NUTRITION AND ENVIRONMENTAL TEMPERATURE INTERACTION IN CHICKS: EFFECT OF FEED INTAKE ON BROILER PERFORMANCE AT THREE TEMPERATURES

By

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AT THREE TEMPERATURES

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INTRODUCTION

Total productivity and production efficiency of broilers declines as the ambient temperature diverges from the zone of thermoneutrality. This decreased productivity results in substantial economic hardship to poultry producers and consumers around the world. The economic strain during periods of environmental stress is due only in part to increased mortality. Substantial decline in productivity results from altered feed consumption and efficiency of feed utilization. At environmental temperatures below the thermoneutral zone, maintenance requirement for energy is increased. Broilers eat more feed to maintain normal levels of production and efficiency of feed energy use declines. At environmental temperatures above the thermoneutral zone, maintenance requirement for energy is also increased but feed intake is reduced. This lowers productivity and feed efficiency. Research effort to combat the deleterious effects of environmental stress has centered upon nutrition and pharmacology. Nutritional manipulation includes substituting fat for carbohydrates to reduce the heat increment of the diet, feeding extra amounts of feed and minimizing excess amino acids while drugs such as diazepam have been documented as having the ability to induce feed intake. However it is not known if the reduced poultry productivity can be attributed solely to the reduced feed consumption.

The research reported herein was conducted to (1) develop a technique for manipulating feed intake and (2) observe the effects of varying food intake level below, at, and above *ad libitum* consumption levels within cold, hot, and thermoneutral environments.

Chapters are prepared as manuscripts in the style required by specific journals to facilitate publication of experimental results.

CHAPTER II

FORCE FEEDING METHODOLOGY AND EQUIPMENT FOR POULTRY

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Abstract

Methodology and equipment for rapidly force feed poultry meals of a specific size have been developed and tested _in vivo_. The force feeding method utilizes a feeding gun constructed from readily available materials and ground poultry feed combined with water. At the proper feed-to-water ratio feed administered by the gun is free flowing and of constant dry matter content. To test the procedure, five-week-old broiler chicks were force fed three times per day for fourteen days quantum sufficient to simulate consumption by birds receiving feed _ad libitum_. The two groups had similar ($P<.1$) body weight gains, percent dry matter and starch digestibility, feed efficiency, digesta passage rate, and dressing percentage. Each bird could be fed in less than thirty seconds.

Introduction

Feed consumption by broiler chicks is highly correlated with body weight gain (Nir and Shapira, 1974). Many factors such as genetic background (Bordas and Merat, 1981), caloric density (Dale and Fuller, 1979; Smith et al., 1982), amino acid balance (Waldroup et al, 1976), and environmental temperature (Adams et al., 1962) are known to impact feed intake. However, to study metabolic parameters, determine feed metabolizable energy values and evaluate ceilings imposed by feed consumption on broiler productivity feed intake must be controlled. Broiler chicks are frequently either pair fed or force fed to equalize feed intake. With traditional pair feeding, birds are restricted to the feed consumption of the animal consuming the least amount; however, since feed intake patterns are correlated with productivity and experimental treatments may influence feed intake, artifically reducing feed intake could lead to erroneous conclusions. Force feeding techniques enable studies to be conducted at consumption levels below or exceeding voluntary intake. Historically, force feeding has been accomplished by passing moistened feed into the crop through a plastic tube (Nir and Shapira, 1974) and by inserting a glass tube connected to a funnel into the bird's crop and inserting pellets which are then pushed down with a glass rod (Sibbald, 1976). Wehner and Harrold (1982) evaluated other force feeding methods via dry ground feed given via a glass tube inserted into the crop; moist pellets expressed from a modified 60 cc springe; slurry feed delivered into the crop via a 1 cm glass tube, and paste delivered viz. a modified 60 cc syringe. Such techniques are laborious, time consuming (3 to 13 minutes per bird) and not conducive to routine experimental use.

