL. Cave (1981) indicated that the adoption of IL (1L:3D) could enhance carcass quality by significantly ($P<.05$) reducing carcass fatness at 48 and 55 days of age in females and at 55 days in males.

In a subsequent report, Cave *et al*. (1985) conducted experiments with two to seven wk old broilers of both sexes. In a 1L:3D light regime, males had greater percentages of AF, while females responded just the opposite. Suwindra and Balnave (1986), incorporated long periods of darkness up to 10 h. Little response in AF levels was noted. Three equally distributed 2 h lighting periods daily were sufficient to enable normal feed intake and provide for a normal rate of growth. This recommendation was not in agreement with other findings. Shutze *et al*., (1960), Dorminey, (1971), and Dorminey and Nakaue, (1977) found that broilers should be allowed to eat at regular intervals spaced approximately two to three h apart, a feeding cycle corresponding to the average transit time of digesta in 4 to 6 wk old chickens (Tuckey *et al*. 1958).

5. Stocking densities

Research examining the effect of stocking densities on AF has been limited. Buckland *et al.* (1971) noted a significant interaction between stocking density and light with respect to the carcass quality of the birds. Broilers grown at 0.093 m^2 of floor space had higher % A grade carcass ($P<.001$) than birds grown at 0.047 m^2 of space (83.8 vs 75.6%, respectively). Proudfoot *et al.* (1979) noted that increased bird densities resulted in significant linear reductions in BW ($P<.05$) among both males and females and adversely affected carcass quality.

E. Influence of Interactions on Fat Deposition

Interactions between sex, age, genotype, nutrition, as well as environmental factors, can affect fat deposition in broilers. The interaction of sex and age has been discussed earlier. Genotype-environment and genotype-nutrition interactions on AF deposition are briefly reviewed in this section.

Friars *et al.* (1979) studied the amounts of AF in two broiler strain crosses in floor and cage environments, and found that when broilers were reared on the floor one strain deposited a significantly higher amount of AF than the other (42.5 vs. 34.5 g, respectively). When the AF were measured for broilers grown in cages, the genetic differences were much smaller and were statistically insignificant (32.7 vs 31.3 g, respectively). Evans *et al.* (1976) reported that there was an interaction between rearing system (cages vs. floor) and sex, and female broilers reared in cages contained higher percentages of fat than male broilers reared in cages. The opposite was true for the floor reared birds.

Changes in dietary protein can cause different responses in males than in females. Males tend to exhibit a decline in %AF with increased protein levels in the diet. Females react more strongly, with less fat deposition with increased protein in low dietary protein rations than at high protein levels (Mabray and Waldroup, 1981). A study by Ehinger and Seemann (1982) examined the importance of a number of different factors on their interactions upon fat depositions. Males and females among four commercial broiler strains were given four diets differing in protein and energy, and were then slaughtered at four different ages. Among the characteristics, percentages of AF were determined. Age, dietary composition, strain, and sex accounted for total variation in fat depositions by 7,14,4, and 16%, respectively. No interactions for % AF between the four variables were observed. Cherry *et al.* (1978) studied population differences in broiler response to low nutrient density diets during the first part of the growing phase. They concluded that significant ($P<.05$) low nutrient density regime X population interactions existed for AF pad weights of both males and females. This indicates that the response of the different strains to the diets fed were not similar. These results were also confirmed by Have and Scheele (1981). In experiments conducted to examine the influence of strain and density on performance, Buckland *et al.* (1971) noted significant interactions ($P<.01$) for seven wk BW for strain, sex, and stocking density. However, problems can be encountered with respect to selection against fat when different genotypes are ranked differently for performance in different environments. The results of these experiments indicate that interactions represent only a rather small effect upon fat deposition but should be considered during interpretation of the results.

Chapter 3

STUDIES OF MANAGERIAL VARIABLES ON BROILER PERFORMANCE AND ABDOMINAL FAT LEVELS

1. EFFECTS OF TYPE OF HOUSING, SEASON AND COMMERCIAL BROILER STRAIN CROSSES

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ABSTRACT

Six experiments were conducted over two years during different seasons with seventy two hundred commercial broilers of 8 different strain crosses. Four experiments were conducted in open-sided housing during four seasons to study the seasonal and strain effects while two additional experiments were conducted in a windowless mechanically ventilated building to study the effect of housing on performance and abdominal fat (AF) levels at 49 days of age. One strain Petersen X Arbor Acre (P X AA), common to all experiments was used to study housing and seasonal effects.

Raising broilers in open-sided building did not result in any reduction in body weight (BW) (P>.05) or % AF. Seasonal changes resulted in significant differences in all the variables studied. Mean broiler weights for P X AA strain cross at 49 days were highest in winter season (1962 g) and lowest in summer (1735 g). AF levels were highest in spring (2.34) and lowest in winter (1.42). Feed conversions were higher (P>.05) for broilers raised during spring (2.29) when compared to other seasons.

Significant differences in relation to female BW, as well as combined sex and mean % AF levels were noted among different broiler strain crosses. Generally lighter BW at 49 days of age were associated with higher feed conversion and AF levels.

When open-sided facilities are used seasonal and strain cross can alter AF with no detrimental effect on BW in moderate climates.

Key words: Abdominal fat, broiler strain cross, season, housing

INTRODUCTION

Excessive broiler carcass fat is a major concern to the broiler industry because of the consumer's demand for leaner carcasses. Many variables such as genetics, nutrition, environment, rearing conditions and types of housing may have an influence in the amount of fat deposited in the commercial broiler chicken.

In today's broiler industry with numerous available broiler strain crosses with varied genetic background, it is important to determine the influence of such variation on performance and the amount of the abdominal fat (AF) deposited by each strain crosses under different environmental conditions. Goodwin *et al.* (1969) noted a significant difference by sex and strain for percent carcass fat among 12 broiler strain crosses. Van Middlekoop *et al.* (1977) tested two commercial parent lines and six commercial broiler strain crosses and found a difference in AF levels between strains from the same breeder. Twining *et al.* (1978) evaluated the effect of varying dietary protein on body composition in two commercial broiler strain crosses and noted a significant difference among strain crosses in the amount of carcass fat. Becker *et al.* (1981) observed no significant differences in AF between five broiler strain crosses. The lack of significance was attributed to the small sample size of birds sacrificed for AF measurements. Summers and Leeson (1979) did not report any statistically significant differences in visceral and AF levels between four broiler strain crosses at 8 wk of age.

