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EFFECT OF SEASON ON THE METABOLIZABLE ENERGY REQUIREMENT FOR BROILER GROWTH, CARCASS YIELD AND CARCASS COMPOSITION

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ABSTRACT

Two experiments were conducted at The University of Tennessee, Knoxville, poultry farm to evaluate effects of high and low ambient temperatures on the metabolizable energy requirement for broiler growth, carcass quality and carcass composition. The first experiment was conducted in July through September, while the second experiment was conducted in December through February, as these two seasons represent the two temperature extremes prevalent in the southeastern part of the United States.

Both experiments employed a 23% crude protein corn soybean diet with the following dietary energy levels: 2880, 3040, 3200, 3360 and 3520 kcal ME/kg diet. Diets were fed to color-sexable Shaver chicks from 1 day of age until an average treatment live body weight of 2.05 kg was achieved.

In experiment 1, a total of 330 day-old color-sexable chicks were utilized. Eleven male and eleven female chicks were randomly allotted to each experimental group. Results obtained indicated a linear response of both gain and feed efficiency to dietary energy level at 28 and 49 days of age. Abdominal fat pad expressed as percentage of live weight increased in males and females as dietary energy level increased. Abdominal fat pad increased in females approximately 8.42% for every 5% increase in metabolizable energy, and 36.04% for every 5%, or more specifically, 160 kcal ME/kg diet in males.

In experiment 2, increasing dietary energy level improved ($P < .0001$) feed efficiency. Both dietary energy level and sex significantly ($P < .0001$) affected live weight gain. Abdominal fat pad weight was also significantly affected by dietary energy level ($P < .0001$) and by sex ($P < .001$). Chickens fed the low energy diets contained approximately 57% less abdominal fat content than those fed high energy diets. Females contained an average of 20% more abdominal fat than males.

Season had a marked effect on broiler performance. For example, it required 57 days for birds fed the 2880 kcal ME/kg diet to achieve an average live weight of 2.05 kg during the summer, but only 49 days during the winter. In general, these results indicate that 3200 kcal ME/kg diet is adequate during both summer and winter seasons. Although higher dietary energy levels resulted in heavier body weights, the high cost of these high fat diets would probably make such a feeding system not feasible.

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CHAPTER I

INTRODUCTION

In the United States, and most parts of the world, there has been a substantial increase in poultry consumption over recent years. The United States Department of Agriculture (U.S.D.A.) reported that in 1984, 16,088 million pounds of poultry meat was produced in the U.S. In 1985, production went up 5% and 6% in 1986. It has been estimated that production went up 6% or 7% in 1987.

Consumers' preference for cut-up broiler parts has also increased. More than 70% of birds are grown for cutting up and approximately 20% of these for further processing. This trend necessitates further research on factors affecting yield of broiler parts, and the relationship between feed intake, carcass weight and its individual parts expressed as percentage of carcass. Carcass parts include the drumstick, thigh, back, wing, giblets, abdominal fat pad and breast. Breast constitutes approximately 33% of whole carcass weight, has the highest percent edible meat (meat:bone ratio), and is the most valuable part of the carcass.

Some of the major challenges facing the poultry industry today are increasing breast yield, decreasing fat pad size, producing leaner, more disease resistant, more efficient and more rapidly growing birds. The genetic make-up of present bird is different from that 10 years ago. Age to market weight has dropped 100% over the past 50 years (from 1934-84) from 95 days to 49 days; feed conversion improved from 4.3 kg feed per kg gain to 1.96 kg feed per kg gain; 49-day body weight has also increased from 1.3 kg to 1.9 kg, mortality rate has improved from 13.0 to 4.5% and even higher performances are expected in the next few years.

Most U.S. broilers are grown in the South where hot summer and cool winter conditions are prevalent. High environmental temperatures induce heat stress in broilers. This results in panting to dissipate excess body heat to the environment. Heat stress not only reduces growth rate but also increases flock heterogeneity. In recognition of this fact, it has become a common recommendation to feed nutrient dense diets in the summer, less dense in the winter, but there are few sound data to support these recommendations. In fact, there is very little information on optimum dietary energy level where both carcass quality and ambient temperature are included as variables.

Therefore, studies were conducted in both summer and winter, using five levels of dietary metabolizable energy, to better determine effects of high or low ambient temperature on the metabolizable energy requirement for optimum growth, carcass quality and carcass composition of broilers.

CHAPTER II

LITERATURE REVIEW

Effects of Temperature on Feed Intake, Feed Utilization and Growth Rate

There is a deleterious effect of high environmental temperature on broiler performance. As environmental temperature increases, growth rate and feed consumption decrease (Dale and Fuller, 1980; Hurwitz et al., 1980; Deaton et al., 1978; Sinurat and Balnave, 1985; McNaughton et al., 1982; Smith and Teeter, 1987; Charles et al., 1981).

As a result of these facts, it became a common industrial practice to feed nutrient dense diets during periods of heat stress to alleviate problems of reduced feed intake by broilers. Nutrient dense diets contain higher dietary levels of essential nutrients such as amino acids relatively to energy. Such nutrient dense diets are formulated by lowering the amount of supplemental fat without lowering the level of protein, vitamins or minerals. However, Dale and Fuller (1980) found that 5 to 7 week old chickens grew more rapidly when fed either a high-fat or a high-fat, high-density diet when housed in either a constant low or constant high temperature. That they observed no diet x temperature interaction is contrary to common industrial practice. When chickens were housed under a hot environment cycled diurnally, as would occur under natural conditions, it was found that growth depression due to heat was less in chickens fed a high fat diet (Dale and Fuller, 1980). Consequently, their results suggest that during periods of heat stress, a high energy diet may improve performance.