Materials and Methods

A force feeding gun (Figure 1) was constructed by modifying a

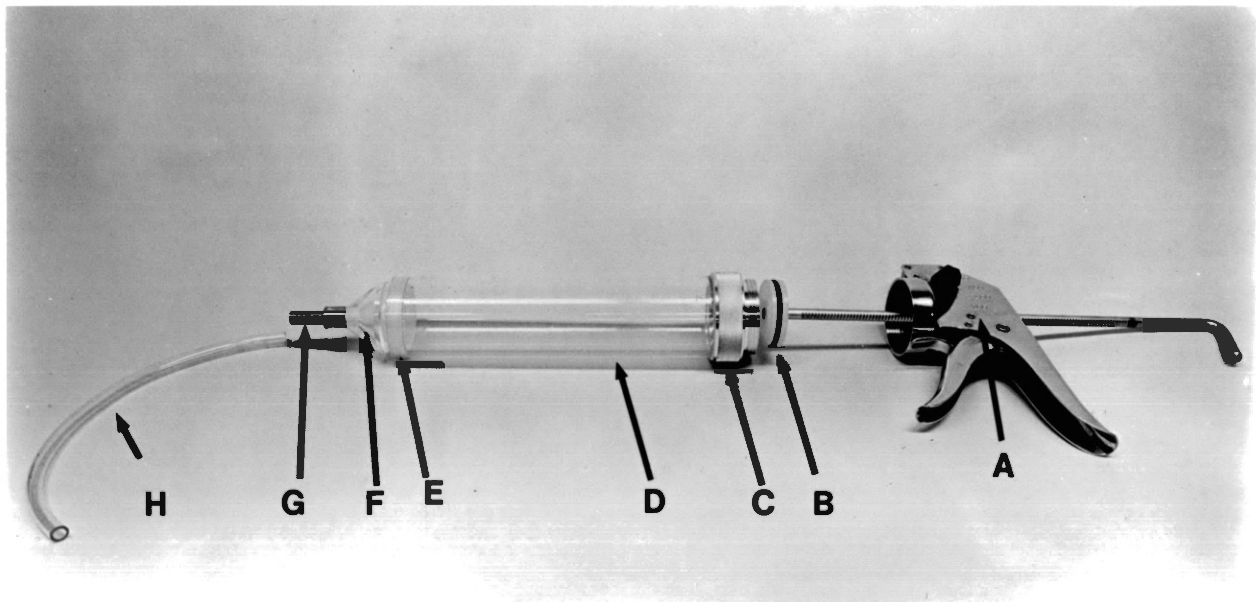

Figure 1. Force Feeding Gun Components: (A) Medigun trigger (B) Nylon plunger + O ring (C) Threaded aluminum pipe (D) Lucite tube insert (E) Lucite threaded female insert (F) Thinwall funnel (G) Stainless steel insert (H) Tygon tube

medigun trigger assembly[a] as follows: (1) The stock metal plunger was replaced with a nylon plunger + O ring to fit snugly lucite tube (Step 3); (2) A 76.2 x 6315 mm diameter aluminum pipe was machined to screw into the medigun assembly and accept a lucite tube (Step 3); (3) A 22.8 x 57.2 mm lucite tube insert was machined at the proximal end to accept a lucite threaded female insert; (4) a thinwall 50.8 mm diameter funnel was machined to fit female threaded insert; (5) A thinwall 50.8 mm stainless steel tube was pressed into the funnel; (6) All inserts were glued with deycon epoxy; and (7) a 8" S-50-HL tygon tube was attached to the stainless steel insert with a hose clamp. Force feeding is accomplished by taring the gun on an electronic scale, inserting the tygon tube into the bird's drop, delivering the approximate quantity of feed, reweighing the gun (negative value on scale represents the amount of feed delivered) and repeating the process if necessary.

