AN EVALUATION OF BROILER METABOLISM AT THREE AMBIENT TEMPERATURES WITH PARTICULAR REFERENCE TO ENERGY AND PROTEIN NEEDS

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CHAPTER I

INTRODUCTION

The modern day's broiler tendency to deposit excess fat is partly a consequence of its rapid growth rate science genetic and phenotypic correlation between growth rate and fat deposition have been found to be positive (Becker, 1978). Fat is a carcass characterstic of high variability and heritability. The average heritability value reported in literature is about 0.5 (Leclercq and Whitehead in :Leanness in domestic birds, pp. 5). Abdominal fat is a significant a significant fat depot in broilers and constitutes a clear loss to consumers and producers. It is even more variable than that deposited either intermascularly or intramuscularly (Ricard, 1975; Becker et al., 1979). Among birds within strains coefficients of variations of 30-35% are typical (Becker et. al., 1979).

Between flocks of modern broilers grown to 56 days under normal commercial conditions abdominal fat varies from about 1.1 to 3.4 in males and 1.9 to 4.1 % of body weight in females (Leeson and Summers, 1980, Fisher , 1984). Such a big variation suggests that fat deposition in broilers may be highly influenced by environmental factors. Coefficient of variation of 30 % has been reported for abdominal fat (Leenestra, 1986) while the values for other adipose tissues ranges between 15-20%. In broilers it is not uncommon for fat to constitute 15-20% of their body weight (Scheele et al., 1981; Griffin and Whitehead, 1982; Leenstra, 1982). According to Leenestra (1986) the total amount of body fat is variable and can be as high as 150-200 g/kg body weight. A minimum of 9 g fat /kg body weight is required for normal body functioning and 20-25 g/kg is present in tissues as physiologically necessary fat. The remaining ,which is over 85% of total body fat and considered unnecessary is found in adipose tissues.

The primary goal of the broiler industry is to maximize lean meat production. In recent years there has been a lot of concern about excess fat deposition in broilers, which

is undesirable from both consumers and producers point of view since consumption of excess saturated fat has been implicated in a number of health problems. In recent years there has been a lot of concern about excess fat deposition in broilers, which is found to be undesirable from both consumers and producers point of view. The disadvantages of excess fat deposition in broilers have been discussed by Jensen (1982). These include consumer resistance to fatty foods and to losses in food preparation , losses in processing and consequential changes in the composition of poultry offal meals, increased cleaning costs in factories, pollution problem in waste water disposal, and concern about, taint, taste and keeping quality. As a contribution to liveweight gain fat growth is also energetically inefficient (Fisher, 1984). Fat synthesis utilizes nutrients which otherwise could be used for lean tissue synthesis and therefore could be considered waste of resource from economics production point of view. Since fat depots and excess fat are thrown away excessive fat in meat constitutes a cooking loss to the house wife. Some of the reasons why livestock producers should be concerned about controlling fat deposition in livestock products are as discussed below.

One of the factors that influences consumer perception of meat is the concern about the relationship between diet and health, in particular between fat and health. To day the consumer is moving away from fat. High dietary fat consumption, in particular saturated fat has been associated with the incidence of obesity (Lissener et al. 1987, Mattes et al. 1988, Kendall et al 1991), cardiovascular diseases (CAST, 1991), diabetes (CAST, 1991), colon and breast cancer. (Kinlein, 1983).The medical recommendation today is therefore to reduce calorie intake from fat as low as 30% (CAST, 1991). Although poultry meat has the reputation of leanness, this situation has put pressure on livestock producers in general to produce leaner carcasses. Aloughth it is well documented that a wide array of environmental and genetic factors influence diversion of consumed nutrients for carcass fat and protein deposition in broilers, the interactive

effect between these factors, in particular between bird age, ambient tempearture stress and feed consumption on targeting of energy for carcass fat or protein accretion to date is still far from being clear. Concern about these issues necessciates the need for more research in the direction of understanding the mechanisms of fat deposition in broilers and the means to minimize it so that nutrients may be diverted to lean tissue accretion. The partitioning of consumed nutrients to tissue lipid and protein is however not controlled only by a single factor but by a multitude of factors singly and interactively.

This study is an attempt to understand and delineate the influence of nutrient consumption level, exposure to ambient temperature extremes, bird age and their interaction on the partitioning of nutrients for deposition as carcass fat and protein and heat production. Furthermore broiler blood chemistry profile alterations and energy and nitrogen requirements under ambient temperature exposure ranging from cold to heat stress have also been studied.

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CHAPTER II

REVIEW OF LITERATURE

Introduction

Lipogenesis in broilers

Unlike in other homeotherms lipogenesis in birds predominantly occurs in the liver. Several studies both in chicken and other avian species indicate that when rate of lipogenesis in the adipose tissue and liver are compared the later is significantly higher and a more important site of de novo lipid synthesis. Fifteen minutes after administration of acetate-$1^{14}C$, 69 % of fatty acid-$1^{14}C$ was recovered from the liver and 16% from the adipose tissue(O'Hea and Leveille,1969). The remainder was accounted for by plasma fatty acids when only these three tissues were considered. Following glucose-U^{14} administration the corresponding values were 87, 6 and 8% respectively . The importance of extra hepatic lipogenesis remains less clear. Yeh and Leveille (1972, 1973) suggested that more than half of the total lipogenesis may take place in other tissues other than in the liver, about 5% taking place in the intestine and 7% in the skin. According to Nir and Lin (1982) 23% of the total lipogenesis takes in the skeleton, 45 % in the liver, 6% in the intestine and 7% in the skin. However, as in all the above studies, the use of acetate as a substrate fails to distinguish between de novo fatty acid synthesis and chain elongation and hence might under estimate hepatic lipogenesis and over estimate extrahepatic lipogenesis (Romos and Leveille, 1974). Similarly, Calabotta et al. (1983) also demonstrated acetate incorporation into bone lipids of mature broilers but were not able to demonstrate lipogenic enzyme activity in these or in adipose tissue preparations.

Fat accretion in broilers

As in other animals the adipose tissue is the major site of fat storage in broilers. The skin and skeleton also store appreciable quantity of fat (Essary and Young, 1977; Hakansson, Eriksson and Svenson, 1978). Triglycreide concentration in adipose tissue, skin, liver, feathers, skeleton and the rest of the body was reported to be 800, 400, 60, 15, 100 and 90 g / kg (Chaner, Nistan and Nir, 1986). Nir and Nistan (In: Leanness in domestic birds, p.144) dissected the apparent adipose tissues of a 9.1 kg broiler and observed that the abdominal adipose tissue (AAT) constitutes the largest lipid depot followed by neck, thigh, back, gizzard, mesenteric, saratorial, breast, crop, proventriculus, bursa of fabricus, pericardium and kidneys. Pinchasov, Nir and Nistan (1985) reported that in modern male commercial broilers the relative growth rate of abdominal adipose tissue is the same as that of the rest of the body between the ages of 20 to 30 days during which the birds growth rate is maximal. However after that when growth rate of the body decreases that of abdominal adipose tissue is maintained or even becomes higher thus resulting in higher allometric coefficient. In broilers , Hood (1984) suggested that up to 14 weeks of age both hypertrophy and hyperplasia took place in the abdominal adipose tissue after which the abdominal fat pad grew by hypertrophy alone. This was consistent with the finding that DNA-deoxyribose content of adipose tissue in pullets reached maximum at 12 to 15 weeks of age. Paff and Austic (1976) observed that between 4 to 9 weeks of age faster growth rate of adipose tissue is accompanied with increased concentration of fat which emplies that after 4 weeks of age hypertrophy is the major mode of adipose tissue growth than hyperplasia.

Methods of describing fat growth

Fisher (1984) indicated the problem involved in describing fat growth and fat depots in broilers as being primarily due to variations in the dissection methods employed

and also the very fact that the fat depots are not discrete, or bounded by membranes . Evans (1977) suggested that fat growth can be described by its allometric relationship with the growth of the fat free body

Strategies to alter body composition in broilers

Genetic selection: There is evidence showing that selection against abdominal fat should be effective (Becker, 1978; Leclercq, Blum and Boyer,1980) in reducing carcass fat in broilers. Such selection could be based on directly observable abdominal fat content (Leclercq, Blum and Boyer, 1980) with the help cloacal caliper which can be used for determining amount of abdominal fat in the live bird (Pyme and Thompson, 1980). The alternative approach is indirect selection for reduced carcass fat as a correlated response to selection for improved feed conversion efficiency (Pym and Solvyns, 1979) or to selection for weight gain on a restricted amount of feed (Eitan, Agursky and Soller, 1983).

Biochemical approach: Selection for very low lipoprotein concentration (VLDL) has been shown to be effective in reducing carcass fatness (Whitehead and Griffin, 1986) and the correlation between the two might be as high as .7

Dietary manipulation: Dietary factors are powerful means of reducing carcass fatness (Leneestra, 1986) including altering calorie to protein ratio, physical form of the diet, restricted feeding etc.

The use of beta agonists in the ration: Although not as popularly used as in other species, clenbutrol, a β-Adrenergic agent has been reported to increase skeletal muscle and lipolytic activity in poultry (Dalrymple et al. 1983).

Anti adipocyte immunity and genetic engineering: These are methods which hold promising future in the fight against adipocity in livestock. The former, which involves raising antibodies against adipocites has been found in rats to increase infilitration score of the adipose tissue and reduce fatness (Flint et al., 1986).The inhibitory effects of the

antiserum were due to cytotoxicity since, in the presence of antiserum, adipocytes began to release large quantities of the intra cellular enzyme, lactate dehydrogenase, and were ultimately lysed (Flint et al., 1986). Genetic engineering, producing transgenic animals with the desired leanness characteristics might be the ultimate solution.

Influence of feed on carcass quality

In recent years, as with carcass composition, tremendous importance is being attached to carcass quality by poultry processors (Round, 1992). Feed can influence carcass quality either directly or indirectly via effects on litter condition and the incidence of leg problems (Round, 1992). Increasing the proportion of dietary protein in relation to dietary energy leads to a kind of diminishing returns, since there is a reduction in carcass fatness continuing beyond the point of maximum live weight gain. There is also continued deterioration in litter condition which might lead to hockburn, etc and consequently carcass down grading by the poultry processor (Round, 1992). This may be associated with increased fecal output or changes in the characteristics of the excreta arising from increased feed and water consumption In addition, poor quality dietary fat will reduce performance and build up oil level in the litter leading to carcass down grading due to hockburn, etc. Since the fatty acid composition of the carcass is influenced by the fatty acid composition and rate of inclusion of the fat, high intake of polyunsaturated fatty acids may exacerbate or lead to oily or greasy carcass and being easily oxidized may reduce carcass keeping quality and increase the incidence of off flavor. This problem might be alleviated by inclusion of antioxidants in the ration. High level of free fatty acids in the dietary fat may also lead to carcass down grading by inducing soap formation, and greasy litter (Round, 1992). High levels of certain fatty acids, depending on the level of fish meal inclusion, its fatty acid composition, can impart fishy taint to poultry carcass. Addition of enzymes in the feed can improve energy

digestibility and reduce excreta viscosity thereby reducing excreta viscosity and litter stickiness and carcass downgrading. Minerals such as sodium, potassium, calcium, phosphorus and magnesium can affect carcass quality indirectly by influencing the occurrence of leg problems, water intake or by soap formation.

Factors altering partitioning of feed nutrients into carcass fat and protein

In reviewing the literature one can come across a number of factors that can influence fat accretion such as dietary manipulation feeding level or nutrient restriction, feeding pattern, ration composition including energy density of the ration, energy to protein ratio of the ration, essential amino acids, dietary fat supplementation; rearing temperature and genotype of the broiler strain.

Nutrient restriction: Most of the studies dealing with feed restriction in broiler chicken reported reduction of body fat and abdominal fat but with final body weight somewhat reduced (Fischer, 1984). Plavnik,I. and S. Hurwitz (1985), Plavnik, et al. (1986). McMurty et al. (1988) obtained improved feed efficiency, reduced body fat and abdominal fat and no reduction of final body weight in broiler chickens subjected to severe early age (6 to 14 days of age) feed restriction. The authors based feed restriction on the metabolizable energy (ME) content of the diet (~13 MJ/kg) and the body weight of the birds where 6.3 kcal/$gW^{.67}$/day was calculated to support maintenance. The birds were fed adlibitum otherwise. Using a similar feed restriction system Jones and Farrel (1989) found out that early food restriction beginning at 7 days of age decreased body fat, improved feed conversion efficiency and had little effect on body weight. Moderate feed restriction was also accompanied by reduction of abdominal adipose tissue (AAT). Rosebrough et al. (1986) observed decreased lipogenic enzymes (malic enzyme and fatty acid synthetase complex) and invitro lipogenesis in energy restricted birds between the ages of 6 to 12 days. Higher level of feed intake favours fat deposition (Nir et al., 1974;

Nitsan, Pethi and Nir, 1984). Energy allowance of 80% of the adlibitum intake in commercial broilers ten days before slaughter reduced body weight to 94% and AAT weight to 74% of the control birds fed adlibitum (Arafa et al 1983). Similar results were reported by Nitsan (1985). Thus when consumption of energy exceeds the maintenance and growth requirment of the animal the excess energy is efficiently converted to body fat since the maintenance requirement becomes lower as food intake increases. When food intake is restricted the need for energy predominates and part of the food protein is used as an energy source for maintenance. During restricted feeding from 8 to 14 days of age Yu et al (1990) observed broiler chicken fed at hourly intervals had less body fat at 8 weeks of age than chicks that were fed either once a day or every other day. Reece et al (1985) observed that meal feeding of broilers tended to increase abdominal fat both at 21 and 22-33C ambient temperature as compared to adlibitum feeding at 21 and 22-33C. Different methods of feed restriction can be applied to broilers ie, qualitative restriction (Plavnik and Hurwitz, 1990), using low nutrient density diets (protein or energy), quantitative feed restriction and the use of chemicals (Pinchasov and Jensen, 1985: Lacey et al.1982). Pinchasov and Jensen added 1.5 % and 3.0 % glycolic acid into broiler feed and obtained 22 and 50% reduction in feed intake from 7 to 14 days of age compared to controls. Lacey et al.(1982) fed broilers five times the recommended dose of trypthophan and obtained a significant reduction in feed intake. Serotinin, which plays an inhibitory role in feeding behavior is a derivative of Tryptophan (Blundell, 1977).

Ration composition: Haris and Creger,(1980) reported that increasing the energy density (ME) of the ration during the first seven days of life resulted in increased AAT weight at 7 weeks. Vogt, Krieg and Harnisch (1985), Francher and Jensen(1986), Bartov (1987) reported neither protein content nor energy density or calorie to protein ratio at early ages have effect on fatness at older or adult age. Increasing calorie to protein ratio in diets increases fat deposition whereas decreasing calorie to protein ratio

decreases fat deposition (Bartov et al., 1974; Farrell, 1974; Kirchgessner et al. 1979). The degree to which dietary energy is utilized is dependent on the energy to protein ratio of the diet (Jackson et al; 1982, Guillaume and Sumers, 1970). Thus in diets high in protein, energy is less efficiently utilized than diets low in protein. These findings could explain why diets with a small ratio between energy and protein give less fat accretion than those with a large ratio, independent of the quality of the protein (Griffith et al., 1977). In three trials Lipistein et al (1975) found that fat deposition increased progressively while feed intake increased as the protein concentration of the balanced finisher diet was lowered by replacing soybean meal with sorghum grain. The increased degree of fatness was suggested to be due to increased intake leading to decreased feed utilization as a result of in adequate dietary protein. Kubena et al. (1972) reported that carcass of chicks fed a diet deficient in lysine contained significantly more ether extract than those fed diets adequate or in excess of the lysine requirement.

Dietary fat supplementation: Fats are the most concentrated source of available energy in poultry diets and there are several advantages to using fat in a ration. The most important of which is to increase the caloric density of the diet and subsequently improve body weight gain and feed efficiency. Waibel (1978) theorized that supplemental fat may have contributed to attainment of a more nearly optimum available energy to amino acid balance for metabolism, resulting in an improvement of protein utilization. This could be attributed to the low heat increment associated with fatty acid utilization since they are directly deposited into body fat without appreciable amount of energy loss as heat. The addition of fat to poultry diets is reported to increase the metabolizable energy (ME) of the diets more than expected from the additivity of the ME's of the individual ingredients (Cullen et al., 1962; Jensen et al., 1970; Sell, 1977; Sell et al., 1979; Mateos and Sell, 1980). Gomez and Polin (1974) and Sibbald and Kramer (1978) reported that fat supplementation seemed to improve the utilization of

nonlipid constituents of diets. Unfortunately, while most fats have similar gross energy values, their available energy concentrations vary widely (Cullen et al., 1962; Sibbald and Kramer, 1977). The availability and utilization of the dietary fat energy is dependent on the composition of the diet (Cullen et al., 1962), the age of the bird (Whitehead and Fisher, 1975) and the level of inclusion of fat (Sibbald and Kramer, 1978) in the diet. It is thought that fats depress feed intake by a general energy-related effect because injection of small amounts of individual long-chain fatty acids intraperitoneally (Cave, 1978), or through inclusion in the feed (Sunde, 1956; Renner and Hill, 1961), do not depress intake to a significant extent. However, some short- and medium-chain fatty acids do depress intake when given intraperitoneally (Cave, 1978) or in the diet (Cave, 1982).

Contradictory reports have appeared regarding the effect of fat supplementation. It has been shown that as the dietary fat supplementation is increased, the amount of abdominal fat increases (Deaton et al., 1981) and the percent body ether extract increased (Deaton et al., 1981). Deaton also reported that under moderate and high temperature regimens, as dietary fat level increased body weight of the broilers increased as did the amount of abdominal fat (Deaton et al., 1981). Maurice et al. (1982) found that a high fat diet during the first week did not affect the weight of the abdominal adipose tissue in one experiment but significantly decreased it in another experiment. Early dietary fat restriction caused an increase in AAT weight at 7 weeks. Bartov (1979) Hillard et al.(1980) and Laudin et al(1985) reported that if fat is added at the expense of carbohydrates with the energy to protein ratio remaining constant, fat supplementation has no effect on invivo hepatic lipogenisis and carcass fat. As already noted it is reported that the substitution of fat for carbohydrates reduces hepatic fatty acid synthesis and the activity of associated lipogenic enzymes. However the work of Hillard, Lundin and Clarke (1980) suggested that this is due to the reduction in

carbohydrate and not to fat per se. When saturated fat was substituted in to a semi-purified fat-free diet to replace 25% of the glucose energy, fatty acid synthesis (in vivo incorporation of 3H2O) declined from 3.85 to 2.07 micro mole 3H20 per minute per gram liver and the hepatic enzymes fatty acid synthase and acetyl CoA carboxylase also declined. When the diet was supplemented with 20% energy as fat, and total energy intake increased, the rate of fatty acid synthesis and lipogenic enzyme levels remained constant. According to Grinbergen, Stappers and Cornelissen (1982) when food intake was controlled, the isoenergetic (ME basis) substitution of carbohydrate by fat in the diet of 5-week old broilers increased growth rate and energy retention but had no effect on body composition. Deaton et al (1981) how ever reported that when dietary tallow was increased from 40 to 100g/kg of diet AAT increased from 17 to 21g/kg body weight in males and from 20 to 24 g/kg in females. Edwards et al (1973), Griffith et al.(1977) and Whitehead and Griffin (1986) reported no significant effect on weight of AAT as a result of dietary fat supplementation. Nistan et al.(1986) observed that increasing dietary fat and protein resulted in decreased carcass fat deposition in high and low fat lines of broilers. Addition of vegetable oils often increases the polyunsaturated fatty acids (18:2, 18:3) at the expense of 16:0 ,16:1 and 18:1 (Whitehead and Griffin, 1986; Nir et al. in Leanness in Domestic Birds, pp. 141)

The fatty acid composition of the fat in adipose tissue and carcass is to a great extent dependent on the relative contributions of lipogenesis and dietary fat. However, Nir et al.(Leanness in domestic birds. pp. 141) reported that increasing the dietary energy content from 12.3 to 13.4 MJ /kg without changing the fat content did not alter the fatty acid profile in the AAT, skin mesenteric adipose tissues (MAT). Since linoleic and linolenic acids are not synthesized by the bird their presence in adipose tissue depends on their presence in the diet. The fatty acid content of poultry meat reflects the fatty acid content of dietary fat (Marion et al., 1963; Schuler et al., 1971). Breed, sex,

and temperature control of pens have only minor effects on the fatty acid distribution patterns (Marion and Woodroof, 1965; Balnave, 1973; Otake et al., 1973). Nonruminants tend to deposit the dietary fatty acids in the same form as ingested; that is, they neither saturate nor desaturate them. Ruminants on the other hand, have microorganism that increase the saturation of the fatty acids ingested (CAST 1991). Therefore the dietary lipids markedly influence the fatty acid composition of the fat of nonruminants, but have little effect on the fat deposition of ruminants. The assembled data on the lipid contents of fowl show that both poultry and game birds contain greater amounts of unsaturated than saturated fatty acids (Fristrom and Weihrauch 1976). Oleic acid is a dominant fatty acid in all tissues of all birds studied (Fristrom and Weihrauch 1976).