It is also known that environmental temperature plays an important role in regulating thyroid activity. Magisood and Reineke (1950) observed in a study with mice that metabolic rate was higher during low temperature than high temperature. This affects thyroxine production, which in turn controls and regulates metabolic rate. High environmental temperature decreased thyroid size while low environmental temperature increased it. Huston and Carmon (1962) reported that birds reared at constant high temperature had smaller thyroids than birds exposed to a fluctuating or cycled temperature similar to natural summer conditions. Results obtained from this study suggest a practical limitation in applying research results obtained under laboratory settings (i.e., constant temperature) to field condition (i.e., cyclic temperature).

Smith and Teeter (1987) studied the influence of feed intake and ambient temperature stress on relative yield of broiler parts. Growth rate, feed efficiency, dressing percentage and yield of edible parts were optimized at 23.9°C. It was also observed that feed intake was increased by 25% and decreased by 10% as ambient temperature was decreased 7.2°C or increased to 35°C, respectively. Abdominal fat content was directly proportional to feed intake.

Research has shown optimum temperature for broiler growth between the ages of 4-5 weeks to be 20°C (Barrot and Pringle, 1950).

Other studies estimated about 21-23°C and that any deviation may result in depressed growth rate (Deaton et al., 1973b; Smith and Teeter, 1987). Optimum temperature for maximum growth of broilers differs with age. Chicks, of course, require higher temperatures than older chickens. In 1982, Wathes et al. compared eight brooding temperatures and found that 31°C for the first week followed by 27°C through 21 days of age supported optimum growth and feed efficiency. However, there is variability among research results regarding optimum temperature, but such research recommendations serve as useful guidelines for producers. Current temperature recommendations are:

Age (Day)	Temperature (C)
1-7	32
8-14	27
15-21	24
22-28	24
>28	21

Fisher (1984) observed a linear increase of 0.19% of body fat content for every one degree increase in temperature ranging between 10°C and 30°C. Rose and Michie (1987) reported that food intake, food conversion ratio and breast yield as a percentage of body weight were decreased as temperature increased, but found no difference in growth rate of turkeys aged 10-15 weeks of age kept at four constant temperatures--14, 17, 20 and 23°C. It was also observed that as ambient temperature increased by 1°C, feed intake and conversion ratio decreased by 1.2% and 0.6%, respectively. Growth rate was not significantly affected by temperature, but turkeys reared at higher temperature tended to have lower growth rate. However, body weight gain, feed intake and feed conversion increased with increasing protein concentration, but yield of eviscerated carcass, breast meat and dark meat (meat from leg, thigh and wing) were not altered. Eviscerated carcass weight, abdominal fat and total meat yield were not altered by environmental temperature. High temperature was believed to have reduced percentage breast meat and increased percentage dark meat, thus decreasing breast:dark meat ratio. Data obtained from this study suggest that high temperature may promote flock heterogeneity. A possible reason for the poor breast meat yield could be due to reduced feed intake during high temperature, hence a reduction in dietary protein consumed. There is a possibility that decreased protein consumption affected breast meat protein synthesis differently from dark meat protein synthesis. It was also demonstrated that regardless of the temperature examined, turkeys had improved body weight gain as the dietary protein concentration increased, although best gains occurred at temperatures near those generally considered ideal for maximum growth. Results further indicated that more feed was consumed at low temperature than high temperature, and the increased feed consumption increased breast meat proportion. The economic value of breast meat is currently twice that of dark meat, hence an increase in the return per kg of meat produced.

The study carried out by Deaton et al. (1978) further elucidated the effect of temperature on broiler performance. Four temperature treatments were compared; three constant temperatures and a 24-hour cyclic regime ranging from 23.9 to 35 to 23.9. It was found that average body weight of males and females reared at the lower constant temperature did not differ from males and females reared at 21.1°C. However, average body weight gain of female broilers reared at 15.6°C was greater than their counterparts at 10°C. The amount of feed required to produce a unit of gain (feed conversion) increased as temperature decreased. At 8 weeks of age, feed conversion was higher for those reared under the cyclic temperature regime as would occur in summer months than birds reared under constant high temperature (21.1°C).

A number of studies have indicated that inclusion of a certain percentage of plant or animal fat may help to reduce the effect of high temperature on feed intake (Mickelberry et al., 1966). Chickens at 3-7 weeks of age grew more rapidly when environmental temperature was kept at 15.6°C and fed a diet containing 3375 kcal ME/kg of diet compared to feeding 3250 kcal ME/kg of diet at the same environmental temperature. An additional increase in body weight gain was not obtained by increasing dietary energy level from 3250 kcal ME/kg diet to 3500 kcal ME/kg of diet when reared at 10°C. However, these investigators observed no difference among broiler females reared under 10, 15.6 or 21.2°C temperature and fed 3250 kcal ME/kg of diet. Broiler males fed 3250 kcal ME/kg of diet and reared in either 21.1°C or 26.7°C environment were larger than those kept at 10°C environment. Feed utilization was found to be the same for broilers reared in 15.6°C and fed 3375 kcal ME/kg of diet as compared to broilers kept in 21.1°C and fed 3250 kcal ME/kg (McNaughton and Reece, 1982). These data support the general rule of thumb that, as environmental temperature increases, the energy requirement for maintenance decreases. It also demonstrates the possibility of substituting dietary energy for fuel cost since broilers fed a high dietary energy diet and kept in lower temperatures performed equally as well as those fed lower energy diets at higher environmental temperatures. Every 1°C drop in temperature may lead to an additional requirement of .09 or .08 kcal ME per gram of diet (Olson et al., 1972). The upper critical temperature of broilers above 1.5 kg body weight was estimated to be 28°C (Anthony, 1981; Meltzer, 1983; Charles, 1981; Berman and Sapir, 1965). Others estimated a wider range of 19-24°C for the final temperature (Deaton et al., 1968, 1972, 1978; Smith and Teeter, 1987; Huston, 1965).