Arbor Acres x Lancet chicks were fed a corn soybean meal starter diet during the first 4 weeks post hatching. On the 1st day of the 4th week post-hatching, following an overnight fast, 24 chicks were weighed and allotted to two experimental groups at random. Birds were individually placed in 12" x 15" wire cages housed in a thermostatically controlled room maintained at 24C with a 12-hour light-dark schedule. Water was provided ad libitum throughout the assay period. Feed consumption by birds consuming feed ad libitum (Group 1) was monitored daily and coupled with body weight to compute consumption/body weight. Force fed birds were weighed and fed accordingly an amount of feed

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[a]MSDAGVET, Division of Merck & Co., Inc., Rahway, NJ 07065

equal to one-third consumption/body weight of the *ad libitum* group at 1, 5 and 9 hour of the light cycle.

The consumption of the basal diet is presented in Table 1. Several feed to water ratios were evaluated. A mixture of 55% water and 45% feed was found to flow easily through the gun at constant dry matter delivery. The diet was formulated to be adequate in all nutrients. Chromic oxide was included so that diet and starch digestibility could be estimated with small fecal samples. Fecal samples were collected daily on days 10-14 and composited for chromium and starch analysis by the Stevenson (1962) and the Macrae and Armstrong (1968) procedures, respectively. Rate of digesta passage was estimated by force feeding birds 20 g feed containing 1% ferric oxide and recording the time of first ferric oxide appearance in feces post dose.

Results and Discussion

The force feeding apparatus was found to deliver a constant feed to water ratio throughout the delivery of the gun contents. Feed particle size and dry matter content of the diet to be fed should be designed to permit the resultant mixture to be fed homogeneously. Large particles may become entrapped at the neck of the gun which will increase the pressure needed to force feed out of the gun. Dry matter contents over 50% increase the pressure required for feeding while excess water permits feed-water separation. Since both feed particle size and diet water binding capacity may vary with experimental rations, diets need to be individually tested for optimal feed/water ratios.

In vivo data is displayed in Table 2. Equal intakes were attained for the experimental period. Body weight gains, feed efficiency,

TABLE 1. Ration composition

Ingredient	IFN	%
Ground corn grain	4-02-935	41.0
Soybean meal (44%)	5-04-604	33.
Corn oil	4-07-822	10.
Meat & bone meal	5-00-388	5.
Corn gluten meal	5-02-900	5.
Polyethylene	--	3.
Dicalcium phosphate	6-01-080	1.
Calcium carbonate	6-01-069	0.9
Vitamin mix	--	0.5
NaCl	6-14-013	0.3
dl methionine	--	0.2
Chromic Oxide	--	0.1

TABLE 2. Dry matter consumption, body weight gain, feed efficiency, dressing percentage, ration digestibility, starch digestibility and digesta passage rate of birds fed ad libitum and by the force feeding technique

	Feeding Technique	
	Ad Libitum	Force Fed
Daily dry matter consumption/body wt. (g/day)	.088 ± .007	.088 ± .001
Body weight gain (g/day)	58.7 ± .9	59.1 ± 1.2
Feed DM/gain	.55 ± .02	.56 ± .02
Dressing percentage	68.5 ± .7	67.7 ± 1.0
Diet DM digestibility (%)	73.5 ± 1.6	75.0 ± 1.9
Starch digestibility (%)	99 ± .4	99 ± .2
Digesta passage rate (min)	263 ± 11.2	231 ± 9.8

dressing percentage and diet dry matter digestibility were similar ($P>.1$) for the two feeding methods. Rate of digesta passage did not differ between treatments although passage was 14% faster ($P<.1$) for birds fed by the new technique. The average time required for two people to force feed each bird was less than 30 seconds per meal. Force fed birds exhibited no signs of discomfort during or after feeding and did not regurgitate food. The simplicity of this procedure should simplify feed intake experiments in the future.