Form of the feed: Form of the ration also plays a role in partitioning of feed nutrients in to lean tissue and lipids. Pelleting and increasing energy concentration favour energy intake and as a result are accompanied by increase in fatness (Fisher and Wilson, 1974; Picard, 1981; Pestii, Whiting and Jensen, 1983; Leclercq, 1986). Pesti et al (1983) reported that crumbling a low density diet increased abdominal fat by 23%, while with a high density diet the form of the feed had no effect on the amount of fat deposited. When chicken are fed mash diets they need more time to consume the same amount of feed than chicken fed pellets or crumps (Jensen et al; 1982). Therefore especially with low density diets mash feeding means feed restriction to some extent.

Ambient temperature: Heat production of animals for a specific age is minimal at environmental temperatures within the zone of thermoneutrality. Deviation of environmental temperature from this zone ,however, is accompanied with increased energy expenditure in the form of heat production for the purpose of maintaining body temperature and as a result energetic efficiency will decrease. Bird feed consumption is inversely related to ambient temperature (Prince et al, 1961, Farrel and Swain, 1977,

Byerly et al., 1978.). The climatic environment in which a bird is raised is an important variable that can influence performance and whether it is cold, thermally neutral or hot depends on the degree of maturity of the bird, its feather cover, its potential growth and desired fattening rate, and on the composition of the feed offered particularly its balance and bulk (Emans, 1987). Literature on the relationship between environmental temperature and growth rate is considerable. Milligan and Winn (1964) found no change in weight gain in 5 week old birds reared at 8 C compared with others kept at 16 C, whereas gain was reduced at 27 C and continued to decline at 32 C. Hurwitz et al.(1979) also observed a decline in weight gain of birds between environmental temperature rose from 20 to 34C. Adams et al (1962a, b) documented a similar pattern of growth at the higher range of temperature while a steady growth rate between 7 and 18C has been reported by Deaton et al (1973,1974) and a 4.4% decline in growth rate in the temperature range of 24 to 35C by Cerniglia et al.(1976). Bray (1983) observed that the growth reduction of broilers kept at high temperatures was greater in males than females. Thus male broilers are more susceptible to heat prostration than the females under heat stress. In addition it is also a common observation that heavier birds are more susceptible to heat prostration than lighter ones. Howlider and Rose, 1987; Deaton et. al., 1986; DeAndrade et al., 1974, 1976, 1977; and Smith, 1972 reported that heat distress decreased growth rate, average body weight and feed consumption.

Most studies indicate that heat stress increases carcass fat, decreases the live weight gain and feed intake of broilers. Food utilization is improved until the point of heat stress when energy is required to reduce the heat load of the bird , e.g by panting (Howlider and Rose, 1987). However it is not possible to determine the exact temperature at which heat distress occurs because of the interaction of other factors such as relative humidity (Winn and Godfrey, 1967), diet composition (Dale and Fuller, 1980), stocking density (Charles et al. 1978). Kubena et al. (1971) and Bray (1983)

reported that at a moderate temperature the correlation between temperature and total body fat content is positive. Over several experiments, Fisher (1984) found a linear increase of 0.195 g total body fat per degree increase in temperature between 10 and 30 C. Washburn (1986) compared the effect of 70, 80 and 90 F using broiler chicken from 4 to 7 weeks of age and reported no difference in weight of abdominal adipose tissue of the birds subjected to the different ambient temperature. Keshavarz and Fuller, 1979. Dale and Fuller (1979,1980) demonstrated that energetic efficiency of gain (ME/body weight gain) with different dietary treatments was always higher when birds were kept in hot constant (31C) or hot cyclic (22.9 to 32.7C) temperatures as compared to normal constant(20C) or cyclic (15.2 to 21.9 C) temperatures. Kubena et al.,(1971) and Bray(1983) reported that at moderate temperature the correlation between temperature and total body fat content is positive. Washburn(1986) compared the effect of 70, 80 and 90 F using broiler chicken from 4 to 7 weeks of age and reported no difference in weight of AT of the birds subjected to the different ambient temperature.

Sex and age: Both sex and age of the broiler have clear effect on fat deposition. Females tend to be fatter than males and older birds have a higher fat content than younger birds(Lanestra, 1986). At greater ages or higher body weights the increase of fat content in females exceeds by far that in males. Females reach maximum non fat growth at lower dietary protein levels than males(Holsheimer, 1975). Changes in percentage of fat with age are larger than changes in percentage of protein and ash (Lin, 1981; Leenestra, 1982). In females the increase in percentage of total body fat and abdominal fat exceeds greatly that in males (Edwards et al., 1973; Fisher, 1980). Leenestra (1982) found that between 3 and 10 weeks of age the total percentage of fat in females increased from 10 to 19%; in males, in the same age period from 10 to 13%.

Influence of genotype : The importance of genetic factors in fat deposition have been described by Edwards and Denman (1975) who reported differences in fat

deposition between breeds and Ricard (1974), Cherry et al. (1978) and Ehinger and Seemann (1982) who showed differences between strains within breeds. A genetic variation within strain in the total amount of fat was found by Friars et al.(1983) who estimated the heritability of total percentage body fat to be 0.48. Hood and Pym (1982) found that chickens of fast growing lines had more and larger fat cells than slow growing lines. Nir and Lin (1982) found with invitro tests , that chickens of heavy strains tended to show more lipogenic activity than leaner lines. Banister et al.(1984) found higher activity of lipogenic enzymes in the fat line than in the lean line , which suggests higher lipogenesis in the fat line. Within strains and generations, the correlation between body weight and relative amount of fat is weak, not significantly different from zero but in nearly all cases positive (Leenestra, 1986). The correlation between amount of abdominal fat and feed conversion within generation is positive in poultry (Leenestra, 1982). Selection for low feed conversion results in less abdominal adipose tissue deposition. McAdam (cross reference Emans, 1987) selected five lines of genetically fast and slow feathering birds for and against heat loss at three weeks of age and observed that they also differed significantly in feathering and abdominal fat at seven weeks of age as shown below.

Line	Feather score	% abdominal fat
1	4.75	3.42
2	3.49	2.54
3	3.00	2.58
4	2.85	2.16
5	2.20	1.66

The correlation between feathering score and % abdominal fat for the above data was .97 and the well feathered birds at three weeks age were considerably fatter at 7 weeks. The effect of feathering on fatness in the above data might be explained by the following two factors:

(I) higher protein requirement in particular that of the sulfur containing amino acids by the fast feathering birds and

(ii) birds with poor feathering loose more heat on an imbalanced feed in a given environment. These two factors could result in a feed which will be balanced for the poorly feathered bird in a given climatic environment being imbalanced for the well feathered bird in the same environment (Emans, 1987).

Influence of interactions: Interactions between nutrition genotype sex and age can influence fat deposition in broilers. The difference in fat content between males and females becomes more pronounced with increasing age. Males and females react differently to changes in dietary protein. Males show a linear decline in percentage abdominal fat with increasing protein level in the diet. Female react more strongly with less fat deposition on an increase in protein at low dietary protein levels than at high dietary protein levels (Mabray and Waldroup, 1983). These authors did not find any interaction between sex and dietary energy if fat deposition is considered. A significant interaction between age of the broiler and dietary composition on fat deposition was reported by Have and Scheel(1981) and Van Gils (1977). Have and Scheel compared fat deposition in 6 and 8 week old broilers that were fed with diets of a constant energy to protein ratio, but that differed in concentration. The 6 week old chicken fed on a feed of 12 MJ ME/Kg had less than 80% of the fat content of chickens given a feed with 15 MJ ME/Kg, while at 8 weeks of age there was no difference in fat content between the groups whether fed 12 or 15 MJ/Kg.

Interactions between genotype and nutrition have also been reported. Cherry et al.(1978) and Have and Scheel (1981) found that the effect of energy:protein ratio on fat deposition was considerably different between different commercial broiler strains. Leclerq (1983) compared lean and fat line broilers on diets differing in protein content and observed that the lean line had lower body weight on low protein diet than the fat line while on a high protein diet both lines were similar in body weights. This suggests that the lean line has higher protein requirment than the fat line . Differences in fat deposition were more pronounced on the diet lowest in protein(8.1% fat in the lean line and 16.9% for the fat line) than on the diet highest in protein (6.8% vs 11.7%). Nitsan et al. (1986) reported the depressing effect of high dietary fat and protein on lipogenesis was more pronounced in the high fat line of broiler than in the lean line. Ehinger and Seeman (1982) studied the importance of different factors and their interactions as follows. They used males and females of commercial broiler strains, four diets differing in protein (19% and 24%) and energy (12.14 MJ and 14.23 MJ ME/Kg) and four slaughter age (35, 41, 47 and 53 days). The percentage of abdominal fat was measured and it was found that age was responsible for about 7% of the total variation, dietary composition for 14%, strain for 4% and sex for 16%. Interactions had a significant effect on body weight and absolute amount of abdominal fat but not on percentage of abdominal fat. Friars et al. (1979) studied genotype x environment interaction by comparing the amount of abdominal fat of two broiler strain crosses in floor and cage environments and found that one broiler strain, when reared on the floor contained a significantly higher amount of abdominal fat than the other (42.5g vs. 34.5g). However the difference between the two strains was not significant when both were reared in cages.

Thermo regulatory mechanisms in birds

In avian species and other homeotherms heat distress, is characterized by elevated body temperature, and occurs when heat production exceeds the bird's ability to dissipate heat. It occurs most frequently in tropical regions, but is also a seasonal problem in temperate climates. Birds, like most mammals, are homeotherms and must consequently maintain deep body temperature relatively constant over a wide range of ambient temperatures (Meltzer, 1987). The deep body temperature of a mature chickens is generally higher than mammals, being in the range of 41-42 (Kadano and Besch, 1978; Arieli et al. 1980; Meltzre 1983a),vs 38 C (Freeman, 1965). Bird heat production normally results in a thermal gradient from the warm interior (core) to the cooler surface (shell). In order to maintain their deep body temperature in about the same level as the ambient temperature broilers like other homeotherms have developed physical and chemical or metabolic thermoregulatory mechanisms.

The physical thermoregulation mechanisms can be classified under three major categories: Nonevaporative, evaporative heat loss and behavioral thermoregulation which includes surface adjustment (Freeman, 1983). All poultry classes utilize nonevaporative heat loss as the major means of heat dissipation when housed below and within the thermoneutral ambient temperature environments (Arieli et al., 1980; Van kampen, 1981b). Heat losses through radiation, convection and conduction may be lumped together as nonevaporative or sensible heat loss while heat loss through respiratory and cutaneous water evaporation may be referred to as evaporative or insensible heat loss. Nonevaporative cooling is an important means to dissipate heat. Birds manipulate nonevaporative heat loss through increased vasodilation of extremities (Nolan et al., 1978) thereby shunting blood and heat from the gastrointestinal tract to peripheral tissues. Nonevaporative cooling, however declines as ambient temperature increases since the temperature differential between bird body temperature and the

environment is decreased (Van Kampen, 1974). Evaporative cooling is an important route of heat dissipation during high ambient temperature stress when non evaporative cooling declines (Van Kampen 1974, 1981). Since the fowl has no sweat glands, H_2O loss via evaporation overwhelmingly occurs via the moist surface layer of the respiratory tract to the inspired air which is "saturated" with water vapor at body temperature (Kerstens, 1964). Heat lost through evaporation at lower temperature represents only a fraction, but increases dramatically through 26-35 C where it may contribute as much as 80% of total heat loss from the body (Kerstens 1964; Van Kampen, 1981). Arieli et al., (1980) estimated 4 mg/Kg.min C of evaporative water loss from heat distressed birds housed at ambient temperature of above 26 C. This represents an 8 fold larger amount than in the 2-26 C temperature range. Romijn and Lokhorst (1966), reported that at ambient temperature of 34 C and relative humidity of 40% an adult hen dissipates over 80% of total heat by evaporative means but this was reduced to only 39% on increasing the relative humidity to 90% and the bird becomes hyperthermic. Other avian homeostatic processes that help maintain body temperature homeostasis when confronted with an elevated heat load include increased respiration rate (Mather et al., 1980) and increased water intake (Squibb et al., 1959). Metabolic thermoregulation which involves a number of hormones

(Freeman, 1983) such as the hypophyseal, thyroid adrenal and pancreatic hormones is also an important means of thermoregulation by altering the metabolic rate depending on the ambient temperature, elevating the metabolic rate when the ambient temperature is low in order to compensate for the increase in sensible heat loss , keeping it at minimal when the ambient temperature is comfortable to the bird and again raising it when ambient temperature above the thermo neutral zone due to the activation of the cooling mechanisms (Robertshow, 1981). Farner (1964) produced evidence to show that panting in birds is stimulated by elevation of temperature of the panting center in the

anteriodorsal wall of the midbrain and not by stimulation of peripheral receptors. However Siegel (1968) stated that the entire panting response can be abolished by bilateral vagotomy in chickens.

Heat distressed broilers have elevated blood pH and reduced HCO3- and PCO2 (Marder et al., 1974; Arad and Marder, 1983; Bottje and Harrison, 1985; Teeter et al., 1985; Branton et al., 1986. Management strategy for minimizing the deleterious effects of heat distress includes reducing heat gain or increase heat loss by provision of suitable environmental modifications.

Broiler energy utilization under thermal distress

The net energy available to an animal exceeding immediate demand is typically retained as glycogen, lipids, and (or) protein. Likewise stored energy is mobilized when an animal's demand exceeds the energy from the feed consumed. Heat is dissipated via several pathways under the control of thermoregulatory mechanisms to maintain a rise or fall in body temperature. Some studies with ruminant animals (Young, 1976) have indicated lower energy digestibility during cold stress. Often, increased intake is credited with lower digestibility during cold , however covariate analysis has shown that the observed decrease in dry matter digestibility is due to temperature alone. During cold stress heat increment may be of importance to keep the body warm thereby reducing the need to produce extra heat by combusting feed nutrients through shivering or other cold induced thermogenic processes. On the other hand during heat distress , when the body thermoregulatory mechanisms are directed to dissipate excess heat from the body to maintain homeothermy , heat increment may be a burden to the animal. Consequently the relationship of heat increment to energetic efficiency is positive during cold weather but negative during hot weather. Behavioral and physiological adjustments by the animal resulting from the effect of stressors alter energy intake and its partition within the

animal, the amount of nutrients available for production, the level of productivity and the efficiency of feed utilization (NCR, 1981).

Successful design and operation of poultry house ventilation systems depends on accurate data concerning the sensible and insensible heat dissipation by the housed birds (Reece and Lott, 1981). Available data as well as theoretical consideration, indicate that environmental temperature affects heat production of broilers. Deaton et al. (1969), Reece and Lott, (1981), Van Kampen, (1981) and Chwalibog and Eggum, (1989) observed that the sensible heat output of broilers is inversely related to ambient temperature. It has also been suggested that growth rate might also influence heat production of broilers (Kuenzel and Kuenzel, 1976). Earlier studies in general indicate that heat distress increases carcass fat and decreases protein gain. However available information suggests that the effect of ambient temperature, age (body weight) and feeding level interaction on metabolic rate of broilers and targeting of nutrients for carcass fat or protein deposition is a subject requiring further investigation.

Basal metabolic rate in broilers

The heat production of an animal during complete rest in a thermoneutral environment in post absorptive state is termed basal metabolic rate and serves as a base line for measuring energy increments associated with various activities such as muscular work, feeding and keeping the body warm in cold weather (Brody, 1945). In homeotherms, the basal heat production per body weight decreases with increase in weight. The relationship between metabolic rate and body weight is exponential in mature animals. The value of 0.75 has been accepted as the international standard for the exponent b in metabolic equations of the form $M=aWb$ for birds and mammals (Kleiber, 1965) where M=metabolic rate, Wb=metabolically effective body weight, and a=a constant of proportionality. However Kibler and Brody (1944) and Kunzel and

Kunzel (1977) reported an exponent of 1.0 for white leghorn and broiler chicks up to 500 g body weight and suggested that the exponent 0.75 may not be valid for growing chicks. Haron and Meltzer (1983) determined resting metabolism and reported that leghorn pullets have an exponent of 0.986 until the birds achieve a body weight of 163 g at about the age of 3.5 weeks and an exponent of 0.63 thereafter until the birds reach a body weight of about 1495 g when they reach the general curve with the exponent 0.75. The same authors also found out that broilers have different metabolic curves and exponents during their growth phases, ie an exponent of 0.882 for both sexes until the birds are fully feathered at the age of 23-26 days after which the females have an exponent of 0.627 and the males an exponent of 0.483 at maturity.

One of the variables which might partly explain the superior growth performance of broilers as compared to layers is a lowered basal metabolic rate (Kunzel and Kunzel, 1976). The lower basal metabolic rate and heat production would mean a saving of energy to the broiler chick which might be diverted at least in part to growth (Sturkie, 1986).