Another important question is whether the depressed growth rate associated with high ambient temperature is entirely due to reduced feed intake, or are other factors responsible. Cowan and Michie (1978) reported that altering nutrient density at a constant high temperature did not alleviate depressed growth rate, even though equally fed broilers housed under high or low temperatures performed differently. This suggests that the depressed growth rate observed in broilers reared at a high temperature is not entirely due to environmental temperature effects on feed intake but that other factors are involved.

Effects of Genotype, Sex and Photoperiod on Protein and Lipid Synthesis

Abdominal fat pad deposition is also affected by genetic factors. Geneticists have proven that abdominal fat pad size may be reduced through intensive selection for leanness, which results in a higher metabolizable energy requirement for maintenance (LeClercq and Saadoun, 1982). Work by Robbins (1981) showed that a heavy breed (Hubbard) tended to retain 15% more dietary energy than a light breed counterpart (New Hampshire). There is also a sex-related effect on growth rate and nutrient utilization. Robbins (1981) found that body fat content of males increased as dietary energy level increased. This occurred when dietary crude protein increased in direct proportion with dietary energy (constant calorie:protein ratio) and when dietary energy level was increased in isonitrogenous diets (variable calorie:protein ratio). At a constant calorie:protein ratio, body fat content of females was unaffected by energy concentration. No increase in body fat content of females was observed as dietary energy level increases in isonitrogenous diets. These results, therefore, demonstrated that body fat content of males is dependent on energy level and not calorie:protein ratio whereas females tended to be strictly dependent on calorie:protein ratio. There is tendency for males to consume more feed than females but deposit less fat (Robbins, 1981). This is due to the fact that males grow faster than females, thus excess energy consumed by males may be offset by their rapid growth rate. Other mechanisms involved in fat deposition are not yet fully understood. Until these mechanisms are known, there will continue to be a need to manually remove the fat pad from broilers at processing plants. Even though it adds to yield produced, it is perceived as waste by consumers.

The response to photoperiod has also been studied. Robbins et al. (1984) demonstrated that females kept at 16 hours of light:8 hours of dark (16L:8D) consumed more, grew less, and had less percent body fat than females kept under constant light. Studies indicate that the shorter photoperiod reduced energy utilization in females. By contrast males reared at 16L:8D consumed less feed and grew less rapidly than males under at constant light. The effect of photoperiod was more noticeable in females because depressed growth rate observed in males was strictly due to reduced feed intake, but in females was due to reduced energy utilization. In formulating diets for broilers, it is extremely important to take these factors, both environmental and genetic, into consideration since they play an important role in metabolizable energy requirement and utilization, as well as overall body composition of broilers.

Fat Supplementation and Beneficial Effects on Growth Rate and Feed Utilization

Most poultry feed in the United States consists primarily of corn and soybean meal which do not furnish adequate amounts of energy. For this reason considerable quantities of fats are used in poultry feed, primarily as a potent source of energy. Fat contains 2 to 3 times the energy contained in grains and approximately 3 to 8% fat can be incorporated into diets to increase energy level.

Supplemental fats such as corn oil enhance appearance, texture and flavor of feed. Fat also supplies essential fatty acids, primarily linoleic. However, a high percentage of fat requires a dietary antioxidant to prevent rancidity which may decrease diet palatibility. Rancidity may also destroy labile essential nutrients such as vitamins.

Abdominal Fat Pad Vs. Total Body Fat

Excess abdominal fat is undesirable, but it is understood that a certain percentage of body fat is desirable because it tends to improve flavor and palatibility and thus increases overall meat quality. Yoshida and Morimoto (1970) indicated that at least 0.9% of the live broiler weight should be in the form of fat in order to support and maintain life. The amount of fat that can be deposited depends primarily on dietary energy intake. It is also believed that nutrition may affect abdominal fat pad more than total body fat (Jackson et al., 1982). On the average, fat constitutes approximately 3% of the live body weight of broilers. The amount of energy required to synthesize one gram of fat is equivalent to that required for one gram of protein tissue synthesis (Pullar and Webster, 1977), but decreases feed conversion rate. Protein deposition is accompanied by 75% water whereas fat deposition displaces water. Therefore, as broilers convert feed into protein tissue rather than adipose tissue, a higher amount of gain is expected and thus a better feed conversion. Fat has been shown to be the most variable component of the broiler's body (Lohman, 1973).

Percentage moisture decreases with age, whereas percentage fat increases with age.

The coefficient of variation of abdominal fat is almost double that of total body fat. Becker et al. (1979) indicated that abdominal fat pad tends to vary among birds far more than fat deposition inter- and intra-muscularly. These results indicate that the total body fat content may be reduced progressively by reducing abdominal fat pad size. As previously mentioned, the weight of the abdominal fat pad is more easily reduced by nutritional means than inter- and intra-muscular fat.