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CHAPTER III

EFFECT OF FEED INTAKE AND TEMPERATURE ON GROWTH AND CARCASS TRAITS OF BROILERS

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Abstract

Four-week old broiler chicks were reared under three environmental temperatures: cold (C,7.2C), Hot (H,35C) and thermoneutral (TN,23.9C) for two weeks and force-fed to intake levels approximating 69, 88, 103, 116 and 135% of thermoneutral controls receiving feed *ad libitum*. Birds consuming feed *ad libitum* in the C and H environments exhibited reduced body weight gain (26 and 43%) feed efficiency (29 and 21%), dry matter digestibility (7 and 22%) and carcass yield (36 and 34%). The C and H environments decreased P<.05) percent carcass abdominal fat by 92% and 16%, respectively. Cold elevated voluntary feed consumption by 5% while H reduced (P<.05) feed consumption 28%. Increasing feed consumption within an environmental temperature by force feeding increased carcass weight gain linearly (P<.01) in the TN environment quadratically (P<.01) in the H and C environment. Carcass yield exceeded the *ad libitum* fed controls within a given environmental temperature only in the case of H stress. Increasing feed consumption 26% above H *ad libitum* fed controls increased carcass gain 19%. Gastrointestinal

tract mass increased linearly ($P<.05$) with feed intake accounting for -7 to 39% of body weight gain. Abdominal fat gain increased linearly ($P<.01$) by 1600% with feed intake across temperature. Feed efficiency and ration digestibility declined linearly with increased feed intake within each environmental temperature. Digesta passage rate tended to decline linearly ($P<.01$) with increased feed intake but was not influenced by temperature. The data reported herein indicate that feed intake regulation limits poultry weight gain in heat stressed birds and that probably physiological processes other than feed intake regulation limit productivity in C and TN environments.

Introduction

Many environmental factors are recognized as having a major impact upon production of meat from broiler chicks. Such factors include ambient temperature, relative humidity, light duration and intensity, air pressure, air movement, and population density (NRC, 1981a). An ideal combination of the various climatic events is described as effective ambient temperature. Variations in the effective ambient temperature frequently result in alterations in food intake, metabolism and heat dissipation. Environmental temperature is regarded as being foremost among these due to its deleterious effects upon animal production. Prince et al. (1961), showed a 12.5% increase in feed efficiency when environmental temperature was increased from cold stress (7.2C) to a thermoneutral (23.9C) environment for broilers raised from 4 to 8 weeks. Adams et al. (1962), reported that broilers tested during the period from 4-8 weeks of age showed a 16% slower gain in birds held at 32.2C than for those held at 21.1C.

Feed intake of broiler chicks is inversely related to environmental temperature (Prince et al., 1961). Growth rate is depressed at post brooding temperatures above 23C (Milligan and Winn, 1964; Hutson, 1965; Deaton et al., 1973). It has been suggested by Squibb (1959) that the decline in growth rate is a direct result of the reduced feed intake. Reduced intake of a complete diet implies a reduced intake of protein and other nutrients which independent of fluctuating animal nutrient replacements could account for the growth rate depression. The results of Adams et al. (1962) suggest, however, that even when the intake of protein is the same at moderate and high temperatures, the birds at the higher temperatures still grow at a reduced rate indicating that protein, at least, is not the first limiting nutrient.

Cowan and Mitchie (1978) attempted to compensate for weight gain depression at high temperatures by feeding diets which increased concentration of protein ranging from 17.8% to 30.8% of the diet. No improvement was noted when dietary protein alone was increased, however, for each diet, birds kept at 21C grew significantly faster than those kept at 26C which in turn grew significantly faster than those on the 31C temperature regime. This is consistent with the observation that heat stress limits weight gain independent of nutrient status.