Energy requirement for maintenance

In the words of Armsby and Moulton (1925), '' The concept of maintenance must involve the idea of conserving the existing status of the animal while doing no work and producing no product. There should be an exact balance between income and outgo of ash, nitrogen, hydrogen and energy showing that there was neither a loss or a gain of protein, fat, carbohydrate or mineral matter. Strictly there should be no translocation of material within the animal itself". Energy used for maintenance is by definition that part of the net energy consumed that is used for maintenance body functions (basal metabolism, activity etc.) with no energy gain. It accounts approximately to 70 % of the total energy requirement of the adult chicken (Bolton, 1959). A number of factors can

influence the maintenance needs of animals such as nutritional balance of the diet, body weight, growth rate (Keller, 1980), genetic strain feed consumption level (Pinchasov and Galili,1989) and environmental temperature etc. According to Emans (1987) in sheep and chicken maintenance requirement is directly proportional to body protein mass and no energy is required to maintain body lipid. This statement may be supported by the Metz and Dekker (1981) who observed that in pigs fed each 12 hours body lipid has zero turnover rate. The nutritional worth of poultry rations for productive purposes such as growth (protein and fat accretion) or egg production can be attained accurately only if the birds are fed above their maintenance requirement. To achieve this, data on the maintenance requirement of the bird is necessary. Maintenance energy constitutes a major part of the net energy needs of the mature chicken. A major portion of the maintenance energy expenditure is basal metabolism which accounts approximately to 85 % of the maintenance energy (Brody, 1969). Marks (1979) noted that as birds increase in age their proportional increase in body weight gain declines. As a result per unit metabolic size energy requirement for growth also goes down and the excess energy will be deposited as fat (Robbins and Ballew, 1984). Hurwitz et al.(1978) showed that as the broiler grows it's food intake increases in direct proportion to the power 0.66 and in a thermoneutral environment the birds energy requirement can be expressed as the sum of it's maintenance requirement and growth:

$$MER=8.0\ LW^{0.66} + 8.6\ WG$$

where MER =metabolizable energy requirement (KJ/d), LW=weight(g) and WG= weight gain (g/d).

The main objection to this equation is that it does not address the change in composition of the weight gain which takes place as the bird approaches maturity. Deposition of fat requires more nutrient input than lean tissue formation (Forbes, 1988). A number of factors can influence the maintenance energy requirement of an animal such

as nutritional balance of the diet, body weight, growth rate, genetic strain and environmental temperature etc.

Gray and McCracken (1980) working with pigs reported that the heat production (HP) of an animal adjusted to zero energy balance following feed reduction to approximately maintenance level is the best estimate of the maintenance requirement. The fasting heat production (FHP) of an animal has been used by a number of workers as an estimate of it's fasting maintenance requirement (Birkelo et al., 1991). It has traditionally been presented as a function of body weight with bigger animals showing higher FHP (Keller, 1980). However, several authors working on chicken have also indicated that the heat loss of a growing bird is dependent on the plane of nutrition before the calorimetric measurement (Keller et al., 1974, 1976). Thorbek and Henckel (1976) on the other hand reported no influence on heat production in relation to feeding level before starvation could be found in experiments with chicken. Prior plane of nutrition has also been shown to alter maintenance energy requirements in several species (Ledger and Sayers, 1977; Koong et al.,1983; Walker and Garrett, 1970). Koong et al.(1985) reported that higher growth rate is also associated with increased maintenance requirement. Birkelo et al. (1991) estimated maintenance energy requirements of beef cattle as FHP and maintenance metabolized energy (MEm) by respiration calorimetry at thermoneutral temperatures in relation to plane of nutrition and observed that high plane of nutrition (2.2 x maintenance) caused 7 and 14 % increase in FHP and MEm respectively as compared to low plane of nutrition (1.2 x maintenance). Macleod et al.(1988) determined energy and nitrogen metabolism in lean and fat lines of female broilers and reported FHP and maintenance requirement of 996 and 812 KJ/d for the fat line and 1058 and 887 KJ/d for the lean line respectively. The fat and lean lines had similar energy retention but differed ($p < 0.05$) in partitioning of retained energy in to carcass fat and protein (37 % versus 27 % of retained energy stored as carcass protein

and 63 % versus 73 % of retained energy stored as carcass fat in lean and fat line broilers respectively).

Mittelstaedt (1990) using Arbor Acre x Vantress determined the feed required for maintenance of birds ranging in body weight from 500 to 2500 g when fed a basal diet (2791 KCal MEn/kg, 21.5 % CP) at 24 C and reported that the maintenance requirement (% of body weight) decreased quadratically as bird weight increased from 500 to 2500 g.

Broiler hematochemistry

As in human beings and other species of animals, knowledge of blood constituents is of high practical importance since it permits the study of specific pathological changes of certain blood variables and also metabolic alterations of various origin Many factors can influence a particular blood constituent :genetic type (Lewandowski et al. 1986, feeding regime , (Melluzzi et al. 1992, Lewandowski et al, 19860, micro and macro climate, (Melluzzi et al. 1992), rearing technique (Cerolini et al, 1986), age (Melluzi et al,

1992; Sturkie, 1976; Ross et al. 1978), physiological state and sex (Lewandowski, 1986) and as well as pathological factors (Meluzzi et al. 1991).

Influence of handling on blood hematochemical values:

Davidson (1979), Doner (1981), Lewandowski (1986), and Melluzi et al. (1992) have all indicated the influence of blood sampling methods and analysis on the subsequent results. Hemolysis which is one of the result of improper handling of blood samples is often the most commonly encountered problem. Tiez (1976) reported hemolysed samples had elevated potassium, lactate dehydrogenase, and aspartate aminotransferase. Lewandowski et al. (1986), indicating the side effects of hemolysis to be: interference with calorimetric, enzymatic and other chemical reactions suggested that the problem can be averted by using dry clean equipment, gentle drawing of blood

sample through the needle, inverting the test tube rather than shaking, applying gentle rimming of the clot , avoiding overcentrifugation and refrigeration.

Serum protein: Normal serum protein values range from 3 to 6.9 g/dl (Lewandowski et al., 1986) or 5.2 to 6.9 according to Mituka (1981), but vary depending on the type of bird being tested. Allison (1955) reported that serum total protein values are good indicators of the protein store of the animal. Nevertheless it is affected by a variety of factors. Anabolic and catabolic hormones of which testosterone and growth hormone are members of the former cause increase in total plasma due to their anabolic effect (Kaneko, 1989b) while the catabolic hormones thyroxine and cortisol decrease total plasma protein (Sturkie, 1951). Hypoproteinemia is typically caused by parasites, hepatic and renal disorders, stressors and under feeding (Bush and Smith, 1980; Dolensk and Otis, 1973) while hyperproteinemia is associated with generalized infection and dehydration (Dolensk and Otis, 1973; Lewandowski et al.; 1986). In chicken, depletion of dietary protein results in hypoproteinemia and hypoalbuminemia while excess dietary protein manifests it self as hyperproteinemia (Leveille and Sauberlich, 1961). Furthermore, age has been reported to influence serum total protein content. Brandt et al. (1951) , Morgan and Glick (1972), Ross et al. (1976), Sturkie (1976) and Meluizi et al. (1992) observed increased serum protein concentration with increasing age. Hot environments tend to elevate total protein concentration (Meluzzi et al. 1992).

Serum albumin: Albumin is synthesized in the liver and catabolized by all metabolically active tissues (Kaneko 1989b). Although serum albumin content varies with species of animal (Kaneko 1989b), according to Galvin (1980) albumin is by far the largest individual protein fraction in avian serum. Albumin serves as protein reservoir and transport of amino acids (Grimminger and Scanes, 1986). Because of its abundance and small size it is also the most osmotically active (75% of plasma osmotic activity) plasma protein (Kaneko, 1989b). Since serum albumin is reported to bind and transport anions,

cations, fatty acids, amino acids and thyroid hormone, hypoalbuminemia would affect blood concentration of all these compounds (Lewandowski, 1986). Meluzzi et al (1992) reported that albumin concentrations increased in winter with a significant interaction between age and season. Prealbumin, a compound which has not been reported to exist in all other domestic animals is reported to occur in birds for binding thyroxine and transport (Kaneko, 1989b).

Serum glucose: Blood glucose concentration at any time is a net result of an equilibrium between rate of glucose entry into circulation and uptake by tissue (Kaneko, 1989b). Blood glucose values are influenced by an array of factors. Sources of blood glucose are dietary, hepatic production, from fructose and galactose, glucogenic amino acids (gluconeogenesis) and from glycogen through glycogenolysis. Although rate of entry of glucose in to the blood stream relatively short (15 minutes after feeding (Hill, 1971)), glucose uptake or removal by issues is governed by utilization by tissue as energy source or conversion to other products such as glycogen, pentose and lipids (Kaneko, 1989a). The liver holds central position in controlling blood glucose concentration by releasing glucose into the blood when the glucose concentration in the circulation falls below threshold values and taking up glucose when its concentration goes up. Belo et al. (1976) indicated that plasma glucose levels and glucose turnover rate were constant during fasting while Brady et al. (1978) observed that plasma glucose in chicken remained at base line level after fasting. Using tracer studies the authors observed that tricarbon units originally derived from glucose are reincorporated into glucose molecule from which the concluded that little glucose sparing adaptation exists during short term starvation in chickens. Hazzlewood (1986) reported that short term starvation causes immediate mobilization of hepatic glycogen reserve to release glucose into the plasma to support metabolic needs of certain tissues. He also reported that short term starvation (1 to 8 days) does not decrease glucose utilization in chicken per unit body weight as

compared to mammals. From this he concluded that the greatest energy loss during starvation is due to fat depletion and to some extent protein utilization. The fasting state in the human and dog is characterized by decline in blood glucose levels (Owen et al.; 1969; Brady et al. 1977) decreased blood glucose turnover (Kreisberg et al. 1970; Brady et al. 1977) decreased plasma gluconeogenic amino acids (Felig et al. 1969; Brady et al. 1977) and increased blood ketone levels (Cahill et al.1966; Wiener et al. 1971; Brady et al. 1977). The sub cellular location of phosphoenolpyruvate carboxykinase (PEPCK), the key regulatory enzyme in hepatic gluconogenesis being approximately divided equally between the cytosol and mitochondria is similar in these two species (Soling and Kleineke, 1976; Belo et al. 1976) The subcellular location of PEPCK influences the flux of carbon and reducing equivalents between mitochondria and the cytosol during gluconeogenesis in many species of animals (Hanson, 1974; Soling and Kleineke, 1976). The chicken, however unlike other mammals has been reported to maintain plasma glucose levels and glucose turnover during fasting over a period of days (Evans and Scholz, 1971; Belo et al. 1976; Linda et al. 1978) An oxidized mitochondrial redox state is associated with increased phosphoenol pyruvate and glucose production in guinea pig liver, in which 50 % of PEPCK is mitochondrial and it has been proposed in other species with mitochondrial PEPCK , an oxidized mitochondrial redox state would be favorable for phosphoenol pyruvate and glucose production (Soling and Kleineke, 1976). The pigeon and chicken possess almost entirely intramitochondrial PEPCK in the liver which in the pigeon has been reported to remain constant with fasting (Soling et al., 1973)Chamblee and Morgan (1982), on the other hand reported that chicken serum glucose levels decreased within 3 hours of starvation. Langslow et al (1970) reported that compensatory gluconeogenesis, protein and fatty acid catabolism increase greatly during starvation. Glucose levels also increase sharply following stress (Lewandowski et al., 1986). Starvation, hypovitaminosis and disease may cause

hypoglycemia (Chandra et al., 1983; Galvin, 1980). The period for onset of hypoglycemia appears to be dependent partly on bird age. However, unlike other animals chicken develop fasting hypoglycemia much slower (Houpt, 1958). Kumar and Gupta, 1981) observed that hyperthermia and feeding lead to elevated blood glucose level. Lewandowski et al. (1986) reported that blood glucose concentration varies with bird age, time of the day and state of captivity.

Uric acid: In birds uric acid is the main by product of protein, nonprotein nitrogen and purine catabolism (Lewandowski et al, 1986) excreted by the kidney through tubular excretion. The normal range for serum uric acid is from 2-15 mg/dl (Lewandowski et al. 1986). Elevated serum uric acid values have been attributed to renal disease, starvation age and captivity (Lewandowski et al. 1986).

Serum Calcium, Potassum and Sodium: Lewandowski et al (1986) reported that calcium values range from 8 to 12 mg/dl while Mirtuka (1981) reported that normal values averaged from other literature range from 9 to 23.,7 mg/dl. Elevated calcium values have been associated with excess of vitamin D_3 (Rosskopf et al. 1984; Tietz, 1976). Hypo calcenemia has been reported to result from hypoalbumienmia or due to reduced calcium reabsorbtion (Lewandowski et al. 1986). When different studies were compared normal serum sodium and potassium values range from 130 to 170 mEq/l and 2.5 to 6.0 mEq/L respectively. Sodium and potassium levels have been suggested to be influenced by the body's water status. According to Chamblee and Morgan (1982) serum potassium land phosphorous level in birds remained constant within one and half hour of water deprivation while sodium level increased. However serum sodium levels returned to normal upon refeeding. On the contrary, Siegel (1968) reported that increased water consumption in an increase in sodium level and attributed this to an attempt by the bird to remove excess serum sodium.

Serum triglycerides: Many factors influence serum triglyceride levels. Circulating blood lipids are derived from intestinal absorbtion, synthesis or mobilization adipose tissue (Grimminger, 1986). Increased feed intake has been reported to result in increased blood lipids and adipose tissue. With adequate nutrients available in the body, circulating triglycerides are spared which results in increased fat deposition (Grimminger, 1986). Melluzi et al. (1992) reported that Hybro birds had higher triglycerides levels than Arbor acres suggesting influence of breed and genetics on serum triglycerides. These researchers further reported that males had higher triglyceride levels than females. Male chickens selected for increased fatness had greater concentration of triglycerides after an overnight (16 h) fast than those selected for leanness (Hermier et al. 1984). The increase in triglyceride levels was noted two hours following refeeding.

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CHAPTER III

ENERGY AND NITROGEN NEEDS OF THE MALE 3, 5, AND 7 WEEK COBB 500 BROILER[1]

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ABSTRACT: Two experiments were conducted to evaluate broiler maintenance energy (E) and nitrogen (N) needs as well as feed consumption level effects on gain and 10 serum analytes of the 3-7 week old broiler. Maintenance requirements were estimated by regressing live weight (Expt. 1 and 2), E and N gain (Expt. 2) on MEn consumption. In the first study, where only E was studied, live body weight gain of broilers ranging from .56 to 2.45 kg body size increased linearly ($P<.01$) with increasing feed consumption level while daily maintenance energy needs per kg live weight declined quadratically ($P< .01$) from the .56 kg class (169 kcal/kg) to the 2.45 kg weight class (66 Kcal MEn/kg). The exponent required to convert live body weight to metabolic body weight, as estimated using MEn consumption need for maintenance was .339. Metabolizable energy required for growth, averaged over age, was 2.6 kcal/g. In the second experiment additional variables included energy gain (EG), heat production (HP) and carcass protein (P) and lipid (L) gain. Maintenance energy requirements for body weight homeostasis and growth were comparable to experiment 1 being 141, 103 and 73 kcal/kg body weight for the .47, 1.236, and 2.199 kg bird while energy requirement for growth was estimated to be 2.3 Kcal/g. However, considerable repartitioning of energy from endogenous lipid to protein occurred while birds were at maintenance (0 weight or energy gain-loss), suggesting that maintenance energy needs should be redefined to include tissue composition homeostasis. Nitrogen requirement for maintenance was 621, 348 and 257 mg per kg body weight per day for the 3, 5 and 7 week broiler while that for N gain was 1.35, 1.23 and 1.11 g N per gram N gain, giving dietary N efficiency of 74, 82 and 90 %. Within an age group, efficiency of ME and N utilization improved ($P<.05$) as ration consumption increased. Lactate, uric acid and ALT were lower ($p < .05$) in birds with positive energy balance while the reverse was noted with serum triglyceride. Serum Ca, P, Na, K and Tp were not significantly altered by feed consumption level or age.

Introduction

Researchers have historically attempted to describe broiler maintenance energy needs as a function of body weight. Lack of a direct linear relationship between maintenance energy needs and body weight was attributed by Brody (1945) to a declining surface area/body weight ratio as bird weight increased. Brody postulated that the maintenance energy-body weight relationship is exponential, with a exponent of .75 being applicable across species and .66 for poultry specifically.

Various exponents have been utilized to linearize the body weight-heat production relationship, and such body weight transformations are often termed "metabolic weight". Several laboratories , (Van Kampen, 1981; Aharon, 1983) have suggested that metabolic rate and hence the exponent used to convert bird body weight to metabolic weight is not constant, being influenced by carcass composition (Emans, 1987; Macleod et al., 1987), sex (Ferrell et al., 1979), ambient temperature (Close, 1970), ration nutrient balance and genetic strain (Ferrell and Jenikens, 1985). Koong et al. (1985) and Keller (1989) reported that growth rate of chicks might impact maintenance energy needs while workers with other species have similarly suggested that prior plane of nutrition of cattle (Ledger and Sayers, 1977), pigs (Koong et al., 1983), and rats (Walker and Garrett, 1970) impacts the maintenance energy requirement. In contrast Thorbek and Henckel (1976) observed no relationship between chick BMR and feeding level prior to obtaining classical BMR (24 h fasting) estimates. Though these studies and/or interpretations suggest that maintenance energy expressions may be variable, the fact remains that about 70% of the metabolizable energy consumed by broilers is used for maintenance (Bolton, 1959) necessiating that methodologies be developed to identify and quantifying critical sources of variation.

Various approaches have been used to estimate maintenance energy needs. Webester (1977) regressed metabolizable energy intake (MEI) of rats against energy stored as fat and protein :

$$MEI = A + bR_{e,p} + cRE_{e,f}$$

where $R_{e,p}$ and $R_{e,f}$ are energy retained as protein and fat respectively and A is the maintenance requirement. Hurwitz et al. (1978), suggesting that broiler energy requirements may be considered as the sum of the requirements for maintenance and body weight gain generated the following :

$$MER = 8.0\ LW^{0.66} + 8.6\ WG$$

where MER is the metabolizable energy requirement (KJ/d), LW is live weight (g) and WG is weight gain (g/d). Pinchasov (1990) and Bornstein et al. (1979) applied the Hurwitz's method to partition bird energy needs for maintenance and growth without validation. Macleod et al.(1987) and Jones (1993) estimated maintenance energy requirement of broilers as the metabolizable energy intake required for zero energy retention using the equation:

$$AME = A + ER$$

where AME= apparent metabolizable energy intake, ER= energy retention and A is the maintenance energy requirement when ER=0. The former authors reported values of 253 and 238 Kcal /d as the maintenance energy need of lean and fat female broilers lines weighing 2.29 kg, respectively, suggesting that lean tissue has a higher maintenance need.

Classically, the method used to estimate the exponent required to convert body weight to metabolic body weight has been the slope coefficient obtained by regressing log metabolic rate or heat production (Kleiber, 1945) or log O_2 consumption (Meltzer, 1983) against log bird body weight. As such, literature values range from .48 (Kunzel and Kuenzel, 1977; Meltzer, 1983) to the classical .75 value. Brody (1945) and Mitchel (1962) indicated that body weight to the power .66 is more appropriate for

poultry. However, as discussed above exponent estimates are variable making application difficult leading Meltzer (1983) to propose that broilers have two metabolic curves, the first with an exponent of .882 to the age of 23-26 days for both sexes and thereafter an exponent of .627 for the females and .483 for the males.

The objectives of the studies reported herein were to determine energy and nitrogen requirements of the male 3, 5 and 7 week old broiler for body weight, energy, and nitrogen homeostasis as well as growth. Further the study also sought to estimate the metabolic body size exponent and the serum chemistry profile for 10 analytes as related to energy balalnce.

Materials and methods:

PRE-EXPERIMENTAL: Both experiments utilized commercial male broilers. Chicks were obtained at hatching, fed starter ration and reared in floor pens under continuous tungsten filament lighting until reaching the required weight (Expt 1) or age (Expt 2) category.