Effect of Calorie:Protein Ratio on Growth Rate, Protein and Fat Retention and Synthesis

Obesity occurs when caloric intake exceeds what is required for lean body mass synthesis and maintenance. It has been suggested that wide calorie:protein ratios promote lipid deposition due to the fact that birds will overconsume diets low in protein or amino acids. It has been demonstrated that rations high in energy tend to promote rapid growth and better nutrient utilization. Availability of vegetable oil and other forms of fats has made it possible to study in great depth the relationship between protein:calorie ratio and carcass yield and quality. Hill and Dansky (1950) found that growth rate was reduced by feeding rations high in dietary energy and low in dietary protein and that growth was restored when the energy level was lowered. Donaldson et al. (1956) showed that chicks reared to 4 weeks of age and fed supplemental fat in their diets tolerated wider protein:calorie ratios before growth was impaired than did those which received no added fat during rearing. There was no adverse effect on growth rate with low, moderate and high fat diets as long as the calorie:protein ratios were no wider than 43.9, 48.6 and 53.7 kcal PE/lb/1% CP diet, respectively. However, feed efficiency increased as the energy level was increased. It was also found that wider calorie:protein ratios (beyond 50 kcal PE/lb/1% CP diet) increased both fat and gross energy content and also decreased water and protein content of the carcass. The reduction in moisture level was probably due to excess fat deposition. Reduced feed conversion and growth rate resulted as the calorie:protein ratio exceeded 43.9, 48.6 and 53.7 kcal PE/lb/1% CP diet on low, moderate and high fat diets, respectively. Their results further demonstrated that as the calorie:protein ratio increased, less dietary protein and more dietary energy were required per unit of body weight gain. Obviously, there is a beneficial effect of fat in nutrient metabolism.

Similarly, Jackson et al. (1982) observed a high correlation between dietary energy:protein ratio and carcass composition of broilers reared to 49 days of age. Abdominal and total carcass fat content responded to calorie:protein ratio, whether expressed on a percentage or absolute weight basis. However, maximum protein deposition occurred at 20% dietary crude protein in contrast to the increase in percent carcass protein observed above this level. Dietary energy level was also shown to be positively correlated with carcass and abdominal fat and negatively correlated with percent carcass protein. Absolute carcass protein remained constant regardless of the dietary energy level. Similarly, other experiments conducted have shown carcass quality to be a function of dietary energy level, whereas carcass protein and moisture content are dependent upon calorie:protein ratio. Jackson et al. (1982) observed a decline in carcass components as dietary energy level increased when protein level was held constant.

In another study, Summers et al. (1965) fed chicks semi-purified and practical diets to evaluate the effects of a wide range of energy and protein levels on weight gain, feed efficiency and carcass composition. Results showed that carcass protein increased and fat decreased in a linear fashion with increasing dietary protein. Carcass protein was reduced and carcass fat increased when dietary energy levels were increased.

Generally, amino acid requirements are expressed as a percentage either of the diet or per unit dietary energy. Protein intake obviously plays an important role in protein synthesis and degradation rate. In a study with rats, Muramatsu et al. (1963) reported that protein turnover rate increased when dietary protein was increased from 0 to 250 or 400 g/kg diet. Muramatsu et al. (1985) found that both the fractional and absolute rate of protein synthesis increased with increasing dietary protein concentration up to 200 g/kg of diet, and above this concentration remained almost constant when feed intake was ad libitum.

Several studies have indicated that the efficiency with which protein is retained depends on dietary levels of protein and energy

(Velu and Baker, 1974). This holds true in almost all cases. High levels of energy but low protein will result in nitrogen being a limiting factor in protein synthesis and vice versa.

In poultry, the energy requirement is expressed as metabolizable energy. The metabolizable energy is that portion of dietary energy that is available for tissues synthesis, carrying out of vital physical activities, maintenance of body temperature, muscle contraction and relaxation. Hill and Dansky (1954) reported that broilers were able to increase growth by increasing intake of low energy diets, but that total energy intake decreased as the level of dietary energy decreased. McNaughton and Reece (1982) estimated a metabolizable energy (ME) requirement of 3375 kcal/kg diet for broilers kept at 15.6°C. However, others have indicated metabolizable energy requirements as low as 2800 kcal ME/kg of diet (McDonald and McClymant, 1956) to as high as 3300 kcal ME/kg of diet (Herbert et al., 1979).

Effect of Early Nutrition on Abdominal Fat Pad Size

Recent work has centered around feeding low energy diets at least for the first few weeks posthatching. It is assumed that the number of adipose cells are established at this stage of life and later carried to adulthood. It may, therefore, be possible to regulate the overall rate of fat accretion during early stage of life. However, data of Kubena et al. (1974) and Deaton et al. (1973a) demonstrate that compensatory growth of adipose tissue does occur in birds started on low energy diets when finished on high energy diets.

Jensen et al. (1987) studied the effect of caloric restriction during the first week of life on subsequent abdominal fat pad size in male broiler chicks. Results obtained showed that chicks fed diets containing 28% protein and 2850 kcal ME/kg diet for the first 7 days followed by a 23% protein, high fat diet had more abdominal fat pad than for the other treatments. In another experiment, chicks were fed diets varying in dietary protein, with or without supplemental fat for the first 7 days. Chicks were then intermingled and fed a corn-soybean starter and finisher diet to 49 days of age. Chicks started on diets containing 28% protein had more abdominal fat at 7 weeks of age.

Hargis and Creger (1980) observed that restriction of caloric intake in early life (first 7 days), regardless of the caloric value of the finisher diet, produced the least amount of abdominal fat pad at 7 weeks of age. On the other hand, Griffiths et al. (1977) found no difference on fat pad development of broilers fed low energy diets ad libitum versus high energy diets ad libitum.

Effect of Monesin on Growth Rate

Coccidiosis is a major poultry disease. Coccidiosis has been a potential hazard to the industry. The protozoa invade and infect the digestive tract causing poor feed utilization and stunted or poor growth and possibly death.