Heat increment is the increase in heat production following consumption of food by an animal in a thermoneutral environment (NRC, 1981b). During cold stress heat increment is useful in offsetting the increased rate of heat loss. However, when animals are reared under heat stress conditions heat increment aggravates the problem by adding more heat to an already stressed animal. Heat increment for proteins is greater than for carbohydrates with fats having the lowest value of the three (McGilvery, 1979). Oxidation of glucose via glycolysis requires many more reactions than the B-oxidation of fatty acids and as such more heat is produced. Glucose has a gross energy value of 673 kcal per mole, of which 418 kcal per mole or 62% is conserved as acetate. In the case of a 16-carbon fatty acid with a gross energy value of 2398 kcal per mole, 70% or 1672 kcal per mole is conserved as acetate. Complete oxidation of carbohydrates produces 36 ATPs resulting in a calorie/ATP of 18.69. When palmitate is completely oxidized, 129 ATPs net is produced which gives a calorie/ATP of 18.59. This would indicate that there is not much difference in the amount of energy that is lost as heat from the two types of feed. However, much of the fatty acids consumed goes to form adipose tissue which is an energy conserving process and as such produces less heat than the catabolism of carbohydrates. The thermodynamic efficiency of ATP formation from glucose is 38% when glycolysis, the citric acid cycle and oxidative phosphorylation are in operation whereas for fatty acid oxidation it is 40%. The high heat increment for protein may be associated with the fact that urea is synthesized from excess nitrogen intake and this process requires ATP. An energy deficiency during heat stress could be caused by reduced feed intake, resulting in turn from the discomfort of dietary heat increment. Any reduction in heat increment of the diet would increase the amount of usable energy available to the bird, first by increasing the net energy in relation to metabolizable energy intake. Waldroup et al. (1976a) reported increased weight gains when excess levels of essential amino acids were minimized. This was thought to be due to the decrease in heat increment. Other attempts have been made, with some degree of success, to overcome the deleterious effects of heat stress by manipulating dietary constituents with low heat increment such as fat (Waldroup et al., 1976b; Dale and Fuller, 1979).

The energy requirements of animals increase above the zone of thermoneutrality, since additional calories must be used to dissipate body heat (Brody, 1945) by utilizing thermoregulatory mechanisms such as panting. This causes the deleterious effects of reduced energy intake observed under heat stress to be magnified, since additional energy is required for maintenance. Although feed is utilized more efficiently when feed intake level is 60% or less of full feed (Titus, 1961; Teeter et al., 1983, submitted) because of the increased energy requirement at high temperatures, the decline in feed intake is accompanied by lowered feed efficiency (Hurwitz et al., 1980).

The regulation of feed intake is an example of a homeostatic mechanism, or the self-regulating negative feed back systems which serve to maintain the constancy of the internal environment (Hafez and Dyer, 1969). It has been suggested by Ahmad et al. (1974) that chemostatic and thermostatic mechanisms of feed intake control are operational in the chicken, and that these mechanisms help to control feed intake. Chemostatic mechanisms include glucostatic regulation whereby feed intake and blood glucose concentration are closely related, especially in non-ruminants; lipostatic regulation, observed in rats whereby each day animals mobilize a quantity of fat proportional to the total fat content of the body. In ruminants feed intake response has been shown to be related to the production of volatile fatty acids. Blood acetate concentration increases after eating and peaks with cessation of eating, at the same time it closely parallels ruminal concentration of VFAs. Intraruminal or intravenous infusion of VFAs at high levels will reduce voluntary feed intake. Brobeck (1960) proposed that animals eat to keep warm and stopped eating to prevent hyperthermia, thereby causing feed intake to become an integral part of the body temperature regulation process. He also implied that this thermostatic mechanism is related to thermoregulation whereby the heat increment causes satiety. The regulation of food intake by temperature apparently follows the scheme where detector systems located in the gut, organs, skin and hypothalamus will detect changes in environmental temperature and they in turn send out activating signals to the central nervous and endocrine systems which exert controlling action on feed intake. The hypothalamus is directly involved in the regulation of feed intake and energy balance, with "centers" involved in hunger and satiety.