EXPERIMENT 1: The first experiment was conducted to estimate the ME required for growth and body weight homeostasis of the 5, 1.0 , 1.5, 2.0, and 2.5 Kg broiler. To achieve this, 2 bird populations (separated in time by 8 weeks) and housed in 5 floor pens each, were monitored for body weight at 3 day intervals. When the pen mean reached the approximate target weight , chicks within 5 % of the population mean were selected and allocated at random to individual wire cages. The experiment was thereby replicated in time with 15 birds per weight class for the two populations. The wire cages were housed within a thermostatically controlled room (24 C^0) under continuous fluorescent light. Following a 12 h overnight fast bird body weight was recorded and the birds assigned at random to one of five feeding levels including: 0, 2, 4, 6, and 8% of fasted body weight. Ration was provided

once daily for a two day consumption period followed by a second 12 h fast prior to recording final body weight. Fecal collection trays were utilized to collect excreta output over the assay period. Excreta dry matter was determined (AOAC, 1984) such that apparent ration digestibility might be determined according to Stevenson (1962). Whole bird dry matter was determined, following euthanasia with CO_2 by placing birds in a drying oven to constant weight.

EXPERIMENT 2: The second experiment was conducted to estimate the ME and N required for growth and body weight homeostasis as well as to relate tissue compositional changes with 10 serum analytes. Chicks were acquired at 14 day intervals such that simultaneous observations might be made on the population at 21, 35 and 49 days of age. Birds from each age group were selected at random three days prior to experiment initiation, intramuscularly injected with ketamine HCL (40 mg/Kg of body weight) to achieve anistetic induction and surgically fitted with body temperature transmitter (Mini Mitter Telemetry System, Sunriver, Oregon 97707) as described by Belay and Teeter (1993). Immediately following transmitter implantation birds were allowed a 3 day surgical recovery period while housed at 24 C in individual open circuit respiratory chambers (51 x 34 x 41 cm). During the recovery period grower ration (Table 1) containing .1 % Chromic oxide as a digestibility marker and water were provided for adlibitum consumption Details of the respiratory chamber construction and operation are described elsewhere (Belay and Teeter, 1993; Wiernusz and Teeter, 1993).

Immediately following the adjustment period birds were fasted 12 h, weighed to the nearest gram and randomly assigned to feeding levels composed of 0, .5, 1, and 1.5x the maintenance energy requirement estimated from experiment 1. Ration provided during the experimental phase was fortified with .3 % Ferric oxide so that excreta originating from feed consumed during the experimental period might be collected.

Feeding was accomplished by dividing the daily allotment into six equal feedings for each of the three days. On the fourth day feed was removed and the birds fasted for 12 h before final excreta collection and bird weights were recorded.

Upon completetion of the 12 h fasting period final body weight was recorded and blood samples collected from the ulinaris vein as described by Dien (1986) using a 3-ml syringe. Sodium , potassium, calcium, chloride, phosphorus, triglyceride, total protein, alanine amino transferase, and uric acid, were determined on serum samples using : Roche Kits (Hoffman-LaRoche, Nutley, NJ 07042) for chloride (No. 44029), magnesium (No. 44169), triglycerides (No. 44120), uric acid (No. 44124), total protein (No. 44903), calcium (No. 44033), phosphorus (No. 44031) and alanine amino transferase (No. 44644). In all instances, serum variables were measured using a Cobas Mira wet chemistry analyzer (Roch diagnostic Systems Inc., Montclair, NJ 07042-5199) with sodium and potassium values assayed via sodium and potassium selective electrode module (No. 44498) of the Cobas Mira..

Feed intake, water consumption, body weight change, body temperature, liters O_2 consumption(OC), and liters CO_2 production (CP) were estimated during the experimental period as described by Weirnuz and Teeter (1993). Additional variables included nitrogen balance (NB), determined metabolizable energy consumption (AMEC; Farrel, 1978), AMEC corrected to zero nitrogen balance (AMEnC) and chick heat production (HP), energy gain (EG), lipid gain (LG) and protein gain (PG) using equations proposed by Mcdonald and Teeter (Mcdonald, 1993) as follows:

$$HP=27.8683\ NB +4.1529\ CP+.0598\ AMEC$$

$$EG= -26.2798\ NB -4.3953 CP+ 1.00083\ AME_nC$$

$$LG= -.62484\ CP-1.00614\ AMEC+1.13929\ AME_nC$$

$$PG= 0.1457\ CP+0.8224\ AME_nC+0.84025\ AMEC$$

STATISTICAL HANDLING OF DATA: Polynomial equations were developed by regressing breathing air O_2 and CO_2 concentration entering and exiting the chambers

against time (t), t^2 and t^3. Estimates of broiler CO_2 production were obtained by computing the difference between integrated incoming and outgoing CO_2 values. Statistical analysis of the data was carried out via ANOVA following the general linear models procedure (SAS, 1982). When a significant F statistic was observed treatment means were separated using Duncan's multiple range test (Steel and Torrie, 1960). Linear regression equations relating body weight and tissue composition changes with nitrogen and energy consumption were performed so that maintenance and growth needs as well as tissue stability might be estimated. The nitrogen requirement for maintenance and tissue nitrogen gain was estimated by regressing nitrogen balance per unit initial weight against nitrogen intake per unit initial body weight and solving for zero nitrogen balance. The slope coefficient becomes an estimate of nitrogen efficency for tissue nitrogen retention and the reciprocal of the slope gave an estimate of nitrogen requirement per unit nitrogen gain.

RESULTS AND DISCUSSION

EXPERIMENT 1: Broiler body weight gain increased linearly ($P < .01$) with increasing feed consumption and failed to exhibit significant higher order tendency (Table 2). The fact that live weight gain of birds fed at a constant percent of body weight increased with body weight, suggests that maintenance energy needs per unit body and body weight are inversely related. Regressing live weight gain per unit bird initital weight on ME_n consumption per unit initial weight, for each of the 5 wieght classes, yielded the equations displayed in Table 3. Energy required per g body weight gain, estimated as the regression line slope reciprocal, was not influenced by body weight, averaging 2.6 Kcal/g. Lack of an apparant age affect upon energy required per unit live gain suggest that either gain composition of the limit fed birds was similar accross the bird ages

examined, or that the energetic efficiency of tissue gain was not influeced by gain composition.

Using the table 3 regression equations and solving for energy required by the chick for body weight homeostasis (0 weight gain) yielded estimates ranging from 93 to 163 kcal MEn per day for the 0.56 and 2.5 kg birds, respectively. As predicted from the performance data, maintenance energy needs expressed as percentage of body weight declined quadratically as body weight increased. If one can assume that carcass dry matter is related to carcass composition, as suggested by Verstrate et al. (1980) the lack of a feeding level effect on carcass dry matter (Table 4) may suggest that body weight homeostasis reflects tissue homeostasis. However, this is a crude measure and additional validation is needed.

The exponent used to convert body weight to metabolic body weight is classically estimated by regressing log heat production (HP) on log body weight of adult birds, varying in breed and fasted 48 hours (Brody, 1945). This study utilized Cobb chicks with maintenance energy defined as that required for body weight homeostasis and fasted bird HP. Such values may not necessarily parallel classical HP values. Indeed regressing log energy intake (kcal/day) needed for body weight homeostasis (y) on log body weight (x) in kg yielded:

$$Y=4.74+.339\ x,\ R^2=.96$$

As such, the data indicates that the exponent for converting chick body weight, under condition of body weight homeostasis, to metabolic body weight is .339 and not .75, or .66 as suggested by Brody. Reasons for the different exponent may include energetic

efficiency of ME use for body weight homeostasis maintenance being less than 100 %, removal of high heat producing tissues when birds are fasted 48 h, and / or the fact that immature chicks of the same strain were utilized in contrast to adult birds of varying genetic basis. The second study was conducted to further evaluate these and other issues.

EXPERIMENT 2: Results of the second study are displayed in tables 5 to 12. Similar to experiment 1 weight gain increased with feed consumption level. However, in some cases a quadratic fit appeared to better reflect growth and may reflect alterations in tissue gain composition. The energy requirement for live weight gain estimated as the reciprocal of the slope coefficient of the linear equation relating body weight gain to ME consumption fell 11% lower than that observed for experiment 1 birds, averaging 2.3 Kcal/g. These estimates are comparable to the 2.05-2.19 Kcal reported by Hurwitz et al. (1978), the 2.0 reported by Pinchasov et al. (1990), but higher than the 2.0 and the.7 Kcal reported by Bornestein (1979), and Hurwitz et al. (1980). Differences in energy requirement for growth between the 3 age classes was not significant and might have been masked by comparable ME consumption per body weight since this was not found to be different between the three groups.

Solving the gain vs MEn consumption equations found in Table 5 for energy required for live weight homeostasis of the 3, 5, and 7 week old broiler yields estimates comparable to experiment 1 values. The maintenace energy need of the 3 week .56 kg broiler (93.7 kcal/d) is similar to the 99 kcal/d reported by Bornestein (1979), the 89

kcal/d estimate of Jones (1994) for a 27 day old broiler (unspecified weight) and the 95 kcal/d needed by a .56 kg (Macleod et al.,1988). In general, maintenance energy estmates of other workers (ARC, 1963 ; Huwitz et al., 1978; Bornestein ,1979) for older broilers were higher than our estimates which might be explained by a higher energy cost of activity since their birds were floor reared rather than being confined to respiratory chambers as is the case in the present study.

Experiment 2 birds at zero weight gain showed significant positive energy balance (Table. 11) thus contradicting the classical definition of an animal at maintenance The observed positive energy balance at body weight homeostasis suggests a shift in carcass composition resulting from reduction in carcass dry matter. On the other hand, birds at tissue energy homeostasis (Table. 12), were found to be in positive protein balance and negative lipid balance suggesting a shift in composition from lipid to tissue protein. Therefore the results suggest that both body weight homeostasis and tissue energy homeostasis may not be reliable for estimating an animal's true maintenance needs. It might be more appropriate to express maintenance needs based on tissue composition

Regressing the log MEn consumption required for live weight homeostasis on the log of live weight yields an equation whose slope represents the exponent to convert body weight to metabolic body weight as described by Brody (1945). In contrast to the .339 observed in the first study, the value for experiment 2 was estimated to be .57. As discussed earlier exponent values are influenced multifactorially (Van Kampen, 1981;

Aharon, 1983) by carcass composition (Emans, 1987; Macleod et al., 1987), sex (Ferrell et al., 1979), ambient temperature (Close, 1970), ration nutrient balance and genetic strain (Ferrell and Jenikens, 1985). In the present study experiment 2 birds were fed on a ration of higher caloric density than experiment (3201 vs 2791 Kcal/kg). Therefore this might have contributed to the observed difference.

Literature values estimating the exponent for live weight to "metabolic weight" conversion have historically led to inconsistent values. Brody first proposed that .75 (1945) is the appropriate exponent, when viewed accross species, and later modified the value to .66 for applications to avian species. Mitchell (1962) and later Hurwitz et al (1978) used the .66 exponent to express the maintenance energy requirements of broilers. These values are higher than the .48 exponent reported by Kuenzel and Kuenzel (1977) and Meltzer (1983) for broilers of approximately comparable body weight or age. Meltzer (1983) proposed that male broilers have an exponent of .483 from 23 days of age to maturity. Combining the studies reproted herein, and using the data to estimate the live-metabolic weight conversion exponent yields a value of .46 and is comparable to the work reported by the above authors.

As discussed, exponent variability has been speculated to be attributed to to a number factors such as carcass composition difference (Emans, 1987; Macleod et al. 1987), ration nutrient balance (Ferrell and Jenikens, 1985) etc. Since live to metabolic weight transformations are frequently utilized to better reflect various aspects of metabolism, it is essential that appropriate sources of variation be identified. Published studies with broilers, however, suggest that there is little agreement among researchers

and editorial bords regarding exponent application, with values ranging from .48 to .75. Meltzer (1983) attempted to account for descrepencies by proposing that male broilers have an exponent of .882 until the age of 23-26 days and an exponent of .483 till maturity, similar to that reported by Kuenzel and Kuenzel (1977). Considerable variation also exists in the application of the MWT term, with some authors utilizing it to express basal or resting metabolic rate (Farrell, 1974; Macleod, 1990) while others apply MWT to some combination of BMR plus feed consumption (Macleod, 1992; Jones, 1994). Further more while it is evident that the metabolic curve of the fasting bird is different from that of the fed, quite often exponent derived from the fasting bird is used for transforming the fed bird weight to MWT. Standardization of the MWT term is critical to the advancement of energetic studies. Based on the results of the present study and application by others the following classifications of MWT may be needed:

1. MWT_f: Metabolic weight as related to fasting HP, or the exponent required to convert fasted live bird mass to a transformed value that when regressed against
   heat production attributed to fasting has a slope of zero.
2. MWT_m: Metabolic weight as related to body weight homeostasis or the exponent required to convert fed live bird mass at body weight homeostasis into
   a value that when regressed against total heat production has a slope of zero.
3. MWT_t: Metabolic weight as related to tissue (protein and fat) homeostasis

4. MWT_{fc}: feed consumption: exponent required to convert fed body weight to a transformed value that when regressed against feed consumption has zero slope.
5. MWT_g: Metabolic body weight as related to growth, exponent required to convert fed live bird mass into a transformed value that when regressed against heat production attributed to growth has a slope of zero.

Additional factors also have the potential to impact MWT_f and MWT_m. Carcass composition may impact MWT_m since various studies (Grahm et al., 1974; Ferrell et al., 1979; Emans, 1987; Macleod et al., 1987;) have reported that HP is correlated with carcass protein contents. In expressing bird maintenance energy need it might be more appropriate to use AMEn rather than AME since there will not be tissue protein gain involved. Substrate source would also be expected to impact HP, especially if considerable metabolic change is required to replace endogenous losses and/or provide energy. Tissue substrate use in trial 2 is made more complicated by the fact that the chicks, at constant body weight, were in negative lipid balance and positive protein balance. This suggests that body weight maintenance of the 3 to 7 week old chick is a poor indicator of true tissue maintenance needs. Altering the calorie-protein ratio may be necessary to achieve maintenance estimates with tissue composition homeostasis.

Similar to trials1 and 2 live weight gain, nitrogen gain for experiment 2 birds increased linearly with increasing feed consumption level with no evidence for quadratic or higher order tendency (Table 7). Similar to ME, within an age group, efficiency

nitrogen utilization above maintenance improved as ration consumption increased. Nitrogen requirement for nitrogen homeostasis (Table 6) was 621, 348 and 257 mg per kg body weight per day for the 3, 5 and 7 week broiler. Grams nigrogen required per g of N gain averaged 1.35, 1.23 and 1.11 g, providing N efficiency of 74, 82 and 90 %. The results also suggest that nitrogen requirement for protein accretion is 202 ± 5 , 183 ± 12 and 166 ± 7 mg per gram protein for the 3, 5 and 7 week broiler. Regressing log nitrogen requirement (Y) for bird nitrogen homeostasis against log initial body weight (x) yielded the equation:

$$Y = -92.0053 + .431431\ x$$

suggesting that the exponent required to convert bird live weight to MWT to be .43.

In order to contrast energy requirement for lipid and body weight homeostasis lipid, and body weight gains were regressed separately against ME consumption yielding the equations shown in Table 10. Solving for zero lipid or weight gain gave 67, 87, and 90 Cal per gram body weight as ME needed to achieve lipid homeostasis in the 3, 5 and 7 week old broiler while the corresponding estimates to achieve body weight homeostasis were 141.1, 102.8 and 73.4 Cal per gram body weight per day. Within the 3 and 5 week age groups, the results indicate that body weight homeostasis demands more energy than lipid homeostasis, reflecting the lipid use for protein accretion which was not as pronounced in the 7 week broiler.

Literature has historically stated that net energy for maintenance is equivalent to fasting heat production in domestic animals. However in the present study energetic

efficiency of ME use for maintenance (the slope of the equation relating fasting heat production to maintenance energy consumed for body weight homeostasis was about 70 %. Reasons potentially include less than 100 % energetic efficiency might be removal of high heat producing tissues upon 48 h fasting. Significant ($P<.05$) linear relationship was observed between level of MEn consumption and total CO2 production within age or weight class. Similarly, HP, EG, PG and LG increased linearly ($P < .0001$) with feed consumption (Table 8) and were impacted by age x feed consumption level interaction.

Serum lactate, uric acid, ALT and tryglyceride values varied with positive and negative energy balance. Lactate, uric acid and ALT were lower ($p<.05$) in birds with positive energy balance while the reverse was noted with serum triglyceride (Table 13). Birds fed below maintenance energy had greater than 50% higher ALT activity than their full fed counterparts. In humans elevation of ALT activity is associated with hepatic diseases (Best and Taylor, 1985). Therefore this might suggest that low energy consumption may be related to altered liver integrity, though this interpretation is speculative. Serum Ca, P, Na, K, and Cl were not significantly altered by feeding level.

TABLE 1. Composition of grower rations used in experiments 1 and 2.

Ingredient	Experiment 1	Experiment 2
	% of diet	
Ground corn	58.5	61.00
Soybean meal	37.1	30.00
Animal fat		4.64
Dicalcium phosphate (22% Ca, 18% P)	2.49	1.95
Limestone (38% Ca)	.93	1.35
Salt	.52	.45
Vitamin mix[1]	.26	.26
Trace mineral mix[2]	.10	.10
DL-Methionine	.10	.25
Calculated analysis		
ME, kcal/kg	2791	3201
CP	21.5	20.1
Lysine	1.05	1.08
Methionine+cystin	.75	.89
Ca	.84	1.09
P, available	.59	.49

[1] The vitamin mix supplied 9900 IU vitamin A, 2750 IU cholecalciferol, 33 IU vitamin E, 11 mg vitamin B_{12} , 6.6 mg riboflavin, 44 mg niacin, 11 mg d-pantothenic acid, 449.4 mg choline, 3.3 mg menadione, 1.1 mg folic acid, 3.96 mg pyridoxine, 1.98 mgthiamin, .11 mg d-biotin

[2] The mineral mix supplied 160 mg Ca, 100 mg Zn, 120 mg Mn, 75 mg Fe, 10 mg, 2.5 mg

TABLE 2. Feed consumption effects on live weight gain (g/day) of limit fed broilers used in experiment 1.