There are few approved drugs available to control coccidiosis, notably among them is monesin, an anticoccidial agent which is widely used in poultry feed today. Research has shown that there are some beneficiary side effects associated with the anticoccidial agent withdrawal period. Recent studies have shown that monesin feeding and withdrawal affects broiler performance. It was illustrated that feeding monesin (100 ppm) depressed growth and withdrawal of monesin from feed for 5 or 7 days produced higher feed consumption and weight gain values compared with unmedicated broilers. No further growth improvement was obtained when the withdrawal period was increased to 10 days. Percent protein, lipid, ash and moisture were not affected by monesin feeding or withdrawal. However, abdominal fat content of unmedicated females was higher than those medicated with monesin even when expressed as a percent of body weight (Metzler et al., 1987). It therefore appears that monesin feeding and withdrawal does influence abdominal fat and body weight. These results were further confirmed by McDougald and McQuistion (1980) who found an increase in feed consumption and weight gain upon the withdrawal of monesin for a 5 or 7 day period. Feed intake and growth rate were lower in chicks fed diets containing monesin. However, this effect was less pronounced when chicks were fed higher levels of fat. It appeared that high levels of fat tended to reduce the depressive effect of monesin. Feeding high levels of protein did not improve growth rate or feed intake. Chicks fed diets containing high levels of fat and protein gained more weight and had lower feed to gain ratios than chicks fed diets containing lower levels of fat and protein. Monesin was also found to have an effect on dry matter and nitrogen retention. The magnitude of dry matter and nitrogen retention in females was less when a diet high in soybean oil was fed. A similar level of tallow resulted in a less pronounced effect on most parameters. Monesin supplementation may not affect dietary metabolizable energy utilization, but may increase feed to gain ratio (Bartov, 1987). Fat source and level may alleviate the depressive effect or toxicity of monesin to some degree.

Effect of Processed Keratin on Abdominal Fat Pad Reduction

Poultry by-products are a good source of protein and are also relatively good sources of energy. In addition, poultry by product also serves as a source for minerals and unidentified growth factors. This has made the replacement of some components of practical diets with feather meal possible. Hydrolyzed feather meal which contains 85-90% crude protein is commonly used.

A number of experiments have been conducted to investigate the level of feather meal that could be tolerated by broilers. Replacing 6% soybean meal with feather meal has been shown to have maintained growth rate, feed efficiency and reduce abdominal fat. Cabel et al. (1987) fed diets that met the National Research Council (NRC, 1984) nutrient requirements for 35 days, followed by diets containing varied levels of supplemental feather meal (0, 2, 4 or 6%). Results showed that addition of more than 2% dietary feather meal reduced abdominal fat. They observed no difference in weight gain, feed utilization or dressing percentage. Results suggest that short time feeding of feather meal during the finishing phase may reduce abdominal fat in broilers. Substitution of 5% protein of a practical soy-corn diet with feather meal protein resulted in equally good growth performance (Moran et al., 1966). On the average, it appears that broilers can tolerate 5% or more feather meal if amino acid balance is maintained (Morris and Balloun, 1973).

CHAPTER III

MATERIALS AND METHODS

Experimental Animals and Treatments

Two experiments were conducted using day old Shaver color sexable chicks. Upon hatching, chicks were placed in floor pens with wood shavings as litter. All experiments and work were conducted at The University of Tennessee, Knoxville poultry farm. Chicks were confined in a brood ring until 3 days of age. Infrared gas brooders were used, and a 24-hour constant light schedule was maintained. Chicks were fed practical corn-soybean meal starter diets containing 23% crude protein, with one of the following metabolizable energy levels: 2880, 3040, 3200, 3360, or 3520 kcal ME/kg of diet. Because most poultry rations at present in the United States contain 3200 kcal ME/kg of diet, it was taken as the standard energy level treatment, while the other four treatments were formulated by going 5% and 10% above and below 3200 kcal ME/kg of diet, making five treatments. The energy level of the diets was varied by the addition of vegetable oil, more specifically soy oil. Chicks were fed a practical corn-soybean starter diet containing 23% crude protein for 4 weeks and followed by a 21% crude protein ration as grower-finisher to 49 days of age.

Feed and water were provided ad libitum. Mortality was recorded daily and feed consumption data were adjusted as deaths occurred.

The summer experiment was conducted using 330 straight-run day-old Shaver chicks. The experiment commenced on July 21 and ran through September 15, 1987. The objective of this experiment was to evaluate the effect of summer temperatures on broiler performance. Each treatment (dietary energy level) was replicated 3 times in a completely randomized design, and each replicate group consisted of 11 male and 11 female chicks. Feed and water were provided ad libitum. The compositions of the corn-soybean meal starter and finisher diets are presented in Tables 1 and 2, respectively. The following brooding temperatures were used:

Age (Day)	Brooding Temperature (°F)
1-7	90
8-14	80
14-21	75
22-28	75
>28	70

Daily high and low temperatures at bird level were recorded throughout the study using a hi-low thermometer and are reported in Table 3. Total feed consumption, average body weight, mortality, and feed efficiency data were collected at 49 days of age. On day 49, 5 male and 5 female birds were randomly selected from each pen (150 birds total; 30 birds/treatment) and slaughtered with the following data collected: live body weight; dressed carcass weight; abdominal fat pad (as percentage of live weight); breast, leg, thigh and back expressed as percentage of carcass weight. Treatments that achieved the target weight of 2.05 kg by 49 days were discontinued, while others continued until 2.05 kg average body weight was attained,

Table 1. Percentage Composition of the Corn-Soybean Meal Starter Treatment Diets.

Ingredient	Treatment Designation T1	T2	T3	T4	T5
Corn (9.0% CP)[a]	57.81	54.08	50.36	46.63	42.91
Soybean meal (48% CP)[a]	32.90	33.59	34.27	34.94	35.62
Soy oil	.41	3.45	6.50	9.55	12.60
Fishmeal	2.50	2.50	2.50	2.50	2.50
Alfalfa meal	2.50	2.50	2.50	2.50	2.50
Dicalcium phosphate	1.50	1.50	1.50	1.50	1.50
Limestone	1.10	1.10	1.10	1.10	1.10
Salt	.25	.25	.25	.25	.25
$MnSO_4$	.025	.025	.025	.025	.025
DL methionine	.20	.20	.20	.20	.20
Vitamin mix 6[b]	.60	.60	.60	.60	.60
Monensin[c]	.20	.20	.20	.20	.20
Total	100.00	100.00	100.00	100.00	100.00
% CP	23.00	23.00	23.00	23.00	23.00
Kcal ME/kg	2880	3040	3200	3360	3520
Calorie:Protein ratio	125	132	139	146	153

[a]Determined by laboratory analysis.