Broilers are grown year-round and the changes associated with the levels of AF in the broiler carcasses may be influenced by environmental conditions such as seasonal changes, and types of housing. Merkley *et al.* (1980) conducted trials at four different periods of the year and reported that the leaf fat of 5 different broiler strain crosses were significantly affected by strain crosses and sex. Broilers processed in December had the lowest percent of AF (2.76% in males, 3.51% in females) than those in September which had the highest (3.40% in males, 4.23% in females). Yamane *et al.* (1979), conducted two trials and found the influence of age, season and housing on AF deposits in broiler chicken. The results revealed that the ratio of AF deposits expressed as a percent of dressed weight rose with increase in age. In investigating relationship between rearing conditions and AF deposits, the authors reported no significant differences among seasons with respect to percent AF. Broilers raised in windowless housing had the highest levels of AF levels in the summer while those raised in open-sided buildings had highest levels of AF during winter in both sexes. Kubena *et al.* (1974a) reported increases in percent AF levels with increases in rearing temperatures in 8 wk old broilers within each sex.

The mild environmental climate of Willamette Valley in Oregon is ideal for rearing broilers. Broiler strain crosses react differently under these mild environmental conditions than the more severe rearing conditions of the south or east. Therefore, these experiments were conducted to determine the effect of housing, different broiler strain crosses, and seasons on broiler performance and levels of broiler carcass fat.

MATERIALS AND METHODS

Eight different commercial broiler strain crosses (Peterson, P X Arbor Acres, AA; AA X AA; Hubbard, H X AA; Tatum, T X AA; AA X P; H X H; Vantress, V X H; and Ross, R X H) were utilized in six experiments to study the effect of housing, season and strain crosses on carcass abdominal fat (AF) level and performance.

Season of the year was determined by the date of processing in each experiment. The four seasonal experiments (Trials 1 through 4) took place in conventional curtain sided broiler housing facility (open-sided). In order to study the effect of housing 2 additional trials (5 and 6) were conducted during summer and fall, only in a windowless housing facility. The choice of broiler strain crosses was decided by the availability of hatching eggs at the time of each trial. Only one strain cross Petersen X Arbor Acre (P X AA) was made available in all experiments. In order to eliminate interaction effect from strain only data from P X AA broilers were used to analyze effect of housing and season. Broilers in all experiments were raised up to 49 days of age. Seasons, broiler strain crosses and types of housing for each trial are listed in Table 3.1.

The open-sided facility consisted of an uninsulated curtain sided building with eight pens. Side curtains were fully opened after 21 days of age, and the broilers were exposed to outside temperature fluctuations up to market age. Daily average temperatures were calculated using minimum and maximum readings during a 24 h period. The thermometer was 1 m above ground. Average temperatures for each season were computed using daily averages for the last 28 days of experiment during which broilers were exposed to outside air. Temperature data were provided by the Oregon State University Climate Institute.

The windowless housing facility which contained eight pens was mechanically ventilated. A squirrel cage fan with a 300 cfm capacity (8.5 cubic meter) provided ventilation for each pen. The fan operated on a time clock according to the age of the broilers and the room temperature. After 21 days of age, the fan was set to maintain 21 C temperature in the room.

The standard managerial practices in brooding and rearing were followed in all experiments as outlined by North and Bell (1990). One hundred eighty five day-old straight-run chicks per pen (3 m X 4.5 m) were distributed in eight pens in each experiment. Each strain cross was replicated twice and randomly assigned to the eight pens. The chicks were provided *ad libitum* mash feed and water. Lighting was provided for 24 h from day-old up to 49 days (market age). A two-phase feeding program was used for all experiments. The starter mash diet consisted of 23% crude protein (CP) and was fed from day-old to 21 days of age. The finisher mash diet consisted of 21% CP and was fed from 22 days to 49 days of age (market age) as detailed in Table 3.2. Broiler chicks were placed on wood shavings litter (10 cm deep), and an electric brooder was placed in each pen. The temperature under the brooder was 35 C during first wk, and was reduced to 21 C by the third wk. The total feeder space was 750 linear cm, and the water trough space was 2 m for each pen. Artificial light was provided by a 40 watt, white incandescent bulb, placed 2.3 m above the floor. Light intensity at the height of the birds was approximately 15 lux directly under the bulb and about 5 lux in the corners of the pen.

Male and female BW and feed conversions were measured at 49 days of age. At 49 days of age a random sample of 8 males and 8 females from each pen (16 males and 16 females per treatment) were chosen to determine the carcass fat level. The birds were subjected to a 10 h fast, weighed prior to sacrifice for the removal of the carcass AF at 49 days. The leaf and gizzard fats were excised from each bird by the same individual, weighed immediately and percentage of the AF calculated from the data and expressed as a % of live BW.

Analysis of variance (ANOVA) was used in evaluating statistical differences. Significant means were separated according to Least Significant Difference as described by Snedecor and Cochran (1980). Statgraphics version 4.0 (1989) was used in the analysis of the data. In the absence of interactions among the main effects (strain cross, housing and season) one way ANOVA was used.

RESULTS AND DISCUSSION

Data from trials 1 and 2 (summer and fall) were pooled for Petersen X Arbor Acre (P X AA) to compare the effect of housing in open-sided building to trials 5 and 6 conducted during the same seasons in a windowless environment (Table 3.3). Open sided housing did not result in any significant reduction (P>.05) in AF levels and body weight (BW). No differences were noted in relation to feed conversions in relation to housing type. This study is not in agreement with Yamane *et al.* (1979) in which higher % AF in broilers raised in windowless houses was observed when compared to open-sided buildings. The differences may be due to use of different strain. After 21 days of age the temperatures in the windowless housing were maintained at 21 C while average air temperatures for the open-sided building were at 16 C. Based on the finding by Kubena *et al.* (1974a) positive relationship between environmental temperatures and AF levels exist. It is evident that temperatures in windowless housing had a direct influence on the levels of AF.

Performance and AF levels can be significantly altered by seasonal changes when broilers are raised in open-sided house environment (Table 3.4). Daily recorded average temperatures for the last 28 days in each trial were 18 C (summer); 15 C (fall); 10 C (winter) and 12 C (spring) in the Willamette Valley in Oregon. In studying the seasonal effect female and average body weights were significantly altered by seasonal changes. Average body weights were significantly higher during winter and fall seasons (1962, and 1929 g) compared to summer and spring. This may indicate different response by sex to changes in ambient temperatures. This hypothesis was also confirmed by Howlider and Rose (1987). Feed conversion for broilers raised during spring (2.29) was not significantly higher than other three seasons. Average % AF did not follow a pattern similar to BW. Broilers raised in spring had significantly higher % AF (2.34%) when compared to summer, fall and winter (1.79, 1.75, and 1.42 respectively). The results confirm previous research by Merkley *et al.* (1980) in trials conducted at four different periods of the year. Broilers processed in December had the lowest percent of AF (2.76% in males, 3.51% in females) than those in September which had the highest (3.40% in males, 4.23% in females). This is contrary to the finding of Yamane *et al.* (1979), who reported that broilers raised in open-sided buildings had the highest levels of AF during winter in both sexes. Best overall performance in terms of high BW and lowest % AF were observed during colder months of the year namely fall and winter seasons.