Live daily weight gain (g)						
	Feed consumption level (% of body weight)					
Initial weight (g)	0.0	2.0	4.0	6.0	8.0	Mean+SEM
555	-33.76^{e}	-24.88^{d}	-16.72^{e}	-8.64^{b}	.53^{a}	-85.47+1.65
1013	-50.92^{e}	-29.32^{d}	-12.12^{c}	3.0^{b}	18.28^{a}	-14.22+1.67
1423	-52.6^{e}	-18.09^{d}	4.0^{c}	24.44^{b}	44.76^{a}	.5+2.57
2079	-56.29^{e}	-16.4^{d}	12.29^{c}	41.49^{c}	64.5^{a}	9.12+4.98
2450	-62.34^{e}	-15.14^{d}	17.26^{c}	54.57^{b}	89.37^{a}	16.74+3.99
Mean+SEM	-51.58	-20.7+2.4	.94+3.2	22.97+3.1	43.49+3.3	

^{a,b,c,d,e} Means followed with unlike superscripts are different ($P < .05$)

TABLE 3. Regression equations[1] used to estimate feed and MEn need for body weight homeostasis expressed as feed / day.body weight , kcal / day and kcal / day. kg body weight of experiment 1 broilers

			Feed required for maintenancee		Daily AMEn (Kcal) need for maintenance	
Body weight (g)	Equation	R	% body weight	per day (g)	per day	per kg body wt.
555	y=-.063384+1.047171 x	R=.94	6.05	33.58	93.72	168.85
	y=-.063727+1.090835 x-.69727 x^2	R=.95	6.08	33.74	94.17	169.68
1013	y=-.047128+1.06054 x	R=.97	4.44	44.97	125.53	123.92
	y=-.04979+1.3943 x-5.2796 x^2	R=.98	4.26	43.15	120.43	118.89
1423	y=-.033069 +1.06033 x	R=.96	3.12	44.40	123.91	87.08
	y=-.036292+1.474099 x-6.55126 x^2	R=.98	2.81	39.99	111.61	78.42
2079	y=-.026074+1.043018 x	R=.96	2.5	51.98	145.06	69.78
	y=-.02658+1.116785 x -1.320681 x^2	R=.96	2.45	50.94	142.17	68.39
2450	y=-.024042+1.010628 x	R=.97	2.38	58.31	162.74	66.43
	y=-.024861+1.123247 x-1.900256 x^2	R=.98	2.19	53.66	149.75	61.12

[1]Live weight gain regressed on ration consumption per unit initial weight.

TABLE 4. Carcass dry matter (%) of limit fed broilers used in experiment 1.

	Feed consumption level (% of body weight)					
Initial weight (g)	0	2	4	6	8	MEAN+SEM[1]
.555	30.4	30.5	29.4	29.5	30.3	30.02+.44
1013	33.4	33.5	32.8	33.0	32.6	33.1+.37
1423	34.2	34.1	34.2	33.5	34.0	34+.39
2079	33.0	32.8	33.6	34.0	32.3	33.1+.69
2450	32.6	33.2	33.6	33.3	32.7	33.1+.52
MEAN+SEM	32.7+.48	32.8+.49	32.7+.48	32.7+.47	32.4+.49	

[1]standard error of mean

TABLE 5. Estimated maintenance energy and feed needs as judged by body weight homeostasis of the 3, 5 and 7 week old broilers used in experiment 2

				Feed required for maintenance		Daily AMEn (kcal) need for maintenance	
Body weight, (g)	Age (weeks)	Equation[1]	R	(% body weight)	per day (g)	per day	per kg body weight
470	3	y=-.059367+.420777x	.99	4.66	21.9	70.11	141.09
1236	5	y=-.04257+.414035x	.97	3.18	39.27	125.69	102.82
2199	7	y=-.028401 +.387152x	.96	2.19	48.19	154.25	73.36

[1]Live weight gain per initial weight regressed on ration MEn consumption per initial weight.

TABLE 6. Maintenance nitrogen needs of 3, 5, and 7 week old broilers used in experiment 2

			Maintenance Nitrogen requirement (g)	
Body weight, (g)	Age (weeks)	Equation	per day	per kg body wt.
470	3	y=-.000459+.739071x, R=.98	.121	.621
1236	5	y=-.000286+.821237x, R=.96	.430	.348
2199	7	y=-.000232+.900907x, R=.98	1.36	.257

y=Nitrogen balance per body weight perday, g; x=Nitrogen intake per body weight, g/day

TABLE 7. Feed and nitrogen consumption, weight gain, feed efficiency ration digestibility coefficient and nitrogen balance for experiment 2 limit fed broilers.

	Age											
	3 weeks				5 weeks				7 weeks			
	Feed cons. x maintenance				Feed cons. x maintenance				Feed cons. x maintenance			
	0	.5	1	1.5	0	.5	1	1.5	0	.5	1	1.5
Feed cons. g/day	0^{d}	16.46^{c}	26.18^{b}	44.51^{a}	0^{d}	26.89^{c}	54.52^{b}	86.04^{a}	0^{d}	25.69^{c}	61.82^{b}	86.46^{a}
AME cons., kcal/day	0^{d}	43.71^{c}	73.95^{b}	123.01^{a}	0^{d}	69.38^{c}	166.8^{b}	256.41^{a}	0^{d}	71.96^{c}	188.86^{b}	265.48^{a}
Nitrogen intake, g/kg/day	0^{d}	$.99^{c}$	1.73^{b}	2.92^{a}	0^{d}	$.66^{c}$	1.36^{b}	1.92^{a}	0^{d}	$.38^{c}$	$.81^{b}$	1.16^{a}
g/day	0^{d}	$.49^{c}$	$.78^{b}$	1.32^{a}	0^{d}	$.81^{c}$	1.63^{b}	2.58^{a}	0^{d}	$.77^{c}$	1.78^{b}	2.59^{a}
Weight gain, g/day	-30.21^{d}	-9.79^{c}	1.64^{b}	25.95^{a}	-57.78^{d}	-21.57^{c}	13.91^{b}	54.92^{a}	-72.12^{d}	-28.62^{c}	9.73^{b}	38.55^{a}
Gain/Feed.	-	$-.64^{c}$	$.04^{b}$	$.67^{a}$	-	$-.91^{c}$	$.27^{b}$	$.71^{a}$	-	-1.37^{b}	$.17^{a}$	$.5^{a}$
Dig. Coef. (%)												
Apparent	-	54.48^{b}	59.19^{a}	58.46^{a}	-	52.29^{b}	67.16^{a}	64.94^{a}	-	58.16^{b}	66.29^{a}	66.87^{a}
True	-	68.16^{a}	67.78^{a}	63.53^{a}	-	65.31^{a}	73.62^{a}	68.99^{a}	-	70.91^{b}	74.89^{a}	73.09^{a}
Nitrogen balance, g/kg/day	$-.49^{d}$	$.31^{c}$	$.87^{b}$	1.66^{a}	$-.27^{d}$	$.19^{c}$	$.89^{b}$	1.33^{a}	$-.25^{d}$	$-.13^{c}$	$.53^{b}$	$.78^{a}$
g/day	$-.21^{d}$	$.16^{c}$	$.38^{b}$	$.75^{a}$	$-.34^{d}$	$.24^{c}$	1.07^{b}	1.73^{a}	$-.59^{d}$	$.27^{c}$	1.22^{b}	1.75^{a}

^{a,b,c}Means in a row within an age class followed by unlike superscripts are statistically different ($P < .05$)

TABLE 8. Grower ration feeding level (FL) effects on 3, 5 and 7 week broiler metabolizable energy intake (AMEC), nitrogen corrected metabolizable energy intake (MEnC), heat production (HP)[1], energy gain (EG)[2], protein gain (PG)[3], and lipid gain (LG)[4] andefficiency of energy use for AME (AME eff.)and AMEn (AMEn eff.) class

		AMEC	AMEnC	HP	EG	PG	LG		
Age (weeks)	FL (x m)	Kcal /kg / d				g / kg / d		AME eff.	AMEn eff
3	0	-	-	70.17	-86.5	-.19	-9.97	-	-
	.5	87.6	85.04	136.91	-53.12	4.9	-9.74	-.66	-.69
	1.0	163.89	156.75	170.91	-10.84	7.87	-6.91	-.01	-.01
	1.5	270.61	257.08	200.28	67.74	11.39	-.18	.25	.26
5	0	-	-	49.40	-59.08	-.64	-6.94	-	-
	.5	56.71	55.08	66.93	-11.48	2.39	-3.03	-.21	-.22
	1.0	138.51	131.18	93.38	44.09	5.8	-1.02	.32	.34
	1.5	197.87	186.91	117.38	79.64	8.75	3.57	.41	.43
7	0	-	-	20.86	-27.33	-.66	-2.69	-	-
	.5	35.12	34.08	38.87	-4.4	1.42	-1.51	-.03	-.04
	1.0	82.42	78.03	51.56	30.46	3.33	1.2	.37	.39
	1.5	119.7	112.72	75.1	43.39	4.9	1.59	.28	.39
Effects:									
Age		NS	NS	P< .001	NS	P< 01	P< .001	NS	NS
FL		P<.001	P < .001	P< .001	P< 001	P< 01	P< .001	P< 001	P< 001
Age x FL		NS	P < .001	P< .001	P<001	P< 01	P< .001	NS	P< 05

[1]HP=27.8683 NG+4.1529 CP+.0598 AMEC, [2] EG=-26.2798 NG+4.3953 CP+1.00083 AMEnC, [3]PG=.1457 CP+.8224 AMEnC
+.84025 AMEC, [4]LG=-.62484 CP-1.00614 AMEC+1.13929 AMEnC,

TABLE 9. CO_2 production[1] predictive equations for the 3, 5 and 7 week old broilers used in experiment 2.

Age (weeks)	Equation	R
3	.019786+.201466 (weight gain)	.89
5	.013731+.098728 (weight gain)	.81
7	.010937+.108209 (weight gain)	.86
3	.019392+.038412 (energy gain)	.37
5	.012892+.036818 (energy gain)	.6
7	.009874+.042734 (energy gain)	.62
3	.010395+.058263 (fat gain)+1.860379 (protein gain) +36.4998 ((fatgain)(protein gain))	.89
5	.010533+.143184 (fat gain)+.767517 (protein gain)	.81
7	.008606+.192124 (fat gain)+.77511 (protein gain)	.82

[1]liters per gram body weight per day, weight gain=g/body weight per day, fat gain=g per body weight per day, protein gain= g per body weight per day.

TABLE 10. Weight gain[1] , energy gain[2], protein gain[3], fat gain[4] , heat production (HP) [5] and CO_2[6] production predictive equations from MEn consumption (MEnC) for the 3, 5 and 7 week old broilers used in experiment 2.

Predicted variable	Age (weeks)	Equation	R
Weight gain[1]	3	-.059367+.420777 (MEnC)	.99
Weight gain[1]	5	-.04257+.414035 (MEnC)	.97
Weight gain[1]	7	-.028401+.387152 (MEnC)	.96
Energy gain[2]	3	-.022482+.456382 (MEnC)	.99
Energy gain[2]	5	-.030068+.574914 (MEnC)	.98
Energy gain[2]	7	-.024294+.547482 (MEnC)	.97
Protein gain[3]	3	-.001578+.04622 (MEnC)	.96
Protein gain[3]	5	-.000339+.042256 (MEnC)	.98
Protein gain[3]	7	-.000269+.045547 (MEnC)	.98
Fat gain[4]	3	-.00126+.018755 (MEnC)	.71
Fat gain[4]	5	-.003210+.036843 (MEnC)	.84
Fat gain[4]	7	-.00295+.032707 (MEnC)	.77
HP[5]	3	.019951+.5993 (MEnC)	.96
HP[5]	5	.029508+.424441 (MEnC)	.98
HP[5]	7	.023837+.448403 (MEnC)	.96
CO_2[6]	3	.008867+.034695 (MEnC)	.83
CO_2[6]	5	.009767+.047919 (MEnC)	.81
CO_2[6]	7	.007912+.090316 (MEnC)	.79

[1, 3, 4] grams per gram body weight per day, [2, 5] Kcal per gram body weight per day, [6] liters per gram body weight per day. MEnC=Nitrogen corrected metabolizable energy consumption, kcal/g body weight per day

Table 11. Characterstics of Experiment 2 broilers at body weight homeostasis[1]

	Age (weeks)		
Variable	3	5	7
Body weight,g	470	1236	2199
Weight gain,			
g / kg body wt.	0	0	0
g / d	0	0	0
Energy gain			
kcal / kg. body wt	41.91	9.04	15.87
kcal / d	19.65	35.90	34.90
Protein gain,			
g / kg. body wt.	4.94	4.01	3.07
g / d	2.32	4.95	6.76
Lipid gain,			
g / kg. body wt.	.76	.56	-.33
g / d	.36	.70	-.72
O_2 consumption,			
l/kg body wt./ d	16.19	17.28	17.10
l / d	7.61	21.36	37.61
CO_2 production,			
l / kg body wt./ d .	13.76	14.69	14.54
l / d	6.47	18.16	31.97
Maintenance energy,			
Kcal / kg body wt./ d	141.09	102.82	73.36
Kcal / d	66.31	127.09	161.32
HP,			
Kcal/ kg body wt./d	104.51	73.15	56.73
Kcal / d	49.12	90.43	124.80
HP / maintenance energy	.74	.71	.77

[1]values were derevied by regressing each variable against MEn consumption and solving for MEn consumption required for body weight homeostasis

Table 12. Characterstics of Experiment 2 broilers at tissue energy homeostasis[1]

	Age (weeks)		
Variable	3	5	7
Body weight,g	470	1236	2199
Energy gain			
kcal / kg. body wt	0	0	0
kcal / d	0	0	0
Weight gain,			
g / kg body wt.	-38.64	-20.92	-11.22
g / d	-18.16	-25.85	-24.68
Protein gain,			
g / kg. body wt.	.69	1.87	1.75
g / d	.33	2.31	3.85
Lipid gain,			
g / kg. body wt.	-.39	-.13	-.12
g / d	-.19	-1.61	-2.71
O_2 consumption,			
l/kg body wt./ d	12.45	14.44	14.02
l / d	5.85	17.85	30.84
CO_2 production,			
l / kg body wt./ d .	10.58	12.27	11.92
l / d	4.97	15.17	26.21
Maintenance energy,			
Kcal / kg body wt./ d	49.26	52.29	44.37
Kcal / d	23.15	64.63	97.57
HP,			
Kcal/ kg body wt./d	49.46	51.71	43.73
Kcal / d	23.24	63.91	96.17
HP / maintenance energy	1.00	.99	.99

[1]values were derevied by regressing each variable against MEn consumption and solving for MEn consumption required for tissue energy homeostasis

TABLE 13. Feed consumption effect on 3, 5 and 7 week old cobb x cobb broiler blood constituents

	Age (weeks)														
	3					5					7				
	(Feeding level x maintenance)														
	0	.5	1	1.5	SEM	0	.5	1	1.5	SEM	0	.5	1	1.5	SEM
Lact. mg/dl	34.00^{a}	29.10^{b}	25.01^{c}	20.02^{d}	3.0	35.82^{a}	33.83^{ab}	30.78^{ab}	26.10^{b}	2.8	31.35^{a}	28.63^{a}	24.81^{a}	1.21^{b}	2.1
Tg mg/dl	47.12^{a}	55.10^{b}	74.00^{c}	71.9^{c}	2.8	33.47^{a}	27.24^{a}	34.64^{bc}	38.07^{bc}	2.5	23.03^{a}	22.17^{a}	28.75^{a}	40.39^{b}	3.0
ALT,U/L	5.00^{a}	4.10^{b}	2.90^{c}	1.70^{d}	.60	6.63^{a}	1.96^{b}	1.99^{c}	1.59^{d}	.52	3.60^{a}	2.56^{b}	2.16^{b}	1.20^{b}	.30
Uric Acid, mg/d	3.9^{a}	3.12^{a}	2.50^{b}	2.12^{b}	.30	4.15^{a}	2.92^{ab}	2.38^{b}	2.36^{b}	.31	4.37^{a}	2.56^{b}	2.62^{b}	2.69^{b}	.40
TP, mg/dl	4.4	4.23	4.43	4.1	.81	4.06	3.8	3.54	3.03	1.1	3.54	3.1	3.39	3.57	1.9

a, b means followed with unlike superscripts are statistically different

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CHAPTER IV

AMBIENT TEMPERATURE DISTRESS, FEED CONSUMPTION AND AGE EFFECTS ON BROILER CARCASS COMPOSITION, HEAT PRODUCTION, SERUM CONSTITUENTS AND ENERGY AND NITROGEN REQUIREMENTS

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ABSTRACT : One experiment was conducted to study nutrient consumption level, age (3, 5, 7 weeks) and ambient temperature effects on broiler partitioning of consumed energy and nitrogen into maintenance and tissue accretion (protein, lipid) as well as on serum chemistries (lactate, triglyceride, glucose, total protein, uric acid, createnin, albumin, Ca, P, Na, K , Mg and Cl). Temperature impacted ($P<.05$) broiler nutrient consumption, weight gain , and feed efficiency, the effect being related to bird age-weight. Body lipid and protein deposition was impacted by ambient temperature bird weight and metabolizable energy consumption level. Lipid deposition linearly increased with energy consumption within temperature and age-weight class, but linearly decreased with increase in chamber temperature from 17 to 31 C. Protein deposition response to temperature was related to bird age-weight, showing linear increase with increase in temperature ($P >.05$) for the 3 week bird and quadratic response for the 5 and 7 week bird, increasing to 24 C and declining thereafter. Heat production linearly increased with increase in chamber temperature. Heat production response to level of energy consumption within temperature was related to bird weight and ambient temperature. Maintenance energy need of the 3 week bird decreased from 155 kcal/kg body weight at 17 C to 86 kcal /kg body weight at 31 C while that of the 5 and 7 week broiler showed quadratic trend, being lowest at 24 C than at 16 or 31 C. The actual values at 17, 24 and 31 C for the 5 week bird were 98, 96, and 108.5 kcal /kg and that of the 7 week bird 111, 72.5 and 145.43 kcal /kg body weight. The energy requirements for growth was not impacted by ambient temperature and averaged 2. 7, 2.7 and 2.8 kcal per gram for the 3, 5 and 7 week bird. Nitrogen retention increased

(P <. 01) with ME consumption and temperature (P > .05) for the 3 and 5 week bird. For the 7 week bird however nitrogen retention was higher at 24 C than at 16 or 31 C. Similarly, nitrogen efficiency was higher at 24 C than at 16 or 31 C for the 3 week broiler and at 24 and 31 than at 16 C for the 5 week broiler. Maximum nitrogen efficiency for the 7 week broiler was observed at 24 C. Broiler maintenance nitrogen need per kg body weight of the 3 and 5 week linearly decreased with increase in ambient temperature while the 7 week was lowest at 24 C. Serum uric acid, createnin, albumin, total protein, calcium, magnesium, phosphorus, sodium and chloride concentrations were not impacted by feed consumption level or ambient temperature while lactate and triglyceride values were influenced both by feed consumption (P <. 01) and ambient temperature (P<. 05). Furthermore the feed consumption level x temperature, feed consumption x age, and feed consumption x age x ambient temperature interaction on serum lactate values was significant (P < .05). The age x ambient temperature interaction on serum triglyceride was also significant (P <.01). Serum triglyceride of the 5 week broiler showed linear decrease with increase in temperature while uric acid of the 7 week bird showed the opposite trend, being positively correlated with temperature. Other serum variables remained unaltered by ambient temperature. No interaction between bird age-weight and temperature was also observed on serum analytes.

INTRODUCTION:

Earlier studies in general suggest that level of feed intake and ambient temperature have effect on broiler fat accretion. Thus when consumption of energy

exceeds the maintenance and growth requirement of the bird excess energy is efficiently converted to body carcass fat since the maintenance requirement of the bird becomes lower as food intake increases.

Heat production of an animal for a specific age is minimal at environmental temperature within the zone of thermonutrality and deviation of environmental temperature from this zone is accompanied by increased energy expenditure in the form of heat production for the purpose of maintaining body temperature and as a result less substrates will be available to be diverted to carcass fat and protein. Studies in general indicate that increased ambient temperature increases carcass fat, decreases the live weight gain and feed intake of broilers. Food utilization is improved until the point of heat stress when energy is required to reduce the heat load of the bird , e.g by panting (Howlider and Rose, 1987). However it is not possible to determine the exact temperature at which heat distress occurs because of the interaction of other factors such as relative humidity (Winn and Godfrey, 1967), diet composition (Dale and Fuller, 1980), stocking density (Charles et al. 1978).