[b]Vitamin premix provided per kilogram of diet: Vitamin D, 750 ICU; Vitamin A, 4175 IU; Riboflavin, 4.75 mg; Vitamin B_{12}, .011 mg; Niacin, 42 mg; D-calcium pantothenate, 7.3 mg; Choline chloride, 469 mg.

[c]Monensin premix (Coban®) equivalent to 45 g monensin per pound, Elanco Products Co., Indianapolis, IN 46285.

Table 2. Percentage Composition of the Corn-Soybean Meal Finisher Treatment Diets.

Ingredient	Treatment Designation T1	T2	T3	T4	T5
Corn (9.0% CP)[a]	61.74	58.02	54.29	50.57	46.84
Soybean meal (48% CP)[a]	27.17	27.85	28.53	29.20	29.88
Soy oil	.11	3.16	6.21	9.25	12.30
Fish meal	2.50	2.50	2.50	2.50	2.50
Alfalfa meal	5.00	5.00	5.00	5.00	5.00
Dicalcium phosphate	1.50	1.50	1.50	1.50	1.50
Limestone	.85	.85	.85	.85	.85
Salt	.25	.25	.25	.25	.25
$MnSO_4$	.025	.025	.025	.025	.025
DL methionine	.050	.050	.050	.050	.050
Vitamin mix 6[b]	.60	.60	.60	.60	.60
Monensin[c]	.20	.20	.20	.20	.20
Total	100.00	100.00	100.00	100.00	100.00
% CP	21.00	21.00	21.00	21.00	21.00
kcal ME/kg	2880	3040	3200	3360	3520
Calorie:protein ratio	125	132	139	146	153

[a]Determined by laboratory analysis.

[b]Vitamin premix provided per kilogram of diet: Vitamin D, 750 ICU; Vitamin A, 4175 IU; Riboflavin, 4.75 mg; Vitamin B_{12}, .011 mg; Niacin, 42 mg; D-calcium pantothenate, 7.3 mg; Choline chloride, 469 mg.

[c]Monensin premix (Coban®) equivalent to 45 g monensin per pound, Elanco Products Co., Indianapolis, IN 46285.

Table 3. Observed Ambient Temperatures for Summer and Winter Experiments.

Period (Days)	Average Low Temperature (°F)		Average High Temperature (°F)	
	Summer	Winter	Summer	Winter
10-19	77.22	72.36	94.82	76.37
20-29	75.44	60.40	91.45	66.50
30-39	73.61	63.69	90.00	68.79
40-49	67.60	64.84	85.33	70.13
50-57	65.00	-	80.00	-

after which chickens were slaughtered and the same data collected for analysis, carcass yield and composition at 2.05 kg body weight.

A winter experiment was conducted December 16 through February 5, 1988, utilizing 420 day-old Shaver chicks. Fourteen male and 14 female chicks were randomly allotted to each experimental group. The compositions of the treatment diets were the same as used in the summer experiment.

Five treatments were imposed and each treatment was replicated 3 times. Chicks were fed ad libitum. For this experiment ambient temperature was lowered 1°F each day according to the temperature schedule presented in Table 4. The observed temperatures are reported in Table 3. Objectives of this study were to evaluate the effect of cool winter temperature on broiler performance. On day 49, following overnight fasting, similar data as were collected in experiment 1 were also collected for both carcass yield and composition at 49 days of age and 2.05 kg body weight.

Data were analyzed using the GLM procedure of SAS. The linear, quadratic and cubic effects of energy level on each dependent variable were tested.

Table 4. Winter Experiment Ambient Temperature Schedule.

Age/Days	Date	Temperature Setting (°F)
1	12/16/87	90
2	12/17/87	90
3	12/18/87	89
4	12/19/87	88
5	12/20/87	87
6	12/21/87	86
7	12/22/87	85
8	12/23/87	84
9	12/24/87	83
10	12/25/87	82
11	12/26/87	81
12	12/27/87	80
13	12/28/87	79
14	12/29/87	78
15	12/30/87	77
16	12/31/87	76
17	1/1/88	75
18	1/2/88	74
19	1/3/88	73
20	1/4/88	72
21	1/5/88	71
22	1/6/88	70
23	1/7/88	69
24	1/8/88	68
25	1/9/88	67
26	1/10/88	66
27	1/11/88	65
28	1/12/88	64
29-49	1/12/88-2/5/88	Held at 64°

CHAPTER IV

RESULTS

Summer Experiment

Body weight and feed efficiency data at 49 days and 2.05 kg straight-run body weight are presented in Table 5. The linear effect of energy was significant for each variable (Table 6). Only those birds fed 3520 kcal ME/kg diet achieved an average straight-run live body of 2.05 kg by 49 days of age; chickens fed diets containing 3200 or 3360 kcal ME/kg required 51 days; those fed 3040 kcal ME/kg, 52 days; and those fed 2880 kcal ME/kg, 57 days. Those birds requiring more than 49 days to achieve the 2.05 kg target weight had significantly lower feed efficiencies (Table 7).

Forty-nine day carcass data are presented in Table 8. There was a highly significant effect of energy on carcass weight and fat pad percent (Table 9). Those chickens fed the low energy diets were lighter and contained less fat. They also tended to have a higher percentage of legs plus thighs. Although significant treatment effects were noted for the percentage of back and wings, these may have been due to differences in the way in which the carcasses were cut up.