Significant differences were noted among various strain crosses in relation to female BW, as well as combined male and female BW and average % AF levels (Table 3.5). Generally, better feed conversions were associated with lower AF levels as indicated by T X AA cross with a feed conversion of 2.08 and an average AF level of 1.79 when compared to R X H cross with significantly higher feed conversion and AF levels (2.30 and 2.59%, respectively). The results also indicate that high degree of variability in parameters such as AF levels make the ranking of different strains very difficult. Griffiths *et al.* (1978) also noted a significant difference between various strains with respect to fat deposition. Van Middlekoop *et al.* (1977) reported considerable differences in AF between stocks from different breeders which was not confirmed by this study. Based on the results from this study different strain crosses cannot be ranked based on performance.

An attempt in establishing correlation coefficient between mean BW, and AF levels did not reveal any significant relationships suggesting that BW have little effect on AF development in agreement with research previously conducted by Griffiths *et al.* (1978). A significant ($P<.05$) correlation coefficient of $r=0.29$ between feed conversion and AF levels indicated factors other than feed utilization were involved with fat deposition.

Based on the conditions of these experiments, fluctuations in environmental temperatures caused by seasonal changes can help in reducing % AF levels without any detrimental effect on BW. Better feed conversions can also result in reduced cost of feeding. On a commercial scale, this information can be used in lowering overall production costs.

Table 3.1. Housing, season, and broiler strain crosses for each experiment

	Broiler Strain Crosses							
	Petersen X Arbor A (P X AA)	Arbor A X Arbor A (AA X AA)	Hubbard X Arbor A (H X AA)	Tatum X Arbor A (T X AA)	Arbor A X Petersen (AA X P)	Hubbard X Hubbard (H X H)	Vantress X Hubbard (V X H)	Ross X Hubbard (R X H)
a Trial 1 Summer	X				X	X		
a Trial 2 Fall	X	X	X	X				
a Trail 3 Winter	X	X	X	X				
a Trial 4 Spring	X					X	X	X
b Trial 5 Summer	X	X	X	X				
b Trial 6 Fall	X	X	X	X				

[a] denotes uninsulated mechanically ventilated windowless house

[b] denotes uninsulated open-sided house

Table 3.2. Composition of broiler starter and finisher diets

Ingredients	Starter	Finisher
	(%)	(%)
Corn, yellow	60.27	65.42
Soybean meal, 47.5%	32.25	27.50
Meat meal w/bone ml, 50% CP	5.00	5.00
Alfal meal, dehy, 17% CP	1.00	1.00
Defluo.rock phos. (32% Ca,18% P)	.42	.25
Limestone flour	.35	.13
Salt, iodized	.25	.25
Trace min mix 1	.05	.13
Vitamin premix 2	.20	.20
d,l methionine (98%)	.10	.10
Baciferm (40g/lb) 3	.05	.05
Zoamix (25%) 4	.05	.05
Calculated analyses:		
Crude protein %	23.34	21.50
Met energy, kcal/kg	2952.00	3015.00
Calcium, %	.97	.82
Avail phos, %	.48	.44
Meth, %	.49	.49
Meth + Cyst, %	.88	.88

1
Supplies per kg of feed: calcium, 97.5 mg; manganese, 60 mg; iron, 20 mg; iodine, 1.2 mg; zinc, 27.5 mg; cobalt,0.2 mg; copper, 2 mg.

2
Supplies per kg of feed: Vitamin A, 3300 IU; vitamin D3, 1100 ICU; riboflavin, 3.3 mg; d-pantothenic acid, 5.5 mg; niacin, 22 mg; choline, 191 mg; vitamin B12, 5.5 mg; vitamin E,1.1 IU; menadione bisulfide complex, 0.55 mg; folacin, 0.22 mg.

3
Gratuitously provided by International Mineral & Chemical Corporation, Mundelein, IL.

4
Gratuitously provided by Salsbury Laboratories, Charles City, Iowa.

Table 3.3. Effect of broilers reared in open-sided and windowless building on mean body weight, feed conversion and abdominal fat levels up to 49 days of age for Petersen X Arbor Acre strain cross

Type of Housing	Mean Body weight[1]			Feed Conv[1]	Mean Abdominal Fat[1]		
	Male (M)	Female (F)	M+F		M	F	M+F
	------	(g)	------		------	(%)	------
Open-Sided	2080	1760	1918	2.11	1.58	2.14	1.89
Windowless	2153	1822	1986	2.05	1.52	2.38	1.95
SE ±	30	30	28	0.04	0.06	0.09	0.05

[1] Mean values in each column are not significant at P>.05.

Table 3.4. Effect of season of the year on mean body weight, feed conversion, and abdominal fat levels in broilers reared up to 49 days of age in open-sided housing facility for the Petersen X Arbor Acre strain cross

Season of Year	Mean Body Weight[1] Male (M)	Female (F)	M+F	Feed Conv[1]	Mean Abdominal Fat[1] M	F	M+F
	(g)				(%)		
Summer	1880[a]	1595[a]	1735[a]	2.02[a]	1.34[ab]	2.24[ab]	1.79[a]
Fall	2096[a]	1785[b]	1929[b]	2.17[a]	1.50[bc]	1.99[a]	1.75[a]
Winter	2097[a]	1804[a]	1962[a]	2.07[a]	1.11[a]	1.71[a]	1.42[a]
Spring	1901[a]	1610[b]	1747[b]	2.29[a]	1.88[c]	2.81[b]	2.34[b]
SE =	34	18	22	0.05	0.05	0.10	0.06

[1] Mean values in each column with different superscripts denote significance at P<.05.

Table 3.5. Effect of broiler strain crosses on mean body weight, feed conversion, and abdominal fat levels in broilers fed up to 49 days of age

Broiler strain crosses[2]	Mean Body weight[1] (g)			Feed Conv[1]	Mean Abdominal Fat[1] (%)		
	Male (M)	Female (F)	M+F		M	F	M+F
P X AA	2047^{abcde}	1741^{cd}	1891^{bc}	2.11^{a}	1.48^{a}	2.25^{abc}	1.86^{a}
AA X AA	2101^{cdef}	1805^{d}	1938^{cd}	2.09^{a}	1.85^{bc}	2.65^{cd}	2.25^{c}
H X AA	2179^{e}	1828^{d}	1993^{d}	2.09^{a}	1.75^{ab}	2.39^{abcd}	2.08^{ab}
T X AA	2006^{abc}	1626^{b}	1805^{ab}	2.08^{a}	1.44^{a}	2.13^{ab}	1.79^{a}
AA X P	1975^{abc}	1445^{a}	1690^{a}	2.23^{a}	1.82^{abc}	2.04^{a}	1.93^{ab}
H X H	1963^{ab}	1634^{bc}	1808^{ab}	2.27^{a}	2.40^{d}	2.75^{d}	2.57^{c}
V X H	2015^{abcd}	1797^{cd}	1892^{cd}	2.26^{a}	2.09^{bcd}	2.94^{d}	2.52^{c}
R X H	1950^{a}	1650^{bcd}	1755^{ab}	2.30^{b}	2.32^{cd}	2.85^{d}	2.59^{c}
SE =	15	16	15	0.02	0.06	0.07	0.05

[1] Mean values in each column with different superscripts denote significance at $P<.05$.