Kubena et al. (1971) and Bray (1983) reported that at a moderate temperature the correlation between temperature and total body fat content is positive. Kleiber and Dougherty (1934) and Weinchester and Kleiber (1938) observed an increase in carcass fat of chicks and a concomitant decrease in moisture in moisture content as environmental temperature was increased. Similarly, Kubena et al. (1972) reported a significant decrease in carcass fat in response to decreasing ambient temperature. Over several experiments, Fisher (1984) found a linear increase of 0.195 g total body fat per degree increase in temperature between 10 and 30 C. Perrault and Leeson (1992) observed higher fat but lower protein content in broiler chicks reared at 15.5 than at 23.9 C. On the contrary, Adams et al. (1962) reported that there is no significant difference in fat or moisture content of birds reared at 21.1 or 29.4 C. Washburn (1986) also compared the effect of 70, 80 and 90 F using broiler chicken from 4 to 7

weeks of age and reported no difference in weight of abdominal adipose tissue of the birds subjected to the different ambient temperature. Howlider and Rose (1987) reported that there is no relationship between the protein content of the carcass and ambient temperature. Available data as well as theoretical consideration, indicate that environmental temperature also affects heat production of broilers. Deaton et al. (1969), Reece and Lott, (1981), Van Kampen, (1981) and Chwalibog and Eggum, (1989) observed that the sensible heat output of broilers is inversely related to ambient temperature.

Available information suggests that the effect of ambient temperature, age (body weight) and feeding level and their interaction on metabolic rate of broilers and partitioning of feed nutrients into carcass fat and protein is a subject requiring further investigation. Likewise work is needed to define heat dissipation limitations of birds consuming various feed increments.

The objectives of the experiment discussed herein are: To define age (3, 5, 7 weeks), grower ration feeding level (0, 1 x, 2 x, 3 x maintenance) and ambient temperature exposure (17, 24 and 31 C) effects on male Cobb x Cobb broiler partitioning of feed nutrients into carcass fat and protein and heat production, and to estimate the effect of ambient temperature on the 3, 5, and 7 week broiler energy and nitrogen requirement for maintenance and growth as well as blood chemistries.

Materials and Methods:

HOUSING: Cobb x Cobb day old chicks (male) were acquired at 15 day intervals and reared in floor pens with starter ration (3200 K Cal ME/Kg, 23 % CP) access to 3 weeks of age. At 21, 35 and 49 days 12 birds from each age group were selected at random , intramuscularly injected with ketamine HCL (40 mg/Kg of body weight) to achieve anistetic induction and surgically fitted with body temperature transmitter (Mini

Mitter Telemetry System, Sunriver, Oregon 97707). During the following three day recovery and housing adjustment period birds were placed in individual open circuit respiratory chambers (51 x 34 x 41 cm) maintained at 24C in three separate rooms and fed the basal ration (Table1). Details of the respiratory chamber construction and operation are discussed elsewhere by Wiernusz and Teeter (1993). During the adjustment period birds were allowed to consume the basal ration containing Chromic oxide (0.1%) as a digestibility marker.

EXPERIMENTAL: Immediately following surgical recovery birds were fasted overnight, weighed and randomly assigned to feeding levels estimated from a previous experiment at 0, 1, 2 and 3 x the maintenance energy requirement. During the following three days chamber temperature was maintained at 24 C in one room and at 17 and 31 C in the other two rooms. Ferric oxide was added (0.3 %) to the test ration to identify experimental excreta and birds were limit fed six times daily for three days. The chambers were continuously monitored for name variables and data recorded by the Workhorse Data Acquisition and Control System (Omega Engineering, Stanford, Ct 06907) as described by Belay and Teeter (1993). On the fourth day ferric oxide was removed while limit feeding continued. Excreta was collected in fecal trays. Blood samples were collected via wing puncture, serum separated and analyzed for lactate (lact), triglyceride (trig), glucose (Glu), total protein (Tp), uric acid, createnin (crea), albumin (alb) Mg, Ca, P, Na, Cl, and K. using Cobas Mira Wet Chemistry Analyzer . Feed intake, water consumption, body weight change, body temperature, Oxygen consumption, and CO_2 production were monitored. At the end of the experiment body weight was recorded and birds were sacrificed by servical dislocation and whole carcass frozen for laboratory analysis. Excreta was dried to constant weight at 155 F allowed to equilibrate with atmospheric air, ground to pass through 1mm screen and stored in ziploc bag for lab analysis. Whole carcass was autoclaved overnight, weight

recorded, ground uniformly, mixed and representative sample taken for tissue dry matter, nitrogen, energy and carbon analysis. Feed, excreta and respiratory gases were analyzed for C and N to determine C and N balance. The procedure involved combusting tissue, feed and excreta samples in a bomb calorimeter under 30 atm O2, recording gross energy, and analyzing the vapor for CO2. Tissue, feed and fecal nitrogen was determined using Kjeltec Auto Analyzer (Kjeltec auto 1030 analyzer). Carbon gained was estimated using the following equation: CG=FC-EXC-((CO2/22.4) *44*.272727) where CG=grams carbon gained, FC=carbon in feed, EXC=excreta carbon and CO2=liters CO2 produced. Tissue protein gain was calculated as grams nitrogen gained times 6.18 and energy stored as protein as tissue protein gain times 5.7. Carbon stored as protein was estimated by dividing protein gained by .52, the carbon in protein. Fat carbon gained was obtained as the difference between carbon gained and protein carbon gained. Grams fat gained was then obtained by dividing fat carbon gained by .767 which is the carbon content of fat. Fat energy gain was obtained as grams fat gained times 9.13. Heat production (Kcal/mbwt/hr) was estimated as a difference between consumed metabolizable energy and energy gain.

STATISTICAL: Polynomial equations were developed by regressing Oxygen, CO_2 and body temperature against time (t) , t^2 and t^3. Estimates of broiler CO_2 production were obtained by integrating CO_2 function over specified time intervals and adjusting for the control chamber. Statistical analysis of the data was carried out via ANOVA following the general linear models procedure (SAS, 1982). Estimates of maintenance energy requirement for each age class of broiler at each ambient temperature were estimated from a second order regressing model by regrssing body weight gain per initial weight on MEn consumption per initial weight. Energy requirements for growth were obtained by regressing broiler MEn consumption on live weight gain. Similarly,

other response variables including lipid gain (LG), protein gain (PG), energy gain (EG), heat production (HP) and nitrogen requirement were arrived at by regression analysis.

RESULTS AND DISCUSSION

Energy consumption, feed efficiency and growth rate:

Energy consumption of the three week bird was not impacted by temperature (Table 4) while that of the 5 an 7 week bird was severely limited at 31 C . It decreased linearly with increase in temperature from 24 to 31 C. High temperature impacted feed intake of the 7 week bird most and the 3 week least (Table 4), indicating the adverse effect of high ambient temperature distress on feed consumption of broilers is related to bird body weight. The decline in feed consumption at high temperature might help reduce heat load of the bird due to lowered metabolic rate. Water intake increased linearly with increase in temperature for each age-weight group. Feed efficiency of the 3 week chick increased with temperature whilethat of the 5 and 7 week declined as temperatuere increased from 17 to 31 C. (Table 3). The decline in feed efficiency of the 5 and 7 week broiler at 24 and 31 C suggests that the thermo neutral zone fot these age groups might be lower than 24 C and the bird expended extra energy to dissipate excess heat from the body when the ambient temperature reached 24 and 31 C.

Averaged over ME consumption levels, weight gain of the three week bird linearly increased with chamber temperature while that of the 5 and 7 week was quadratic, being higher at 24 C and lower at 17 and 31 C. Body weight gain linearly increased ($P < .001$) with ME consumption at 17 and 24 C but at 31 C, except for the

3 and 5 week bird, no relation was observed between body weight gain and ME consumption of the 7 week bird . Significant ($P < .05$) ME by ambient interaction was observed on body weight gain.

Energy requirement for growth and maintenance:

Broiler energy requirements for body weight maintenance and growth at the three ambient temperatures are given in Tables 6a and 6b while the response surface in Figure 1 dipicts the relationship between maintenance energy need (kcal/kg body weight), ambient temperature and broiler weight. The relationship between maintenance enrgy need, ambient temperature and broiler weight is given by the equation:

$y=605.9251-32.9359\ t + .577918\ t^2 -178.81\ w + 30.962245\ w^2 + 3.34018\ tw$ R=.85

where y= maintenance energy need (kcal/ kg body weight), t=temperature (C), w= body weight (g)

Maintenance energy need of the 3 week bird decreased from 155 kcal/kg body weight at 17 C to 86 kcal /kg body weight at 31 C 1 while that of the 5 and 7 week broiler showed quadratic trend, being lowest at 24 C than at 16 or 31 C. The actual values at 17, 24 and 31 C for the 5 week bird were 97.66, 67, and 108.5 kcal /kg and that of the 7 week bird 111, 72.5 and 145.43 kcal /kg body weight. The energy requirements for growth did not appear to be impacted either by ambient temperature or bird age / weight and averaged 2. 7, 2.7 and 2.8 kcal per gram for the 3, 5 and 7 week bird. The

lack of difference in energy requirement for growth between the three age groups suggests constant body composition or tissue protein to fat ratio

.Tissue energy gain:

Temperature, age-body weight and energy consumption all impacted ($P < .05$) tissue energy gain (Table 5) . At each temperature for each age class, although tissue energy gain was linearly related ($P < .05$) with ME consumption, significant ($P < .05$) age or body weight by temperature interaction was noted (Table 5) on energy gain. Energy gain linearly decreased with temperature. For the 3 week bird, maximum energy gain was obtained at 17 C (where lipid gain was highest and protein gain was lowest) while for the 5 and 7 week it was highest at 24 and 17 C respectively and lowest at 31 C.

Tissue lipid and protein gain:

The relationship between lipid gain ambient temperature and broiler weight is showen in figure 2 while protein gain relation with ambient temperature and broiler weight is given in Figure 3. Literature suggests that ambient temperature alters carcass composition partly by impacting nutrient consumption and partly by changing the animal's response through other as yet unclear mechanism. In the present study both lipid and protein deposition were impacted by temperature ($P < .05$), bird weight ($P < .05$) and metabolizable energy consumption ($P < .001$). The 3 week old broiler lipid gain decreased as temperature increased from 17 to 31 C while its tissue protein

gain showed the opposite trend. Similarly the 5 and 7 week old lipid gain linearly decreased with increase in chamber temperature while non-lipid gain, showed an increasing trend with temperature increase. The correlation between ambient temperature and fat deposition was negative (r= -.3) at P < .05 while that between ambient temperature and protein deposition was positive (r= .28) at P > .5 In all cases the age by feed consumption level interaction on lipid and non lipid or protein gain was significant

(P < .05). Kubena et al (1972), Olsen et al (1972) and Perrault and Leeson (1992) reported leaner birds at 13, and 18.3 and 15.5 C respectively than at higher temperatures while Mickelberry et al. (1966) observed no significant difference in the fat content of chicks reared at 21 or 29 C. Reduced fat accretion relative to energy consumed would mean less available energy for production after the demands for maintenance have been met since the latter has priority. The reduced fat accretion recorded in the present study with increasing ambient temperature is matched with a simultaneous increase in heat production to explain the above phenomenon. Duration of exposure to temperature stress might also influence results since unlike in the present study where birds were subjected to the treatment temperatures for 3 days, most of the earlier studies dealing with effect of environmental temperature on carcass composition were conducted with the birds being exposed to the treatment temperature throughout the rearing period.

Swan and Farrel (1975) reported that with increasing environmental temperature carcass protein deposition was not affected. Similarly Howlider and Rose

(1987) reported no relation ship between carcass protein content and rearing temperature. Our observation in the present study that protein deposition increased with ambient temperature is in agreement with that of Perrault and Leeson (1992) who reported higher protein accretion in broiler chicks reared at 23.9 than at 15.5 C

Heat production:

Within age-weight class, in the range of temperature and nutrient consumption level investigated, heat production in general increased with fed consumption level and ambient temperature. The correlation between ambient temperature and heat production was positive (r=.48) and significant ($P < .001$). For each age group the relationship between ME consumption and heat production was dependent on ambient temperature. At 17 C, the 3, 5 and 7 week broiler, heat production curvilenearly increased throughout the range of ME consumption. Heat production of all age-weight groups at 24 C increased up to 2X maintenance feed consumption after which it showed a declining trend. Heat production of the 3 week bird at 31 C declined with ME consumption above maintenance while that of the 5 week remained unchanged and that of the 7 week increased curvilenearly. The correlation between broiler age and heat production per unit body weight was negative (r= -.53) and significant at $P < .001$.

Nitrogen balance, efficency and requirement for growth and maintenance:.

Nitrogen retention (g nitrogen gained per kg body weight) increased

(P <. 01) with ME consumption and temperature (P > .05) for the 3 and 5 week broiler (Table 3). For the 7 week bird however nitrogen retention was higher at 24 C than at 17 or 31 C. Similarly, nitrogen efficiency (Table 10) expressed as gram nitrogen gained per gram nitrogen consumed was higher at 24 C than at 17 or 31 C for the 3 and 5 week broiler. Maximum nitrogen efficiency for the 7 week broiler was observed at 31 C. Figure 4 shows the relationship between ambient temperature, broiler weight and maintenance nitrogen requirement and is given by the equation:

$$y=4667.92396-213.766\ t + 2.996508\ t^2 - 2104.15137\ w + 234.3289\ w^2 + 46.41316\ tw \quad R= .9$$

where y=maintenance nitrogen need, mg/kg body wt., t=temperature (c), and w=body weight (g)

Broiler maintenance nitrogen need per kg body weight of the 3 and 5 week bird shown as the regression equation intercept in Table 10 linearly decreased with increase in ambient temperature while the 7 week broiler maintenance nitrogen need was lowest at 24 C. This was further supported by our observation that endogenous nitrogen excretion regardless of age-weight was highest for birds exposed to cold stress than those for thermonuteral or heat stress. Nitrogen requirement for nitrogen gain, the slope coefficient of the regression line (Table 10) was not impacted by ambient temperature or bird age or weight.

Serum metabolite concentration:

Mean serum chemistry values generated from the study are presented in Tables 11a-11d. Serum uric acid, createnin, albumin, total protein, calcium, magnesium, phosphorus, sodium and chloride concentrations were not impacted by feed consumption level or ambient temperature while lactate and triglyceride values were influenced both by feed consumption ($P < .01$) and ambient temperature ($P < .05$). Furthermore the feed consumption level x temperature, feed consumption x age, and feed consumption x age x ambient temperature interaction on serum lactate values was significant at the 1, 5 and 5 percent of probability respectively. The age x ambient temperature interaction on serum triglyceride was significant ($P < .01$). Triglyceride of the 5 week broiler showed linear decrease with increase in temperature while uric acid of the 7 week bird showed the opposite trend, being positively correlated with temperature. Other serum variables remained unaltered by ambient temperature. No interaction between bird age-weight and temperature was also observed on serum analytes.

TABLE 1.Composition of grower rations used in the study

Ingredient	% of diet
Ground corn	61.00
Soybean meal	30.00
Animal fat	4.64
Dicalcium phosphate (22% Ca, 18% P)	1.95
Limestone (38% Ca)	1.35
Salt	.45
Vitamin mix[1]	.26
Trace mineral mix[2]	.10
DL-Methionine	.25
Calculated analysis	
ME, kcal/kg	3201
CP	20.1
Lysine	1.08
Methionine+cystin	.89
Ca	1.09
P, available	.49

[1] The vitamin mix supplied 9900 IU vitamin A, 2750 IU cholecalciferol, 33 IU vitamin E, 11 mg vitamin B_{12} , 6.6 mg riboflavin, 44 mg niacin, 11 mg d-pantothenic acid, 449.4 mg choline, 3.3 mg menadione, 1.1 mg folic acid, 3.96 mg pyridoxine, 1.98 mgthiamin, .11 mg d-biotin

[2] The mineral mix supplied 160 mg Ca, 100 mg Zn, 120 mg Mn, 75 mg Fe, 10 mg, 2.5 mg

TABLE 2. Ambient temperature (T) and feed consumption level effect (FL)on weight gain of the 3, 5, and 7 week old broiler

		Age (Weeks)												
		3			5			7						
		T (C)									Interaction effect			
Variable	FL	17	24	31	17	24	31	17	24	31	Age x T	Age x Fl	T x Fl	Age x T x Fl
BWT, Kg	0	.48	.46	.47	1.2	1.13	1.15	2.05	2.29	2.09				
	1.0	.54	.5	.5	1.17	1.23	1.21	1.97	2.16	2.29				
	2.0	.53	.45	.47	1.07	1.26	1.24	2.18	2.29	2.25				
	3.0	.55	.57	.43	1.45	1.25	1.2	2.1	2.38	2.25				
	SEM	.07	.08	.03	.24	.15	.05	.35	.22	.31				
Feed, g / d	0.0	0	0	0	0	0	0	0	0	0	NS	P < .001	NS	NS
	1.0	27.48^{b}	25.73^{c}	39.73^{b}	48.95^{c}	44.2^{c}	43.55^{b}	46.33^{c}	54.13^{c}	20.05^{b}				
	2.0	46.25^{b}	48.92^{b}	47.98^{a}	99.78^{b}	91.06^{b}	93.04^{a}	110.18^{b}	115.07^{b}	109.9^{a}				
	3.0	84.27^{a}	87.5^{a}	64.86a	154.53^{a}	127.64^{a}	109.01^{a}	161.97^{a}	154.46^{a}	120.64^{a}				
	SEM	9.64	3.38	14.43	7.13	9.7	2.89	21.6	4.17	57.58				
WG, g/d	0.0	-30.63^{c}	-31.53^{c}	-27.17^{c}	-71.62^{b}	-43.69^{b}	-38.89^{b}	-97.75^{b}	-108.1	-32.59^{a}	NS	NS	P < .05	NS
	1.0	.9^{b}	-3.^{c}	15.12^{b}	4.10^{b}	17.51^{a}	4.2^{b}	-34.53^{b}	13.66^{b}	-89.49^{a}				
	2.0	12.01^{b}	28.13^{b}	34.53^{a}	42.19^{a}	43.09^{a}	25.45^{a}	55.55^{a}	41.59^{a}	-30.63^{a}				
	3.0	41.89^{a}	37.84^{a}	30.93^{a}	66.07^{a}	61.86^{a}	20.0^{a}	39.79^{a}	39.64^{a}	-46.25^{a}				
	SEM	19.12	8.68	6.94	26.71	17.44	18.99	23.97	18.07^{a}	57.58				

^{a,b,c}Means in a column followed by unlike superscripts are statistically different (P < .05)

TABLE 3. Ambient temperature (T) and feed consumption level effect (FL) on feed and nitrogen (N) efficency of the 3, 5, and 7 week old broiler