Nir et al. (1974), using New Hampshire x Leghorn chicks, demonstrated that force feeding birds to intake levels 70% above normal ad libitum comsumption will result in weight gain enhancement. However, Teeter et al. (1983, submitted) fed commercial broiler chicks (Arbor Acre x Lancet) at temperatures within the thermoneutral zone and found no significant increase in carcass gain with feed intake levels as high as 60% above ad libitum consumption. Possible explanations for this apparent inconsistency is the genetic difference in the experimental animals used. The New Hampshire and Leghorn breeds are smaller, slower-growing (North, 1972; Ensmingher, 1980) and more early-maturing and as such apparently have potential for improvement. The commercial broiler chick, on the other hand, has been selected for high growth rate and consequently high feed intake and may have reached maximum effective feed consumption level. However when the modern broiler chick is subjected to environmental stress, rate of gain is reduced while the genetic potential for high production may remain. Nir et al. (1978) demonstrated that overfeeding birds of light and heavy breeds with differences of 15 and 65% at the beginning and end respectively of the experiment resulted in the light breed exhibiting a 30% increase in weight gain body weight gain while no increase was noted for the heavy breeds. If feed intake is increased in birds subjected to environmental stress, then perhaps there will be an increase in production.

Evidence exists that it is possible to manipulate feed intake by administering drugs such as diazepam and clonidine (Morley, 1980). Potential benefit to the poultry industry of feed intake manipulation independent of animal requirements can only be evaluated by force feeding birds feed intake levels exceeding ad libitum consumption.

The objective of this experiment is to determine if feed intake is limiting body weight gain and carcass yield of edible parts by commercial broiler chicks reared under cold, thermoneutral and heat stress environments.

Materials and Methods

Arbor Acre x Lancet broiler chicks were used in this trial. Chicks were reared from day 1 to day 14 on electrically heated wire floored battery brooders and from day 14 to day 28 on deep litter. During the pre-experimental period the chicks were fed ad libitum with the Oklahoma State University chick starter (Oklahoma Agricultural Experiment Station Research Report #MP-114). On day 28, seventy chicks were assigned at random to individual cages within three environmentally controlled chambers--cold (7.2C), thermoneutral (23.9C), and hot (35C).

The environmental chambers used were 12 ft. x 10 ft. insulated stainless steel rooms equipped with humidistat, air conditioner and heater with the capacity to function between -9 and 57C. Rooms were well-lighted with both fluorescent and tungsten filament bulbs. Birds were on a twelve-hour timed lighting schedule, with the first feed of the day beginning one hour after lights came on. Each chamber contained ninety-six individual cages 15 in. x 8 in. x 14 in., equipped with an automatic watering device, feed pan and fecal collection tray. Birds were adapted to chamber surrounding and the environmental temperature deviated from 23.9C in 5C per day increments during a seven-day period. Birds were allowed to consume experimental ration and water ad libitum.

The experimental design used in this study is based upon the following. A uniformity study was conducted to judge similarities between and within the three environmental chambers. This study utilized thirty 28-day-old Arbor Acre x Lancet broiler chicks per chamber. This size chick was chosen since at this post-brooding stage of growth they are sensitive to heat stress while still rapidly growing. The chicks were fed on the Oklahoma State University chick starter diet for a period of twenty-one days. Parameters examined include feed consumption, body weight gain, and feed efficiency. No statistical difference was detected among ($P<.4$) or with ($P<.2$) the three chambers. These data therefore indicated that each cage within a chamber could be considered an experimental unit. Birds had a mean body weight gain of 827 grams with a variance (s^2) of 14726 associated with the mean. Based on the formula

$$n = \frac{t^2 s^2}{d^2}$$

(Steel and Torrie, 1960) where t_1^2 is the tabulated t value for the desired confidence level and degrees of freedom and d is the half width of the desired confidence interval, the number of observations (n), sufficient to detect a 10% difference between the means of experimental groups was determined to be 5.