[2] Broiler strain crosses
P = Peterson
AA = Arbor Acres
H = Hubbard
T = Tatum
R = Ross
V = Vantress

Chapter 4

STUDIES OF MANAGERIAL VARIABLES ON BROILER PERFORMANCE AND ABDOMINAL FAT LEVELS

2. EFFECTS OF FEEDING REGIMES, DIETARY SALT STOCKING DENSITIES, AND BATTERY CAGES

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ABSTRACT

Consumer complaints of excessive carcass fat in ready-to-cook fryers are of concern to the broiler industry. Because of this concern, an experiment was conducted with 800 commercial, day-old broiler strain cross chicks to compare the effect of feed restriction (*ad libitum*, 95% and 90% of full-fed), dietary salt levels (0, 0.25% and 0.5%), stocking densities (0.06, 0.07, and 0.09 m^2 of floor space/broiler), and battery cages on the level of abdominal fat (AF) and broiler performance at 49 days of age.

Restriction of feed intake after five days of age at 90% full-fed (FF) resulted in a significant reduction in body weight (BW) and feed conversion at 49 days of age when compared to broilers fed *ad libitum*. An AF reduction of 30% was a consequence of a 17% reduction in BW.

Dietary salt fed at 0.5% produced better ($P<.05$) BW than those fed no dietary salt in the finisher diet from 21 to 49 days of age. No difference in AF was observed between the two dietary salt treatments.

Altering stocking densities and rearing broilers in battery cages failed to show improvements in either performance or AF levels. AF levels in broilers at 49 days of age were not influenced by dietary salt levels, stocking densities and battery cages.

Key words: abdominal fat, density, salt, feed restriction

INTRODUCTION

The quantity of abdominal fat (AF) deposited in the ready-to-cook fryer remains one of the major problems to the broiler industry in the United States.

The fat content of the broiler carcass is inversely correlated with carcass water content. This relationship suggests that increased water consumption by broilers may inhibit fat depositions. Methods of increasing broiler water consumption in broilers include higher dietary protein levels (Marks and Pesti, 1984), increased dietary salt levels (Lightsey *et al.*, 1983; Maurice and Deodato, 1982) as well as feed restriction (Marks, 1980).

Feed restriction can serve to reduce AF by decreasing the bird's caloric intake. Nitsan *et al.* (1984) noted that for broilers two and four wk of age feed restriction of less than 75% of normal intake was necessary to decrease body fat content. Other studies directed at the reduction of fat during the final stages of broiler growth have been largely associated with the suppression of non-fat BW (Auckland and Fulton, 1972; Arafa *et al.*, 1983). Plavnik (1987) observed that when broilers were on a restrictive feeding program for 6 to 12 days, starting at 5 days of age, AF levels were reduced by 30% at 56 days of age. Restricted males weighed slightly more than the non-restricted males.

In experiments with dietary salt, Maurice and Deodato

(1982) reported significant decrease in AF levels among five to seven wk old male broilers when a 50-100 mM solution of sodium chloride (NaCl) was added to their drinking water. There was no significant effect upon BW. Marks and Washburn (1983) observed that the addition of 2.4% dietary salt resulted in AF reductions up to 28%. Lightsey *et al.* (1983) also reported that an addition of 0.8% dietary NaCl resulted in a significant reduction of AF levels among broilers.

Altering the physical activity of birds has also been viewed as an environmental factor influencing AF levels. Increased physical activity of the broiler can be achieved through changes in stocking densities (Wenk, 1980), as well as housing of broilers in battery cages (Haye and Simmons, 1978). Research on the effect of stocking density upon AF has been limited. In general, linear reductions of BW can be correlated with higher stocking densities, but this outcome has been accompanied by adverse effects on carcass quality (Buckland *et al.* 1971; Proudfoot *et al.* 1979). Parkhurst *et al.* (1977) reported that broiler performance was unaffected by alterations in stocking densities from 0.06 to 0.07 m^2/broiler. Deaton *et al.* (1974) noted that broilers raised in battery cages had higher AF among both males and females when compared to broilers raised in litter pens.

No prior investigation has been conducted to collectively examine the effects of these managerial techniques. The purpose of this experiment was to compare the efficacy of practices such as restrictive feeding, dietary salt levels, stocking densities and housing types on AF levels and performance in broilers.

MATERIALS AND METHODS

A total of 800 day-old commercial broiler strain cross (Hubbard X Hubbard) chicks were placed in 28 litter floor pens (1.75 m X 1 m) and 4 battery cages (0.75 m^2) as outlined in Table 4.1.

Standard brooding and rearing practices were followed as outlined by North and Bell (1990). A hanging tube feeder (30 cm in diameter), and an automatic water cup were placed for broilers raised on litter pens. An infra-red heating lamp was used as the heat source for each pen and battery cage. Starter mash diets consisted of 23% CP and 2950 kcal ME/kg were fed from day-old to 21 days of age. Mash finisher diets consisted of 21% CP and 3000 kcal ME/kg were fed from 21 to 49 days (market age). All broilers were provided with 24 h of light throughout the experiment.

Four replicates were randomly assigned to each treatment. There were eight treatments. The control group (Treatment 1) consisted of broilers allowed a density of 0.07 m^2 floor space per bird and full-fed (FF) diets containing 0.25% NaCl for the duration of the experiment. Feed restrictions of the control diet were carried out starting at five days of age with daily restriction of 95% and 90% of the FF for Treatments 2 and 3, respectively. National Research Council (1984) feed consumption guidelines were used in determining amount of daily feeding for the restricted treatments. Broilers in Treatments

4 and 5, were fed the same starter ration as the control group and *ad libitum* finisher diets (21 to 49 days of age) containing 0 and 0.5% salt, respectively. Broilers in Treatments 6 and 7 were FF the same feed as Treatment 1 and provided, 0.06 and 0.09 m^2 of floor space per broiler throughout the experimental period, respectively. Broilers in Treatment 8 were housed in four battery cages and FF similar to Treatment 1.

Males and females were weighed separately at 49 days of age, and feed conversion was also determined for each replicate. At 49 days of age, 12 broilers per treatment (6 from each sex) were randomly selected and subjected to a 10 h fast prior to weighing and sacrifice for AF measurement. AF consisted of the fat pad in the abdominal region along with the fat surrounding the gizzard and proventriculus area. Percent AF was calculated as a ratio of the AF and the live BW prior to slaughter.