		Age (Weeks)												
		3			5			7						
		T (C)									Interaction effect			
Variable	FL	17	24	31	17	24	31	17	24	31	Age x T	Age x Fl	T x Fl	Age x T x Fl
Gain / Feed	0.0	-	-	-	-	-	-	-	-	-	p < .01	p < .001	p < .01	p < .001
	1.0	.03[a]	-.13[b]	.38[b]	-.19[b]	.4[a]	.1[a]	-.74[b]	.25[a]	-4.41[a]				
	2.0	.26[a]	.58[a]	.72[a]	.42[a]	.47[a]	.27[a]	.50[a]	.36[a]	-.28[a]				
	3.0	.5[a]	.43[a]	.48[b]	.43[a]	.48[a]	.18[a]	.26[a]	.26[a]	-.38[a]				
	SEM	.26	.09	.05	.28	.27	.18	.24	.16	.22				
N efficency	0.0	-	-	-	-	-	-	-	-	-	NS	NS	NS	NS
	1.0	.47[a]	.37[b]	.63[a]	.42[a]	.68[a]	.48[a]	.51[a]	.65[b]	.39[b]				
	2.0	.37[a]	.62[a]	.69[a]	.5[a]	.64[a]	.65[a]	.62[a]	.78[a]	.76[a]				
	3.0	.5[a]	.45[a]	.52[b]	.53[a]	.66[a]	.23[a]	.47[a]	.68[b]	.65[a]				
	SEM	.11	.06	.09	.22	.04	.07	.06	.10	.16				

[a,b,c]Means in a column followed by unlike superscripts are statistically different (P < .05)

TABLE 4. Ambient temperature (T) and feed consumption level effect (FL) on protein (PG), and lipid gain (LG) of the 3, 5, and 7 week old broiler

		Age (Weeks)												
		3			5			7						
		T (C)									Interaction effect			
Variable	FL	17	24	31	17	24	31	17	24	31	Age x T	Age x Fl	T x Fl	Age x T x Fl
ME, Kcal//kg	0.0	-	-	-	-	-	-	-	-	-	NS	p < .05	NS	NS
	1.0	148.05^{c}	148.5^{c}	232.69^{c}	107.75^{c}	107.39^{c}	118.58^{c}	68.4^{c}	73.87^{c}	20.89^{c}				
	2.0	218.23^{b}	322.52^{b}	296.45^{b}	256.24^{b}	208.73^{b}	266.9^{ba}	150.46^{b}	153.86^{b}	147.05^{b}				
	3.0	430.76^{a}	434.64^{a}	371.92^{a}	306.8^{a}	292.01^{a}	300.10^{a}	203.6^{a}	199.33^{a}	160.06^{a}				
	SEM	35.7	24.08	77.22	109.6	17.22	14.06	3.87	14.03	10.88				
PG, g / kg	0.0	-5.96^{c}	-5.02^{c}	-2.45^{c}	-2.23^{b}	-2.88^{c}	-1.37^{c}	-1.48^{b}	-.58^{c}	-2.13^{c}	NS	p < .05	NS	NS
	1.0	5.35^{b}	4.22^{b}	10.94^{b}	-4.01^{b}	5.49^{c}	3.92^{b}	2.69^{b}	3.67^{b}	.73^{b}				
	2.0	7.09^{b}	15.2^{a}	15.99^{a}	-17.42^{a}	10.45^{b}	11.09^{a}	6.98^{a}	8.74^{a}	8.35^{a}				
	3.0	17.28^{a}	17.49^{a}	17.54a	12.8^{a}	15.09^{a}	18.1^{a}	7.57^{a}	9.88^{a}	7.47^{a}				
	SEM	2.54	1.28	4.85	1.54	1.2	1.46	.44	.58	.21				
LG, g/kg	0.0	-21.33^{c}	--31.2^{c}	-19.96^{c}	-9.24^{c}	-12.19^{d}	--19.97^{b}	-3.86^{b}	-6.34^{d}	-11.72^{b}	NS	p < .05	NS	NS
	1.0	4.47^{b}	.17^{c}	-.93^{c}	.73^{b}	1.42^{c}	--9.31^{b}	-1.05^{b}	.88^{c}	-4.47^{a}				
	2.0	9.71^{b}	10.59^{b}	6.52^{b}	37.10^{a}	9.42^{b}	--5.21^{a}	11.65^{a}	5.18^{b}	6.8^{a}				
	3.0	35.66^{a}	24.9^{a}	25.99^{a}	28.13^{a}	20.81^{a}	-7.3^{a}	15.67^{a}	14.51^{a}	8.48^{a}				
	SEM	8.77	10.81	10.7	10.75	2.91	5.78	2.36	2.76	2.63				

^{a,b,c}Means in a column followed by unlike superscripts are statistically different (P < .05)

TABLE 5. Ambient temperature (T) and feed consumpti level (FL) effect on tissue carbon (C) , and energy gain (E) and heat prodtion (HP) of the 3, 5, and 7 week old broiler

		Age (Weeks)											
		3			5			7					
		T (C)									Interaction effi		
Variable	FL	17	24	31	1	24	31	17	24	31	Age x T	Age x Fl	T x	Age x T x Fl
C , g / kg	0.0	-19.73^{d}	-26.89^{b}	-16.66^{c}	-8^{b}	-10.99^{d}	-16.25^{c}	-3.78^{c}	-5.23^{d}	-10.23^{b}	NS	P < .01	NS	NS
	1.0	6.3^{c}	2.37^{b}	5.09^{c}	1^{c}	4.02^{c}	-5.16^{c}	.61^{b}	2.63^{c}	-3.09^{b}				
	2.0	11.4^{b}	16.28^{a}	13.54^{b}	19	12.85^{b}	9.93^{b}	12.75^{a}	8.66^{b}	9.71^{a}				
	3.0	36.86^{a}	28.62^{a}	29.48^{a}	28^{a}	24.16^{a}	12.00^{a}	16.18^{a}	16.51^{a}	10.83^{a}				
	SEM	7.99	6.83	10.23	2	2.93	4.22	1.86	.91	1.2				
E, kcal / kg	0.0	-109.99^{d}	-126.04^{d}	-93.15^{c}	-12^{c}	-146.29^{d}	-224.52^{c}	-95.06^{b}	-142.54^{d}	-206.9^{b}	P < .05	P < .01	NS	NS
	1.0	43.40^{c}	15.18^{c}	32.66^{c}	2^{b}	57.73^{c}	-80.94^{c}	13.58^{b}	60.93^{c}	-85.74^{b}				
	2.0	81.64^{b}	82.17^{b}	69.65^{b}	31^{a}	189.86^{b}	134.74^{b}	23.53^{a}	223.16^{b}	249.89^{a}				
	3.0	236.91^{a}	188.5^{a}	146.59^{a}	48^{a}	355.75^{a}	101.34^{a}	405.26^{a}	445.24^{a}	276.96^{a}				
	SEM	57.44	33.22	58.39	5	58.28	66.28	70.7	34.65	8.31				
HP, kcal / kg	0.0	14.02^{c}	162.18^{b}	206.84^{c}	18^{b}	90.13^{c}	407.0	184.06^{b}	316.91^{b}	304.7^{a}	NS	NS	NS	NS
	1.0	56.66^{b}	175.82^{a}	293.68^{a}	33^{b}	200.17^{b}	565.94^{a}	247.5^{a}	458.27^{a}	356.1^{a}				
	2.0	64.96^{ab}	242.78^{a}	343.87^{a}	46^{ab}	264.88^{b}	737.98^{a}	208.81^{a}	592.52^{a}	452.3^{a}				
	3.0	121.34^{a}	273.94^{a}	333.06^{b}	58^{a}	292.52^{a}	690.0^{a}	262.99^{a}	527.34^{a}	166.5^{a}				
	SEM	12.33	68.3	33.98	5	22..01	23.36	14.58	15.97	14.35				

^{a,b,c}Means in a column followed by unlike superscripts are statistically erent (P < .05)

TABLE.6a Predictive equations used to estimate energy requirement for body weight maintenance of the 3, 5 and 7 week old broiler under cold thermoneutral and hot environment

Age (weeks)	Body weight (g)	Temp (C)	Equation	R	Maintenence energy (kcal/kg bwt)	Expt. 1 Maintenence energy stimates (kcal/kg bwt)
3	523	17	$y= -.052626+.44125\ x-.351129\ x^2$	.89	155.0	
	480	24	$y= -.056239+.490237\ x-.449203\ x^2$	.95	130.0	140.0
	473	31	$y= -.052567+.697999\ x- 1.023351\ x^2$	.98	86.0	
5	1250	17	$y= -.049907+.598201\ x-.892491x^2$	.93	98.0	
	1219	24	$y= -.02511+.292954\ x-.31635\ x^2$	.91	96.0	103.7
	1207	31	$y= -.028169+.280756\ x-.194609\ x^2$	.81	108.0	
7	2051	17	$y= -.024196-.192711\ x+2.469106\ x^2$	.88	111.0	
	2278	24	$y= -.039655+.689562\ x-1.956818x^2$	.92	72.5	72.2
	2096	31	$y= -.045998+.507523\ x-.839676\ x^2$	.91	145.43	

y= Body weight gain per initial weight per day, x=MEn consumption, Kcal / g body weight / day
[1] Calculated from the regression line relating MEn consumption to weight gain

TABLE.6b Predictive equations used to estimate energy requirement for growth of the 3, 5 and 7 week old broiler under cold thermoneutral and hot environment

Age (weeks)	Body weight (g)	Temp (C)	Equation	R	Energy requirement for growth (kcal/g bwt)
3	523	17	y= .166493+2.664173 x	.88	2.66
	480	24	y=.167329+2.76896 x	.94	2.77
	473	31	y=.125363+2.508053 x	.98	2.51
5	1250	17	y=.123545+2.390314 x	.91	2.39
	1219	24	y=.097049+2.937879 x	.87	2.94
	1207	31	y= .121212+2.809959 x	.81	2.81
7	2051	17	y=.120193+2.421568 x	.9	2.42
	2278	24	y=.107962+2.550631 x	.82	2.55
	2096	31	y=.10372+3.431074 x	.84	2.43

y= MEn consumption, Kcal / g body weight / day, x= Body weight gain per initial weight per day

TABLE. 7 Predictive equations and predicted values for lipid gain and energy needed to form lipid in the 3, 5 and 7 week broilers under cold thermoneutral and hot environment

Age (weeks)	Body weight (g)	Temp (C)	Equation	R	ME / g lipid (Kcal)
3	523	17	y=125.685182+4.804071 x	.94	4.8
	480	24	y=166.08496+4.60006 x	.89	4.6
	473	31	y=151.984655+5.657202 x	.91	5.66
5	1250	17	y=76.381001+6.805387 x	.99	6.8
	1219	24	y=79.85628+5.80955 x	.95	5.81
	1207	31	y=109.887562+3.901256 x	.86	3.9
7	2051	17	y=48.993414+6.482417 x	.93	6.42
	2278	24	y=53.152825+6.5177 x	.96	6.51
	2096	31	y=62.952728 x+5.422695 x.	.97	5.4

[1]Energy required to form a gram of lipid
y=Energy gain as lipid, kcal / kg body weight / day
x= Lipid gain, g / kg body weight / day

TABLE. 8 Predictive equations and predicted values for tissue protein gain and energy needed to form protein in the 3, 5 and 7 week broilers under cold thermoneutral and hot environment

Age (weeks)	Body weight (g)	Temp (C)	Equation	R	ME / g protein[1] (Kcal)
3	523	17	$y=7.105427^{-15}+5.7\ x$	1	5.7
	480	24	$y=5.7\ x$	1	5.7
	473	31	$y=1.4210857^{-14}+5.7\ x$	1	5.7
5	1250	17	$y=1.4210857^{-14}+5.7\ x$	1	5.7
	1219	24	$Y=2.84217^{-14}+5.7\ x$	1	5.7
	1207	31	$Y=7.105427^{-15}+5.7\ x$	1	5.7
7	2051	17	$y=-3.55271^{-15}+5.7x$	1	5.7
	2278	24	$y=-.265713+5.0473x$	1	5.05
	2096	31	$y=5.7\ x$	1	5.7

[1]Energy required to form a gram of protein
X= Protein gain, g / kg body weight / day
y= Energy gain as protein , kcal / kg body weight / day

TABLE. 9 Predicted weight gains and efficiency of ME use for weight of the 3, 5 and 7 week broilers under cold thermoneutral and hot environment

Age (weeks)	Body weight (g)	Temp (C)	Equation	R	Gain / kcal
3	523	17	y=-50.4956+.289 x	.88	.29
	480	24	y=-57.3622+.3188 x	.94	.32
	473	31	y=-45.37+.3168 x	.92	.32
5	1250	17	y=-46.8689+.341 x	.9	.34
	1219	24	y=-23.4712+.2584 x	.9	.26
	1207	31	y=-30.3843+.2355 x	.81	.24
7	2051	17	y=-46.8625+.3344 x	.9	.33
	2278	24	y=-30.1155+.2269 x	.8	.23
	2096	31	y=-28.1845+.1139 x	.4	.11

y= Body weight gain, g / kg body weight / day
x= Metabolizable energy consumption kcal / kg body weight / day

TABLE. 10 Broiler nitrogen requirement for maintenance and nitrogen gain of the 3, 5 and 7 week broilers under cold thermoneutral and hot environment

Age (weeks)	Body weight (g)	Temp (C)	Equation	R	Maintenance N (g/kg bwt.)	N efficency
3	523	17	y=.001241+1.437805 x	.97	1.24	.69
	480	24	y=.000997+1.322728 x	.99	.99	.76
	473	31	y=..000499+1.375985 x	.97	.50	.73
5	1250	17	y=.000602+1.505838 x	.94	.60	.66
	1219	24	y=.000438+1.255712 x	.98	.44	.79
	1207	31	y=.000433+1.26147 x	.97	.43	.79
7	2051	17	y=.000278+1.667789 x	.96	.28	.60
	2278	24	y=.000032644+1.239448 x	.85	.03	.81
	2096	31	y=.000856+1.678948 x	.58	.86	.60

y= Nitrogen intake, g /g body weight / day
x= Tissue nitrogen gain, g / g body weight / day

TABLE. 10b. Broiler nitrogen requirement (mg N/g protein) for protein accretion of the 3, 5 and week broilers under cold thermoneutral and hot environment

Age (weeks)	Body weight (g)	Temp (C)	Equation	R	N per gram protein gain
3	523	17	y=.001241+1.437805 x	.97	230
	480	24	y=.000997+1.322728 x	.99	211.6
	473	31	y=..000499+1.375985 x	.97	220.2
5	1250	17	y=.000602+1.505838 x	.94	240.9
	1219	24	y=.000438+1.255712 x	.98	200.9
	1207	31	y=.000433+1.26147 x	.97	200.8
7	2051	17	y=.000278+1.667789 x	.96	266.84
	2278	24	y=.000032644+1.239448 x	.85	198.31
	2096	31	y=.000856+1.678948 x	.58	268.6

y= Nitrogen intake, g /g body weight / day
x= Tissue nitrogen gain, g / g body weight / day

TABLE.11 Regression relation between ME consumption and heat production (HP) of the 3, 5 and 7 week broilers under cold thermoneutral and hot environment

Age (weeks)	Body weight (kg)	Temp (C)	Equation	R
				.22
3	523	17	y=117.99-.11x	
	480	24	y=236.98-.24x	.52
				.79
	473	31	y=230.27-.184x	
				.26
5	1250	17	y=78.43-.047x	
				.69
	1219	24	y=112.47-.199x	
				.15
	1207	31	y=201.25-.042x	
				.4
7	2051	17	y=30.74+.069x	
				.26
	2278	24	y=56.47+.046x	
				.45
	2096	31	y=107.34-.136x	

y= Heat production, kcal / kg body weight / day
x= Metabolizable energy consumption, kcal / kg body weight / day

TABLE 12a. Ambient temperature (T) and feed consumption level effect (FL) on serum uric acid (Uric), triglyceride (Trig) and lactate (Lact) of the 3, 5 and 7 week oldbroiler

		Age (Weeks)												
		3			5			7						
		T (C)									Interaction effect			
Variable	FL	17	24	31	17	24	31	17	24	31	Age x T	Age x Fl	T x Fl	Age x T x Fl
Uric, mg / dl	0.0	6.19	5.67	7.66^{a}	6.38	5.47^{c}	5.2	4.47	3.38^{bc}	7.56	P < .05	NS	NS	NS
	1.0	7.49	8.39	5.79^{b}	5.65	4.2^{b}	6.79	3.83	4.75^{b}	9.11				
	2.0	8.14	6.37	3.79^{c}	5.28	4.84^{b}	5.89	4.83	6.18^{ab}	5.84				
	3.0	8.51	5.9	3.4^{c}	8.37	7.29^{a}	6.00	5.39	7.29^{a}	5.4				
	SEM	2.97	1.26	.46	2.56	.3	.41	1.08	.50	2.3				
Lact, mg / dl	0.0	11.5	27.5	44.00	57.00	20.5^{c}	26.5	43.00	17.0^{b}	31.00^{b}	P < .05	P < .05	P < .05	P < .05
	1.0	34.00	35.00	62.67	50.67	40.0^{a}	35.5	37.33	35.5^{a}	77.00^{a}				
	2.0	70.5	62.67	40.5	29.00	35.0^{ab}	35.00	20.00	39.5^{a}	22.00^{b}				
	3.0	63.5	24.00	27.00	42.00	31.5^{b}	32.00	19.00	25.5^{a}	19.5^{b}				
	SEM	14.19	17.7	11.98	22.2	2.2	11.99	15.12	3.64	7.31				
Trig, mg / dl	0.0	69.00^{b}	59.5^{b}	67.00	64.00	61.00	94.00	65.00	67.00^{b}	98.00	NS	P < .05	NS	NS
	1.0	102.00^{a}	100.0^{a}	106.67	36.00	103.00	156.00	64.00	78.5^{b}	58.00				
	2.0	105.0^{a}	91.7^{a}	79.00	82.00	104.00	123.67	66.00	94.0^{a}	145.00				
	3.0	96.00^{a}	98.0^{a}	68.00	75.00	149.5	130.11	94.5	98.00^{a}	63				
	SEM	29.03	3.64	7.96	33.98	18.23	28.53	16.98	10.11	21.0				

^{a,b,c}Means in a column followed by unlike superscripts are statistically different (P < .05)

TABLE 12b. Ambient temperature (T) and feed consumption level (FL) effect on serum glucose (Gluc), albumin (Alb) and creatnin (Crea) of the 3, 5 and 7 week old broiler

		Age (Weeks)												
		3			5			7						
		T (C)									Interaction effect			
Variable	FL	17	24	31	17	24	31	17	24	31	Age x T	Age x Fl	T x Fl	Age x T x Fl
TP, g / dl	0.0	3.29	3.8	3.69	3.87	3.88	3.52	3.59	3.7	4.06	NS	NS	NS	NS
	1.0	3.81	3.71	3.19	2.11	3.71	2.87	3.01	4.01	2.99				
	2.0	3.69	3.97	3.19	3.96	3.54	3.43	3.48	3.98	3.91				
	3.0	3.69	3.76	3.61	3.1	3.37	3.50	3.73	3.79	3.63				
	SEM	.48	.34	.40	1.52	.30	.20	1.60	.27	.53				
Alb, mg / dl	0.0	1.21	1.58[a]	1.3	1.13	1.45	1.45[b]	1.56	1.21	1.37	NS	NS	NS	NS
	1.0	1.99	1.37[ab]	1.25	1.20	1.33	1.68[a]	1.22	1.46	1.42				
	2.0	1.32	1.29[b]	1.30	1.41	1.21	1.23[c]	1.28	1.29	1.22				
	3.0	1.34	1.2[b]	1.27	1.13	1.18	1.30	1.25	1.48	1.42				
	SEM	.33	.04	.11	.4	.08	.03	.37	.02	.11				
Crea, mg / dl	0.0	.13	.15	.15	.15	.14	.22	.14	.17	.19	NS	NS	NS	NS
	1.0	.25	.16	.12	.12	.19	.34	.18	.12	.17				
	2.0	.09	.12	.11	.13	.15	.14	.19	.16	.14				
	3.0	.07	.1	.18	.18	.13	.21	.18	.15	.17				
	SEM	.17	.02	.01	.14	.04	.02	.07	.02	.02				