There were a number of significant treatment effects observed for carcass data at 2.05 kg straight-run body weight (Tables 10 and 11). Particularly interesting was that fat pad percentage remained significantly lower in birds fed the low energy diets. Birds fed

Table 5. Performance Data at 49 Days and at 2.05 kg Average Straight-Run Live Weight (Summer Experiment).[a]

	At 49 Days				At 2.05 kg Live Wt.		
	Body Wt.				Body Wt.		
Energy Level	Male	Female	GF	Age	Male	Female	GF
(kcal/kg diet)	(g)	(g)	(g/kg)	(days)	(g)	(g)	(g/kg)
2880	1799	1650	326	57	2336	1861	301
3040	2064	1759	366	52	2128	1867	356
3200	2108	1781	402	51	2172	1960	394
3360	2057	1889	393	51	2262	1887	378
3520	2202	1884	418	49	2202	1885	418

[a]Data are means of triplicate groups of chickens.

Table 6. AOV Summary of Growth Data at 49 Days.

Variable	Root MSE (df)	Significant Effects
Male BW	61.506 (14)	linear effect of energy level ($P < .0001$) cubic effect of energy level ($P < .004$) quadratic effect of energy level ($P < .03$)
Female BW	65.546 (14)	linear effect of energy level ($P < .0005$)
GF	.0231 (14)	linear effect of energy level ($P < .001$)

Table 7. AOV Summary of Growth Data at 2.05 kg.

Variable	Root MSE (df)	Significant Effects
Male BW	128.005 (14)	None
Female BW	105.228 (14)	None
GF	.0124 (14)	linear effect of energy level ($P < .0001$) quadratic effect of energy level ($P < .0001$) cubic effect of energy level ($P < .0001$) quadratic effect of energy level ($P < .004$)

Table 8. Carcass Characteristics at 49 Days of Age (Summer Experiment).[a]

Variable	Males[b] T1	T2	T3	T4	T5	Females[b] T1	T2	T3	T4	T5
Live wt, g	1862	2109	2002	2054	2108	1659	1662	1690	1823	1847
Carcass wt,[c] g	1228	1400	1355	1382	1445	1085	1089	1123	1237	1256
Abdominal fat pad[d]	1.50	1.92	1.88	2.12	2.18	2.03	2.71	2.67	2.92	3.14
Legs and thighs[d]	33.1	31.9	32.8	32.0	31.8	31.8	31.0	30.7	30.4	29.14
Breast[d]	28.5	29.2	28.1	27.4	28.8	30.7	28.3	28.6	29.0	28.3
Back[d]	23.9	24.1	23.4	23.8	25.3	23.2	25.4	22.7	25.1	24.9
Wings[d]	15.4	13.4	14.9	16.1	14.2	15.7	14.4	16.4	15.0	15.2

[a]Data are means of three groups of 5 randomly selected birds per treatment-sex.

[b]T1, T2, T3, T4, and T5 refer to treatment diets 1 through 5 (cf. Tables 1 and 2, pages 22 and 23).

[c]Dressed carcass without giblets.

[d]Expressed as a percentage of carcass.

Table 9. AOV Summary for Carcass Data at 49 Days of Age (Summer Experiment).

Variable	Root MSE (df)	Significant Effects
Carcass wt	67.93 (20)	linear effect of energy ($P < .0001$) sex ($P < .0001$) cubic effect of energy x sex ($P < .05$)
Fat pad	.3545 (20)	linear effect of energy ($P < .0003$) sex ($P < .0001$)
Leg	1.106 (20)	linear effect of energy ($P < .01$) sex ($P < .0003$)
Breast	1.724 (20)	none
Back	1.1082 (20)	Quartic effect of energy ($P < .01$)
Wing	1.372 (20)	Cubic effect of energy ($P < .04$)

Table 10. Carcass Characteristics at 2.05 kg Average Straight-Run Live Weight (Summer Experiment).[a]

Variable	Males[b] T1	T2	T3	T4	T5	Females[b] T1	T2	T3	T4	T5
Live wt, g	2235	2131	2166	2220	2108	1856	1869	1853	1894	1847
Carcass wt,[c] g	1521	1451	1557	1606	1445	1239	1262	1329	1359	1256
Abdominal fat pad[d]	1.57	1.87	2.08	1.84	2.18	1.44	1.90	2.34	2.73	3.14
Legs and thighs[d]	33.8	34.1	33.2	32.0	31.8	33.2	32.6	32.7	32.1	29.1
Breast[d]	29.8	29.3	28.7	30.6	28.8	31.6	30.1	30.9	30.0	28.3
Back[d]	20.5	23.5	24.4	23.6	25.3	21.5	24.3	23.4	24.5	24.9
Wings[d]	12.4	12.1	12.1	11.8	14.2	12.9	12.6	12.1	12.0	15.2

[a]Data are means of three groups of 5 randomly selected birds per treatment-sex.

[b]T1, T2, T3, T4, and T5 refer to treatment diets 1 through 5 (cf. Tables 1 and 2, pages 22 and 23).

[c]Dressed carcass weight without giblets.

[d]Expressed as a percentage of carcass.

Table 11. AOV Summary for Carcass Data at 2.05 kg Average Straight-Run Body Weight (Summer Experiment).

Variable	Root MSE	Significant Effects
Carcass wt	88.4(20)	sex ($P < .0001$)
Fat pad	1.506(20)	linear effect of energy x sex ($P < .05$)
Legs and thighs	1.477(20)	linear effect of energy ($P < .003$)
Breast	1.099(20)	linear effect of energy ($P < .03$) linear effect of energy x sex ($P < .03$)
Back	1.275(20)	linear effect of energy ($P < .0001$) cubic effect of energy ($P < .01$)
Wings	.661(20)	sex ($P < .04$) linear effect of energy ($P < .0002$) quadratic effect of energy ($P < .0001$)

the lower energy diets had a greater yield of all carcass parts except the back and wings. These differences were probably related to age differences rather than diet treatment affects per se.