All of the parameters studied were evaluated statistically using one way ANOVA. Significant means were separated according to Least Significant Difference as described by Snedecor and Cochran (1980). Statgraphics version 4.0 (1989) program was used in the analysis for the data. In the analysis of the data each individual treatment was compared to the control group and the overall error term was used in evaluating significant differences.

RESULTS AND DISCUSSION

Broilers restricted to 90 and 95% of full-fed (FF) had lower ($P<.05$) BW than the FF broilers at 49 days of age. No significant differences were noted in feed conversion (FC) and mortality (Table 4.2) among the feeding regimes. The effect of 90% FF resulted in greater weight loss in females than in males (24% vs 14%, respectively). Feeding broilers at 90% FF resulted in significant decrease in AF when compared to 95% FF and *ad libitum* (1.7% vs. 2.46%), a 30% reduction with 17% body weight (BW) reduction. Therefore, this feeding regime is not economical and concurs with the findings of Auckland and Fulton (1972) who stated that feed restrictions during the final stages of growth resulted in decreases in body fat content accompanied by a decrease in BW.

Feeding dietary salt levels of 0.5% from 21 to 49 days of age, improved mean BW and FC of both sexes when compared to 0% dietary salt (Table 4.3). No differences ($P>.05$) in AF levels were observed among treatments. However, the addition of 0.5% salt in the finisher diet resulted in a 20.7% lower AF levels when compared to 0.25% salt. Lightsey *et al.* (1983) reported that the absence of salt resulted in lowered BW, AF levels and poorer FC. This study found that AF levels of broilers fed 0% salt was equal to the 0.25% level. Lightsey *et al.* (1983) also noted that dietary salt level greater than 0.8%, or providing a 25 mM saline solution in the drinking water resulted in the reduction of broiler AF levels. Marks (1981) and Marks and Washburn (1983) reported elevated water/feed ratios and reduced AF levels without a consequent reduction in feed intake when feeding high dietary salt (2.4%). The absence of NaCl in the diet in this study resulted in lower BW with no corresponding changes in AF levels. This study is in agreement with Marks (1981) and Marks and Washburn (1983) and disagree with the finding that changes occurring in broiler AF levels in the absence of dietary salt.

Altering stocking densities (0.06 and 0.09 m^2/broiler) from the standard bird density (0.07 m^2/broiler) failed to result in differences ($P>.05$) for any of the measured parameters at 49 days of age (Table 4.4). However, significant differences in BW with varied stocking densities have been reported by two investigators. Buckland *et al.* (1971) noted that birds grown in 0.047 m^2 floor space/bird were lighter ($P<.05$) than those grown in 0.093 m^2 floor space/bird at 49 days of age (1542 g vs. 1620 g, respectively). Proudfoot *et al.* (1979) noted that increased broiler rearing densities from 0.09 to 0.03 m^2/broiler resulted in significant ($P<.05$) linear reductions in BW for both males and females and adversely affected carcass quality. In the current investigation, the lack of significance may be attributed to the small magnitude of change in bird densities. The change from 0.06, 0.07 to 0.09 m^2/broiler may have been too small to result in a significant effect upon AF and broiler performance.

Broilers reared in battery cages had significantly poorer feed conversion than their counterparts on litter floor at 49 days of age (Table 4.5). No significant differences were noted ($P>.05$) among the treatments with mean BW, and AF levels. Deaton *et al.*, (1974) observed higher levels of AF in broilers reared in battery cages than broilers reared in floor pens. The higher AF levels in broilers reared in battery cages may be associated with less activity in cages. This study did not find any differences in AF levels.

In comparing each managerial factor, the relationship of dietary salt and AF shows promise for further investigation. Feeding of 0.5% NaCl in the finisher diet resulted in the best combination of high body weight and low AF levels in comparing individual treatments. Feeding regimes of 95% and 90% FF or stocking densities or battery cages demonstrated no promise.

Table 4.1. Description of treatments

Treatment	Type of Housing	Stocking Density (m^2/bird)	Feed Quantity[1]	NaCl[2] (%)
1 (control)	floor pen	0.07	full fed (FF)	0.25
2	floor pen	0.07	95% FF	0.25
3	floor pen	0.07	90% FF	0.25
4	floor pen	0.07	FF	0.00
5	floor pen	0.07	FF	0.50
6	floor pen	0.06	FF	0.25
7	floor pen	0.09	FF	0.25
8	battery cage	0.07	FF	0.25

[1] Feeding based on NRC requirments, weighed in daily after 5 days of age

[2] Percent NaCl added to finisher diets were fed from 21 to 49 days of age
Starter diet was fed from day-old to 21 days of age and contained 0.25%

Table 4.2. Effect of feeding regime on mean body weight, feed conversion, and abdominal fat levels of broilers from day-old up to 49 days of age

Feed Regime	Mean Body Weight[1] Male (M)	Female (F)	M+F	Feed Conv[1]	Mean Abdominal Fat[1] M	F	M+F
	(g)				(%)		
Full Fed (FF)	2055[b]	1767[c]	1911[b]	2.10[a]	2.37[b]	2.47[ab]	2.46[b]
95 % FF	1820[a]	1581[b]	1706[a]	2.23[a]	2.04[ab]	2.82[b]	2.38[b]
90 % FF	1782[a]	1358[a]	1587[a]	2.23[a]	1.52[a]	1.92[a]	1.71[a]
SE =	24	21	16	0.01	0.07	0.09	0.07

[1] Mean values in each column with different superscripts denote significance at P<.05.

Table 4.3. Effect of feeding 0, 0.25, and 0.5% NaCl from 21 to 49 days of age on mean body weight, feed conversion, and abdominal fat levels of broilers from day-old up to 49 days of age

Supplemental NaCl	Mean Body Weight[1]			Feed Conv[1]	Mean Abdominal Fat[1]		
	Male (M)	Female (F)	M+F		M	F	M+F
(%)	(g)				(%)		
0	1892[a]	1587[a]	1731[a]	2.31[b]	2.19[a]	2.65[a]	2.45[a]
0.25	2055[ab]	1767[ab]	1911[b]	2.10[a]	2.37[a]	2.47[a]	2.46[a]
0.50	2115[b]	1773[b]	1960[b]	2.11[a]	1.79[a]	2.27[a]	1.95[a]
SE •	25	21	16	0.01	0.07	0.09	0.07

[1] Mean values in each column with different superscripts denote significance at P<.05.