[a,b,c]Means in a column followed by unlike superscripts are statistically different ($P < .05$)

TABLE 12c. Ambient temperature (T) and feed consumption level (FL) effect on serum total protein (TP), Calcium and phosphorus of the 3, 5 and 7 week old broiler

		Age (Weeks)												
		3			5			7						
		T (C)									Interaction effect			
Variable	FL	17	24	31	17	24	31	17	24	31	Age x T	Age x Fl	T x Fl	Age x T x Fl
K, mg /dl	0.0	8.7	7.91	6.31	8.12	7.80	8.1	8.20	5.90[b]	6.3	NS	NS	NS	NS
	1.0	10.5	9.00	7.66	7.65	6.98	6.94	6.31	6.71ab	7.5				
	2.0	8.41	9.32	6.99	8.34	7.77	8.0	7.30	7.97[a]	8.0				
	3.0	9.91	7.88	9.21	7.11	9.07	7.99	8.10	7.45[a]	8.10				
	SEM	.29	.45	.5	.42	.33	.43	.28	.30	35				
Ca, mg / dl	0.0	6.61	7.97	9.20	8.69	7.14	7.15	9.79	8.10	8.34	NS	NS	NS	NS
	1.0	8.1	10.00	8.43	5.58	8.31	8.10	7.49	8.40	7.91				
	2.0	9.17	10.59	8.06	9.99	7.86	7.79	6.22	9.54	7.25				
	3.0	10.00	10.15	9.41	8.16	8.35	8.23	7.73	6.58	8.45				
	SEM	1.02	.84	1.39	3.38	1.11	.60	1.39	.63	8.67				
P, mg / dl	0.0	6.00	8.19	9.58	9.11	8.51	8.72	4.42	6.72[b]	7.54	NS	NS	NS	NS
	1.0	13.31	10.94	9.59	5.86	9.68	8.49	8.37	8.41[a]	7.49				
	2.0	9.78	12.2	9.19	11.11	8.31	8.53	8.39	8.73[a]	8.79				
	3.0	7.51	9.22	8.39	7.89	9.49	9.00	7.76	6.68[b]	8.00				
	SEM	3.42	1.39	1.62	3.59	1.63	1.33	3.57	.39	3.12				

[a,b,c]Means in a column followed by unlike superscripts are statistically different (P < .05)

TABLE 12d. Ambient temperature (T) and feed consumption level (FL) effect on serum Chloride, Magnesium and and Sodium of the 3, 5 and 7 week old broiler

		Age (Weeks)												
		3			5			7						
		T (C)									Interaction effect			
Variable	FL	17	24	31	17	24	31	17	24	31	Age x T	Age x Fl	T x Fl	Age x T x Fl
Na, mmol / l	0.0	153.5	151.00	157.50	155.5	154.5[a]	152.0	167.00	157.00	155.50	NS	NS	NS	NS
	1.0	152.00	153.00	151.3	100.00	155.3[ab]	150.5	147.50	159.5	166.00				
	2.0	159.00	157.3	152.00	160.00	142.5[a]	149.25	159.00	160.5	155.00				
	3.0	152.5	155.00	151.00	146.00	148.0[b]	151.11	153.50	158.00	155.50				
	SEM	2.98	2.71	6.73	58.34	3.58	6.65	8.07	5.23	3.94				
Cl, mmol / l	0.0	113.00	110.00[a]	116.00	115.50	115.5	106.5	119.5	114.00	114.00	NS	NS	NS	NS
	1.0	108.5	114.0[ab]	113.00	73.3	115.00	114.0	120.33	121.00	122.00				
	2.0	117.5	117.3[a]	115.50	120.00	109.00	113.0	113.00	123.00	112.00				
	3.0	106.00	118.00[a]	114.00	102.00	115.00	112.12	111.00	122.00	121.00				
	SEM	4.78	1.52	4.07	42.67	3.81	4.77	9.69	5.81	8.1				
Mg, mg / dl	0.0	2.61	2.08	2.33	2.10	2.01	1.89	2.20	2.23	2.04	NS	NS	NS	NS
	1.0	2.43	2.45	2.17	1.19	1.97	2.2	1.97	1.94	2.09				
	2.0	2.25	2.5	2.24	2.15	1.98	1.82	1.82	2.07	2.12				
	3.0	2.61	2.21	2.45	2.10	1.93	2.01	1.98	2.06	1.94				
	SEM	.23	.14	.24	.7	.12	.23	.29	.20	1.47				

[a,b,c]Means in a column followed by unlike superscripts are statistically different ($P < .05$)

Table 13. Some correlation coeeficients between variables studied in the experiment

	with	R	P
Crea	HP	.71	< .001
Crea	Temp	.56	< .05
Crea	Energy gain	-.5	< .05
Crea	Fat gain	-.55	< .05
Lact	Age	-.3	< .05
Mg	Age	-.35	< .01
Trig	Temp	.26	< .05
P	Age	.31	< .01
P	HP	-.34	< .01
Fat gain	HP	-.58	< .001
Fat gain	Temp	-.3	< .05
HP	Age	-.53	< . 001

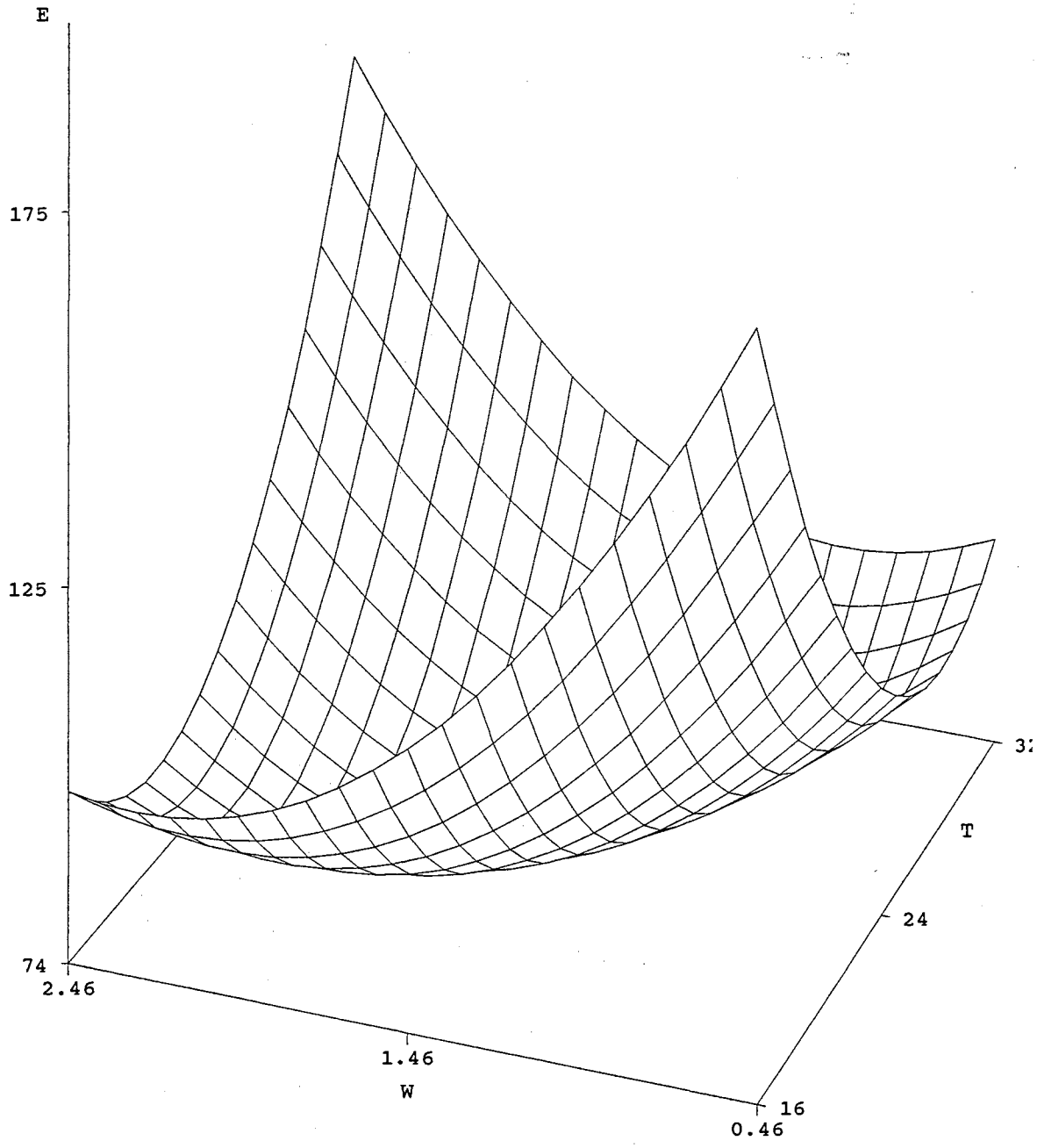
P=phosphorus, Mg=magnesium,
Crea=createnin, Trig=triglyceride, Lact=lactate
HP=heat production per kg body weight
Temp= tempearature

Table 14. Characterstics of broilers under differetambient temperature at b[illegible]ody weight homeostasis[1]

	Age (weeks)								
	3 Temp (C)			5 Temp (C)			7 Temp (C)		
Variable	17	24	[illegible]	17	24	[illegible]31	17	24	31
Body weight,g	.48	.46	[illegible]7	1.2	1.13	[illegible]1.15	2.05	2.29	2.09
Weight gain,									
g / kg body wt.	0	0	[illegible]	0	0	[illegible]0	0	0	0
Energy gain									
kcal / kg. body wt	-25.85	-141.8	[illegible]71.7	15.05	-33.93	[illegible]-59.27	-22.59	-10.5	-21.5
kcal / d	-12.41	-65.23	[illegible]0.69	18.05	-38.34	[illegible]-68.16	-46.32	-24.12	-45.02
Protein gain,									
g / kg. body wt.	3.19	3.02	[illegible]92	2.95	2.01	[illegible]4.58	4.08	3.33	6.83
g / d	1.53	1.39	[illegible]87	3.54	2.27	[illegible]5.26	8.36	7.64	14.3
Lipid gain,									
g / kg. body wt.	-3.29	-17.1	[illegible]0.25	-.19	-4.88	[illegible]-9.18	-4.93	-.89	1.87
g / d	-1.58	-7.82	[illegible]52	-.23	-5.52	[illegible]-10.55	-10.11	-2.03	-3.9

[1]values were derevied by regressing each variablegainst MEn consumption

Figure 1. Broiler maintenance energy requirement (kcal/ kg body wt.) as influenced by ambient temperature (T, C) and body weight (W, kg)



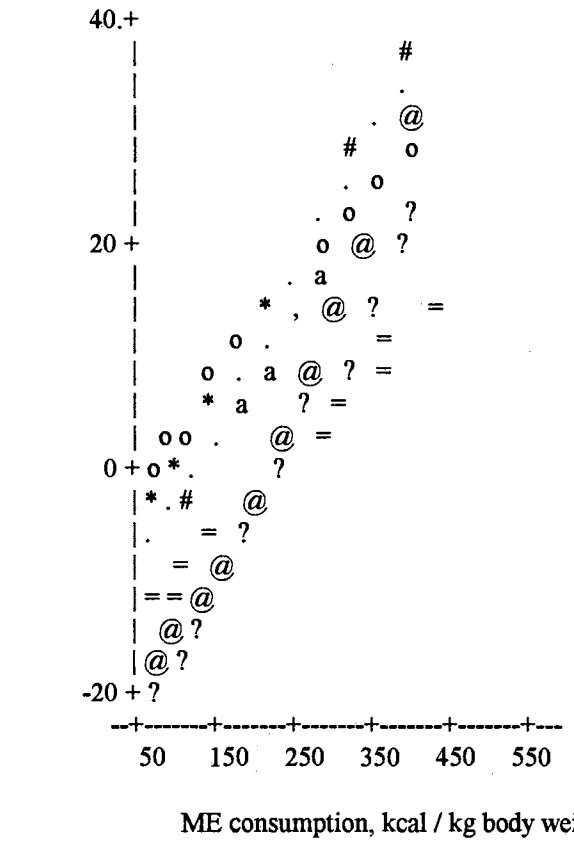


Figure 2. The relationship between lipid deposition (y) and ME consumption (x), of the 3, 5, and 7 week broiler at 17, 24 and 31 C ambient temperature exposure. (...=3 wk broiler at 16 C: y=-9.9786+.0898 x, @=3 wk broiler at 24 C y=-23.51086+.10736 x, ?=3 wk broiler at 32 C: y=-24.149+.096257 x, *=5 wk broiler at 16 C y=-7.54525+.08549 x, #=5 wk broiler at 24 C: y=-11.225574+.09604 x, = =5 wk broiler at 32 C: y=-15.32381+.0569 x, o=7 wk broiler at 16 C: y=-2.0649+.0630178 x, '=7 wk broiler at 24 C: y=-6.05927+.071356 x, a=7 wk broiler at 32 C: y=-9.20029+.0761 x

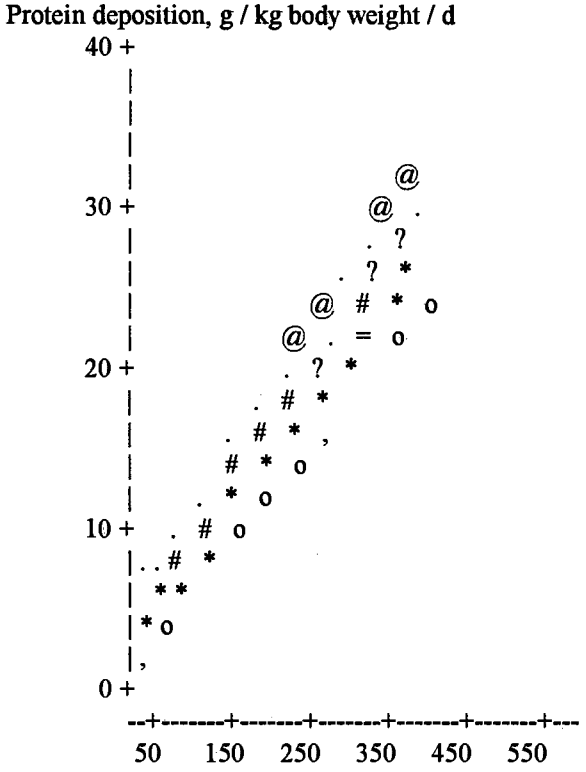
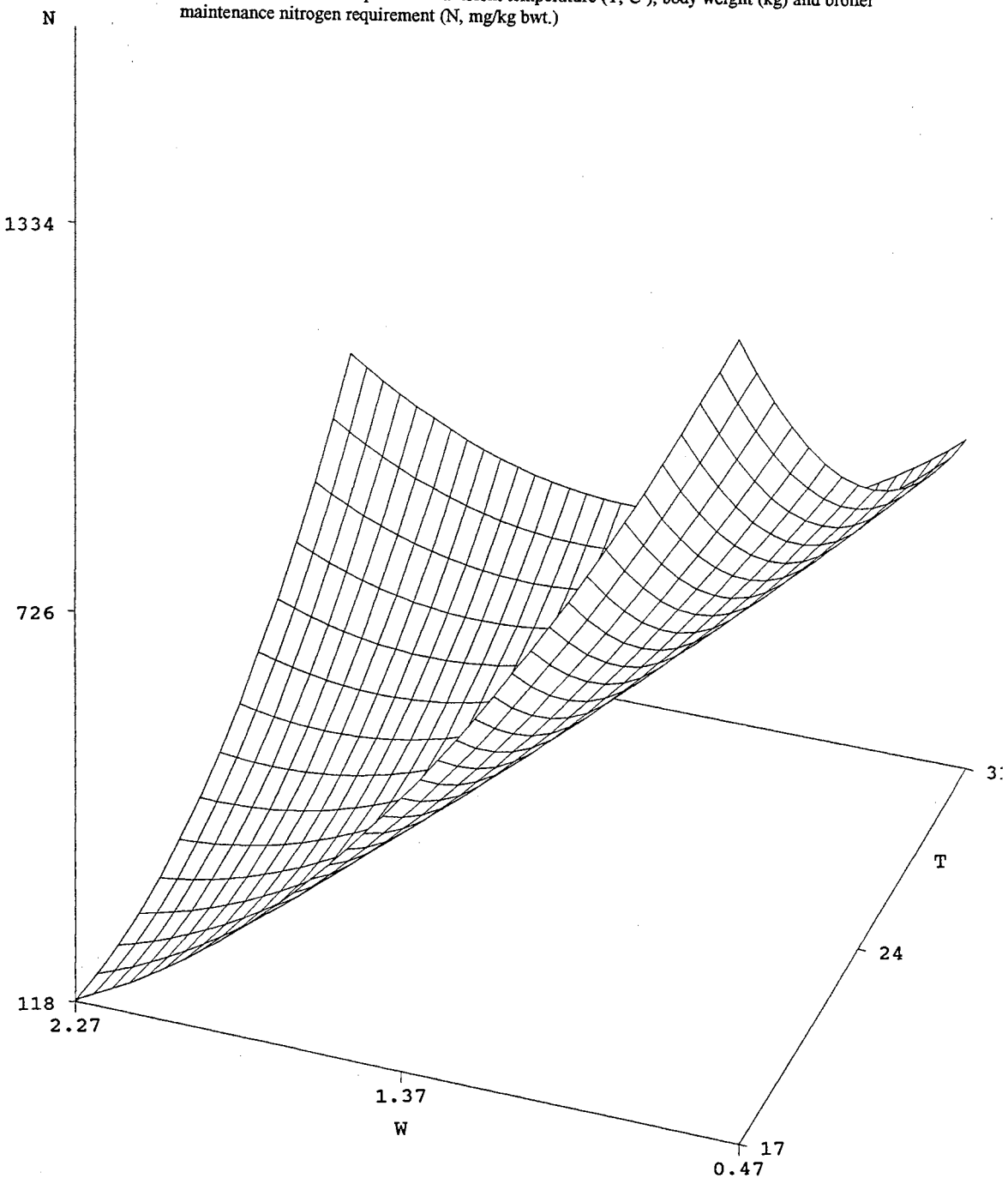


Figure 3. The relationship between protein deposition (y) ,and ME consumption (x), of the 3, 5, and 7 week broiler at 17, 24 and 31 C ambient temperature exposure. (..=3 wk broiler at 16 C: y=-4.775306+.0514 x,@=3 wk broiler at 24 C y=-4.244265+.05588 x, ?=3 wk broiler at 32 C: y=-1.738287+.05425 x, *=5 wk broiler at 16 C y=-1.695183+.04735 x, #=5 wk broiler at 24 C: y=-1.77354+.057386 x, = =5 wk broiler at 32 C: y=-1.173088+.053244 x, o=7 wk broiler at 16 C y=-1.011765+.04588 x, '=7 wk broiler at 24 C: y=-05964+.04677 x, a=7 wk broiler at 32 C: y=--1.5866+.057849 x

Figure 4. The relationship between ambient temperature (T, C°), body weight (kg) and broiler maintenance nitrogen requirement (N, mg/kg bwt.)



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