Winter Experiment

In this experiment all birds met or exceeded the 2.05 kg target body weight by 49 days of age (Table 12). As in the summer experiment, there was a significant linear effect of energy for body weight and feed efficiency (Table 13).

Carcass yield data are presented in Table 14. Carcasses from females contained significantly more fat and legs plus thighs (Table 15). Diet affected only fat pad and no other yield trait. Birds fed the low energy diets contained considerably less fat than birds fed the high energy diets.

Table 12. Growth Performance and Feed:Gain Ratio at 49 Days of Age in Winter.

Energy Level kcal/kg Diet	Body Weight Male (g)	Body Weight Female (g)	GF g/kg
2880	2058	1842	425
3040	2179	1901	434
3200	2249	1846	454
3360	2329	1999	498
3520	2394	2048	524

Table 13. Analysis of Variance of Growth at 49 Days of Age.

Variable	Root MSE	Significant Effects
Male BW	112.990 (10)	linear effect of energy level ($P < .003$)
Female BW	110.226 (10)	linear effect of energy level ($P < .03$)
G:F	.01558 (10)	linear effect of energy level ($P < .0001$)

Table 14. Carcass Characteristics at 49 Days of Age in Winter.[a]

Variable	Males[b]					Females[b]				
	T1	T2	T3	T4	T5	T1	T2	T3	T4	T5
Live wt, g	2101	2201	2206	2285	2352	1666	1840	1865	1969	2004
Carcass wt,[c] g	1483	1513	1571	1602	1647	1255	1300	1345	1436	1438
Abdominal fat pad[d]	.988	1.23	1.34	1.46	2.29	1.17	1.80	1.89	2.29	2.0
Legs and thighs[d]	33.08	33.21	33.18	32.39	32.88	31.67	31.60	32.15	31.93	32.25
Breast[d]	29.83	29.75	29.46	30.00	28.79	30.39	31.09	30.15	30.15	29.30
Back[d]	23.62	23.88	23.90	24.20	24.96	23.87	24.02	24.18	24.72	24.91
Wing[d]	13.47	13.15	13.46	13.41	13.37	14.07	13.29	13.51	13.21	13.58

[a]Data are means of three groups of 5 randomly selected birds per treatment-sex.

[b]T1, T2, T3, T4, and T5 refer to treatment diets 1 through 5 (cf. Tables 1 and 2, pages 22 and 23).

[c]Dressed carcass without giblets.

[d]Expressed as a percentage of carcass weight without giblets.

Table 15. Analysis of Variance Summary for Carcass Data at 49 Days of Age in Winter.

Variable	Root MSE (df)	Significant Effects
Carcass weight	73.0588 (20)	linear effect of energy level ($P < .0001$)
		sex ($P < .0001$)
Fat pad	.32122 (20)	linear effect of energy level ($P < .0001$)
		sex ($P < .001$)
Legs and thighs	.72833 (20)	sex ($P < .001$)
Breast	1.0066 (20)	none
Back	.91573 (20)	none
Wing	.43911 (20)	none

CHAPTER V

DISCUSSION

In both experiments growth and feed efficiency increased most when dietary energy was increased from 2880 kcal ME/kg to 3200 kcal ME/kg. Chickens responded to energy levels higher than 3200 kcal ME/kg in both experiments but to a lesser magnitude. Season had a marked effect. For example, it required 57 days for birds fed the 2880 kcal ME/kg diet to achieve an average live weight of 2.05 kg during the summer, but only 49 days during the winter. There appeared to be no definitive season x energy level interaction, although birds grown under winter conditions weighed an average of 195 g more at 49 days within each energy level. Associated with the poorer growth rate for summer reared birds was poorer feed efficiency. In general these results indicate that 3200 kcal ME/kg diet is sufficient during both the summer and winter seasons. Higher energy levels will yield heavier body weights, but the high cost of these high fat diets would probably not make such a feeding system economical.

In both seasons, abdominal fat was reduced in birds fed the low energy diets. This was true for summer reared birds even when grown to an average live weight of 2.05 kg. Season also affected abdominal fat content--i.e., those reared during the summer contained more abdominal fat than those reared in the winter.

Yield of cut-up parts was significantly affected by dietary energy level in the summer but not the winter experiments. Although statistically significant, these effects were likely the result of the way in which the carcasses were cut up rather than diet per se. The birds in the summer experiment were segregated into treatment groups and slaughtered in sequence (i.e., treatments 1 through 5) during the course of 2 days and by different people. After the data were summarized, this was recognized as a problem. In the winter experiment special care was taken to insure that all persons were making similar cuts, and the birds were cut up randomly. That energy level was without effect for the second experiment leads one to assume that the differences noted in the first experiment were simply artifacts.

The results obtained in this study clearly demonstrate that season has a profound effect on broiler growth and efficiency. The depressing effect of summer temperatures could not be overcome by changing the dietary energy level. The data also clearly demonstrate that feeding low energy diets reduces the amount of carcass fat, but does so at the expense of growth rate. No clear diet effect was observed for carcass part yield.

The current market for cut-up chicken parts is based on yield from birds slaughtered at 2.05 kg straight-run live body weight. To obtain this size bird during the summer required feeding a diet containing 3200 kcal ME/kg for 51 days; however, during winter this target weight was achieved by feeding the 2880 kcal ME/kg diet for just 49 days.

Hence, if market prices are high, it is conceivable that one could economically justify feeding a low energy diet during the winter season. Feed costs would be significantly reduced, and the carcasses would contain substantially less abdominal fat. A reduction in abdominal fat reduces the problems associated with manual removal of the fat and subsequent disposal.

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