Table 4.4. Effect of stocking densities of 0.06, 0.07, and 0.09 m^2/bird on mean body weight, feed conversion, and abdominal fat levels of broilers from day-old up to 49 days of age

Stocking Density	Mean Body Weight[1]			Feed Conv[1]	Mean Abdominal Fat[1]		
	Male (M)	Female (F)	M+F		M	F	M+F
m^2/bird	(g)				(%)		
0.06	2217	1728	1923	2.13	2.18	2.63	2.41
0.07	2055	1767	1911	2.10	2.37	2.47	2.46
0.09	2133	1785	1966	2.12	2.22	2.79	2.43
SE ▪	24.7	21.1	16.2	0.01	0.07	0.09	0.07

[1] Mean values in each column are not significant at at P>.05.

Table 4.5. Effect of floor litter pens and battery cages on mean body weight, feed conversion, and abdominal fat levels of broilers from day-old up to 49 days of age

Type of housing	Mean Body Weight[1]				Mean Abdominal Fat[1]		
	Male (M)	Female (F)	M+F	Feed Conv[1]	M	F	M+F
	(g)				(%)		
Litter	2055[a]	1767[a]	1911[a]	2.10[a]	2.37[a]	2.47[a]	2.46[a]
Battery cage	1980[a]	1676[a]	1849[a]	2.27[b]	2.34[a]	2.51[a]	2.50[a]
SE =	24.7	21.1	16.2	0.01	0.07	0.09	0.07

[1] Mean values in each column with different superscripts denote significance at $P<.05$.

CHAPTER 5

STUDIES OF MANAGERIAL VARIABLES ON BROILER PERFORMANCE AND ABDOMINAL FAT LEVELS

3. EFFECTS OF LIGHTING IN COMBINATION WITH BROILER STOCKING DENSITIES AND DIETARY SALT LEVELS

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ABSTRACT

Four experiments were conducted with 5,900 day-old commercial broiler strain (Hubbard x Hubbard) cross chicks to evaluate the effect of different lighting regimes in conjunction with altering stocking densities and dietary salt levels on broiler performance and abdominal fat (AF) levels to market age (49 days).

The application of 12 h light (L) and 12 h dark (D), recycled daily from ages 21 to 49 days of age resulted in lower ($P<.05$) mean BW when compared to lighting regimes of 24L:0D, 20L:4D and 16L:8D, recycled. Mean BW and AF levels were significantly higher at 49 days of age for broilers exposed to lighting regimes of to 16L:8D, recycled compared to broilers exposed to lighting regimes of 12L:12D (Experiment 1). Broilers raised on 16L:8D had comparable BW and AF levels to those raised under CL.

Reduction of lighting from continuous regime (CL; 24L:0D) to 12L:12D recycled after 21 days reduced ($P<.05$) AF levels in both males and females (Experiment 2). An increase in floor space from 0.06 to 0.08 m^2 resulted in ($P>.05$) improved BW with no differences in AF levels.

The increase in dietary salt levels from 0.25% to 0.5% was not sufficiently large ($P>.05$) in altering BW or AF levels. Intermittent lighting (IL) of 1L:3D resulted in significantly higher BW in males and lower in females with no increase in AF levels (Experiment 3).

The application of 12L:12D lighting from 5 days of age to market age (49 days of age) did not prove beneficial with mean BW and AF levels (Experiment 4). Lighting can be used as a tool for reduction of AF levels. The application of managerial methods such as stocking densities and salt levels for the control of AF level is subject to economic consideration.

Key Words: broilers, abdominal fat, stocking density, intermittent lighting, dietary salt level

INTRODUCTION

The influence of lighting programs on poultry production has gained considerable attention among researchers for a number of years. Most studies have examined the effect of intermittent lighting (IL) and compared it with continuous lighting (CL) on broiler performance. Favorable results were obtained on BW and feed conversion with IL. The improved growth with IL has been associated with altered feeding behavior (Cohn and Joseph, 1960), and increased feed utilization has been obtained through reduced physical activity and heat production (Clegg and Sanford, 1951; Ota, 1967). Excellent reviews of lighting techniques have been provided by Buckland (1975) and by Dorminey and Nakaue, (1977). Cave (1981), demonstrated that the adoption of a lighting regime of 1L:3D, recycled from 15 to 48 or 55 days of age enhanced carcass quality by significantly reducing carcass fatness and by improving the efficiency of broiler production. In a subsequent report, Cave *et al.* (1985) noted different responses by sex and genotype with higher AF levels among males whereas females had lower AF with IL than CL regime. However, Beane *et al.* (1979) reported higher AF in females with 1L:3D lighting when compared with CL regime. Suwindra and Balnave (1986) reported slightly lower AF levels in experiments which incorporated periods of darkness as long as 10 hrs.

Other factors such as dietary salt levels have been reported to alter AF levels in broilers. Maurice and Deodata (1982) reported a significant decrease ($P<.05$) in AF levels in males provided sodium chloride (NaCl) in the drinking water (50-100 mM solution) from 5 to 7 wk of age. Marks and Washburn (1983) concluded that with the addition of 2.4% dietary salt, a significant reduction of AF levels between 17 to 28% could be obtained. Earlier study by this investigator found that dietary NaCl at 0.5% in the finisher broiler diet from 21 to 49 days of age produced better BW than no salt. No differences were noted in relation to AF levels.

In experiments to study the influence of broiler strain and broiler stocking density on performance, Buckland *et al.* (1971) reported that broilers grown at 0.047 m^2 were lighter than those grown at 0.093 m^2 of floor space. Broilers grown on IL with 0.093 m^2 of floor space/broiler were lighter ($P<.05$) than those in CL (1599 g vs. 1620 g, respectively) whereas broilers grown in IL at 0.047 m^2 were heavier ($P<.05$) than birds exposed to CL (1563 g vs. 1542 g, respectively). A significant ($P<.01$) interaction between seven wk BW and densities were observed.

The absence of consistent results of lighting regime, alone or in combination with stocking densities or dietary salt levels by previous investigators prompted further studies on the effect on AF levels and performance. Therefore, the objectives of these studies were to determine the effect of combining lighting programs, stocking densities and dietary salt levels on broiler performance and the level of AF.

MATERIALS AND METHODS

Four experiments were conducted with 5,900 day-old commercial strain cross (Hubbard X Hubbard) broiler chicks. All experiments were conducted in the same windowless, mechanically ventilated house containing eight pens. Each pen (3.0 m X 4.6 m) was separate and light proof from each other, as well as from outside light sources. A squirrel cage fan with a 300 cfm capacity (8.5 cubic meter) provided ventilation for each pen. The fan operated on a time clock according to the age of the broilers and the room temperature.

A two-phase feeding program was used for all experiments. The starter mash diet consisted of 23% crude protein (CP) and was fed from day-old to 21 days of age. The finisher mash diet consisted of 21% CP and was fed from 22 days to 49 days of age (market age). Broiler chicks were placed on wood shavings litter (10 cm deep) and an electric brooder was placed in each pen as heat source. The temperature under the brooder was 35 C during the first wk, and was reduced to 21 C by the fourth wk. The total feeder space was 750 linear cm, and the water trough space was 2 m for each pen. Artificial light was provided by a 40 watt, white incandescent bulb, placed 2.3 m above the floor. Light intensity at the height of the birds was approximately 15 lux directly under the bulb and about 5 lux in the corners of the pen.

Male and female BW and feed consumption were measured at 49 days of age. For each experiment, 32 birds were selected randomly (16 from each sex/treatment), subjected to a 10 h fast, weighed first prior to sacrifice for the measurement of the carcass AF at 49 days. The leaf and gizzard fats were excised from each bird by the same individual, weighed immediately and percentage of the AF calculated from the data and expressed as a percent of the live BW.

The treatments for each experiment were as follows:

Experiment 1:

One thousand three hundred and eighty day-old broiler chicks were equally divided among eight pens. For the first 21 days, all broilers were provided with 24 h light. From 21 to 49 days, four lighting regimes were 20 h light (L):4 h dark (D) recycled; 16L:8D, recycled; and 12L:12D, recycled and 24L:0D (CL). Each lighting regime was replicated twice.

Experiment 2:

One thousand five hundred and sixty day-old commercial broilers were equally placed in eight pens. Four pens were stocked at 0.06 m^2/broiler and four pens were stocked at 0.08 m^2/broiler. Two pens from each stocking density were placed on 24L:0D (CL) light regime and two pens on intermittent light (IL) regime of 12L:12D, recycled from 21 to 49 days of age.

Experiment 3:

One thousand four hundred and eighty day-old broilers were equally distributed in eight pens. An intermittent (IL) regime of 1L:3D, recycled was started in 4 pens from 7 to 49 days of age, and 4 remaining pens had 24L:0D (CL) regime. From 21 to 49 days of age, broilers in two pens from each lighting regime were fed finisher diets containing 0.25% and 0.5% NaCl, respectively.

Experiment 4:

One thousand four hundred and eighty day-old broilers were equally distributed in eight pens. Four pens of broilers were exposed to CL regime, and four pens were exposed to light regime of 12L:12D, recycled from 5 to 49 days of age.

Two way analyses of variance was applied in Experiments 2 and 3 when more than one factor was present to evaluate for interactions. When significant differences were found among populations, the least significant difference (LSD) range test (95% level) was used to separate means as described by Snedecor and Cochran (1980). Statgraphics version 4.0 (1989) was used in the analysis of the data.

RESULTS AND DISCUSSION

Data on broiler performance and AF levels at 49 days of age for broilers exposed to varied light regimes during the growing period are presented in Table 5.1 (Experiment 1). Mean broiler weights (male and female) were higher (P<.05) for broilers under the 16L:8D regime when compared to broilers subject to a 12L:12D regime (1928 g vs. 1838 g). Females grew better (P<.05) under 24L:0D (CL) regime, than under the three intermittent lighting (IL) regimes. Females provided 20L:4D and 16L:8D grew better (P<.05) than those provided 12L:12D. Males grew better (P<.05) under the 16L:8D regime than the 12L:12D treatment. AF levels were lower (P<.05) for broilers reared under the 12L:12D regime than the CL or 16L:8D (1.32% vs, 1.76 and 1.64%, respectively). However, these reductions were achieved at the expense of reduced mean BW. The 16L:8D light regime provided an optimal growth without any detrimental effect on feed conversion or AF levels. Female broilers are more sensitive to changes in lighting programs with respect to AF levels since no differences (P>.05) was observed in male AF levels. This study is not consistent with previous research (Beane *et al.*, 1979) on AF level with IL regime when compared to CL. Suwindra and Balnave (1986) reported that a 6 h lighting period in a 24 h period (three equally distributed 2 h lighting periods) was sufficient for normal intake and normal rate of growth.

Data on the two lighting regimes in combination with two stocking densities are presented in Table 5.2 (Experiment 2). No significant lighting regime X stocking density interactions were observed; therefore, the data were analyzed by lighting and density separately. At 49 days of age, 12L:12D lighting resulted in significantly lower female BW (1801 g) and lower feed conversion and AF levels when compared to 24L:0D indicating different response by sex to changes in lighting. Increasing bird densities from 0.06 m^2 to 0.08 m^2 resulted in significantly improved BW in both sexes. The results of this experiment are in agreement with Proudfoot *et al.* (1979), where increased bird densities resulted in significant ($P<.05$) linear reductions in body weights among both males and females. Mean AF levels were not altered by changes in stocking densities. The economic feasibility of this option on a commercial scale need reevaluation. However, this study is not in agreement with Buckland *et al.* (1971) who reported that at denser stocking density (0.047 m^2/bird), broilers exposed to IL (3L:1D recycled) were heavier than those exposed to CL. At less dense stocking density (0.093 m^2/bird), broilers under IL were lighter than their counterparts in CL treatment. The results from this experiment indicate that lighting of 12L:12D, recycled regime is more effective in reducing AF levels than changes in bird density.

Data on the two lighting regimes with two dietary salt levels are listed in Table 5.3 (Experiment 3). No significant lighting regime X dietary salt interactions were observed; therefore data were interpreted by lighting and salt treatment separately. Intermittent lighting of 1L:3D resulted in higher male BW (2262 g) and lower female BW (1875 g) when compared to 24L:0D. With respect in increased salt NaCl levels in the diet improvements were observed in BW without any increases in AF levels. Lightsey *et al.*, (1983) demonstrated that the addition of 0.8% NaCl to the diet could significantly reduce AF levels in broilers. Marks and Washburn (1983) concluded that the addition of 2.4% dietary salt could result in AF reduction up to 28%. The lack of significant results in AF levels may be attributed to the lower levels of salt used in this experiment (0.25% and 0.5%) when compared to the above mentioned studies which used higher levels of dietary salt (0.8 and 2.4%). The results of this experiment indicated that IL (1L:3D) and 0.5% dietary salt both can improve in improvements in mean BW and lower AF levels.

The data on AF level and broiler performance with CL and 12L:12D light regime are presented in Table 5.4 (Experiment 4). Male and female BW were lighter ($P<.05$) with the 12L:12D light regime than with the CL regime at 49 days of age. Feed conversion, AF level were not influenced ($P>.05$) by providing the two light regimes at an early age. Utilizing a 12L:12D lighting program at an early age is not beneficial for reducing AF levels at 49 days of age.

Under the condition of these experiments, broilers can tolerate periods of dark up to eight h per day (16L:8D, recycled) after 21 days of age without detrimental effects on BW and feed conversion. However, any reduction in AF levels will be accompanied by corresponding decreases in mean BW and may not be desirable, as was demonstrated with broilers provided the 12L:12D light regime (Experiment 1). The negative effect of extended periods of darkness will not be as pronounced if lighting programs are applied after three wk of age instead of starting at one wk. During the initial phases of darkness, some degree of weight reduction may occur. However, based on previous findings (Schutze *et al.*, 1960; Cherry and Barwick, 1962), the ability of broilers to learn to eat in the dark and respond to growth performance was not unexpected. Once broilers have adapted to darkness, some compensatory growth will occur. Experiment 2 indicated that 12L:12D, recycled light program initiated at 21 days of age can result in comparable mean BW and decrease in AF levels at market age (49 days). However, data for 12L:12D regime in Experiment 4 contradict the findings in Experiments 1 and 2 in relation to body weights and show that five days is too early of age for starting a restricted lighting program.

Economical advantages are associated with the use of restricted lighting. Increased densities and salt levels also resulted in better performance without increasing AF levels. The merits of such managerial programs need to be evaluated by individual growers.

Table 5.1. Effect of exposing broilers from 21 to 49 days of age to various light (L) and dark (D) lighting regimes on body weight, feed conversion, and abdominal fat levels at 49 days of age (Experiment 1)

Light Regime	Mean Body Weight[1] Male (M)	Female (F)	M+F	Feed Conv[1]	Mean Abdominal Fat[1] M	F	M+F
	(g)				(%)		
24L:0D	2030^{ab}	1760^{c}	1900^{ab}	2.09^{a}	1.42^{a}	2.10^{b}	1.76^{b}
20L:4D, recycled	2055^{ab}	1720^{b}	1897^{ab}	2.10^{a}	1.40^{a}	1.78^{ab}	1.59^{ab}
16L:8D, recycled	2084^{b}	1730^{b}	1928^{b}	2.06^{a}	1.43^{a}	1.85^{ab}	1.64^{b}
12L:12D, recycled	2007^{a}	1678^{a}	1838^{a}	2.11^{a}	1.17^{a}	1.47^{a}	1.32^{a}
SE	9	3	8	0.02	0.05	0.06	0.04

1
Mean values in each column with different superscripts denote significance at P<.05.

2
L=Light
D=Dark

Table 5.2. Effect of continuous and intermittent lighting and bird densities on mean body weight, feed conversion, and abdominal fat levels at 49 days of age (Experiment 2)

Treatments		Mean Body Weight[1]				Mean Abdominal Fat[1]		
		Male (M)	Female (F)	M+F	Feed Conv[1]	M	F	M+F
		(g)				(%)		
LIGHT	24L:0D	2217	1885^{a}	2030	2.22^{a}	2.36^{a}	3.11^{a}	2.72^{a}
	12L:12D, recycled	2187	1801^{b}	1987	2.07^{b}	1.89^{b}	2.47^{b}	2.19^{b}
DENSITY m^{2}/bird	0.06	2134^{m}	1795^{m}	1960	2.11	2.01	2.92	2.45
	0.08	2270^{n}	1861^{n}	2057	2.18	2.24	2.67	2.46
SE •		10	7	9	0.01	0.03	0.04	0.04

[1] a,b different superscripts denote significance (P<.05) with respect to lighting.
m,n different superscripts denote significance (P<.05) with respect to densities.

[2] L=light; D=dark

Table 5.3. Effect of continuous and intermittent lighting and dietary salt levels on mean body weight, feed conversion, and abdominal fat levels at 49 days of age (Experiment 3)

Treatments		Mean Body Weight[1]				Mean Abdominal Fat[1]		
		Male (M)	Female (F)	M+F	Feed Conv	M	F	M+F
		(g)				(%)		
LIGHT	24L:0D	2236[a]	1906[a]	2079	2.11	1.98	2.42	2.20
	1L:3D recycled	2262[b]	1875[b]	2073	2.14	2.06	2.60	2.33
NaCl %	0.25	2211[m]	1876	2047[m]	2.13	1.95	2.61	2.28
	0.50	2287[n]	1905	2105[n]	2.11	2.10	2.41	2.26
SE •		10	7	9	0.01	0.03	0.04	0.04

1 a,b different superscripts denote significance (P<.05) with respect to lighting.
m,n different superscripts denote significance (P<.05) with respect to %NaCl.

2 L=light; D=dark

Table 5.4. Effect of 12 h light (L) and 12 h dark (D) recycled from 5 to 49 days of age on mean body weight, feed conversion, and abdominal fat levels at 49 days of age (Experiment 4)

Light Treatments	Mean Body weight[1]			Feed Conv[1]	Mean Abdominal Fat[1]		
	Male (M)	Female (F)	M+F		M	F	M+F
	(g)				(%)		
24L:0D	2393[a]	1960[a]	2139[a]	2.09[a]	2.09[a]	2.79[a]	2.44[a]
12L:12D, recycled	2277[b]	1883[b]	2067[b]	2.16[a]	2.01[a]	2.74[a]	2.38[a]
SE =	14	15	30	0.03	0.01	0.17	0.13

[1] Mean values in each column with different superscripts denote significance at $P<.05$.

CHAPTER 6

SUMMARY AND CONCLUSION

Today's commercial broilers are the end product of an extensive genetic selection aimed at increased BW. As a consequence, broilers are consuming energy far in excess of their metabolic ability for tissue growth thereby leading to greater fat deposits.

Genetic as well as nutrition have factors attempted to reduce AF deposits but have not presented any economical solution. An attempt was made to evaluate different managerial techniques aimed at reducing AF without significant detrimental effect on performance. The managerial factors examined were seasonal changes, open-sided compared with windowless housing, sources of the commercial broiler strain, stocking densities, lighting programs, dietary salt levels as well as altered feeding regimes and battery cages.

Seasons and the sources of the strain crosses both have very pronounced effects on BW as well as AF levels. The disadvantage, however, is that these variables cannot be easily controlled at the producer level.

Reduction in feed intake for an extended period of time proved detrimental to performance. Feeding diet with salt level up to 0.5% resulted in weight improvements as well as slight reductions in % AF. Reduction of AF through salt addition in the diet may be beneficial due to changes resulting in water consumption. Stocking densities and battery cages did not result in any changes in BW and AF.

Among factors studied intermittent lighting of up to 8 h of dark each day after 21 days of age provides a technique for imposing control over feed consumption and may be beneficial in reducing AF. The effect of changes in stocking densities and level of dietary salt (0.5%) is not as pronounced as lighting but both improve performance without the addition of AF.

Manipulation of managerial factors can help in substantially reduce AF levels in today's broiler. It is concluded that any attempt which will help in increased efficiency of feed utilization by the bird as well as controlling feed consumption and activity will be beneficial.

Current goals are aimed at maximizing growth per unit of feed consumed regardless of body composition. However, reduction of AF presents an excellent opportunity for substantial savings at both the production and the processing levels. Producers can realize savings through reduced feed and utility costs. The processing plant can in turn take advantage of reduced waste as well as increased salable yields.

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