The present trial was designed as a 3 x 6 factorial with birds randomly allocated to each treatment. There were ten replicates for each force-fed treatment. This number was large enough to detect a 5% treatment difference in the parameters measured. Twenty birds in each chamber served as *ad libitum* controls. Attempts were made to force feed birds to intake levels approximating 70, 90, 110, 130 and 150% of thermoneutral controls receiving feed *ad libitum*.

The force feeding technique employed was that described by Teeter et al. (1983 submitted) which facilitated quick and efficient feeding of birds with minimum stress. The experimental ration (Table 1) was mixed with water in a 45:55 ratio one-half hour before the start of feeding in order to allow the mixture to reach equilibrium. Feed dry matter content remained constant throughout the feeding interval. Force feeding was accomplished twice daily at six-hour intervals beginning at one hour post-lighting and one-half of the daily feeding quantity being delivered. Birds were weighed every three days and the amount of ration adjusted accordingly to provide the specific feed intake level as a percentage of body weight.

Fecal grab samples were collected on days 45 through 48. Body temperature was monitored on day 48 using a digital thermometer equipped with a rectal probe. Temperatures were checked immediately before the first meal of the day was administered, and at one and one-half and

TABLE 1. Ration composition

Ingredient	IFN[a]	%
Ground corn	4-02-935	45.15
Soybean meal	5-04-604	39.19
Corn oil	4-07-882	10.00
Dicalcium phosphate	6-01-080	2.38
Ground alfalfa	1-00-023	1.00
Calcium carbonate	6-01-069	.89
Salt	6-14-013	.40
Vitamin premix[b]		.40
Cr_2O_3[c]		.30
Dl-methionine	5-03-086	.19
Trace mineralized salt		.10
Total		100.00

[a]International feed number

[b]Roche Chemical Division Hoffman-LaRoche,Inc., Nutley, NJ 07410

[c]Fisher Scientific Co., Fairlawn,NJ 07410

three hours post-feeding. Digesta passage rate was recorded on day 49 based on first appearance of red feces following the second meal of the day which contained 1.5% ferric oxide. Following an overnight fast, birds were weighed, blood samples taken with heparinized syringes via heart puncture and transferred to heparinized capillary and storage tubes and placed in an ice chest cooler. Tubes were centrifuged at 3000 rpm for 5 minutes. Hematocrit values were determined by using a circular reader and plasma protein was determined by a refractometer.

All birds were processed immediately after blood samples were obtained. Using a commercial automated processing system, birds were hung on rail, stunned, and bled for 15 minutes then passed through a scalding vat and plucking machine. The carcasses were eviscerated and the gastrointestinal tracts stored in polythene bags separately from the carcasses at -15C for later analysis. Yield determination was carried out by separating the breast, thigh, drumstick and abdominal fat. Dry matter analysis was carried out and ration digestibility determined by chromic oxide analysis using the method of Stephenson (1962). The data were subjected to analysis of variance (Snedecor and Cochran, 1967) and the means separated by the Duncan's Multiple Range Test (Duncan, 1955). The variables tested were body weight gain, dry matter consumption, feed efficiency, hot carcass weight, dry matter digestibility, carcass efficiency, body temperature, digesta retention time, yield of selected edible carcass parts, gastrointestinal tract size, plasma protein, and hematocrit. The sources of variation examined were feed intake level, temperature, and intake x temperature interaction.

Results and Discussion

Body weight gain, carcass gain and feed efficiency values for birds consuming feed *ad libitum* at the three environmental temperatures are presented in Table 2. Birds reared at 7.2C consumed 28 and 45% more feed ($P<.05$) as a percentage of their body weight per day than those in the thermoneutral and hot environments respectively. Birds in the hot and cold environments exhibited reduced body weight gain (43 and 26%) and decreased carcass gain (34 and 36%). Efficiency of production was also depressed by adverse environmental conditions with feed efficiency being reduced by 29 and 21% ($P<.05$) in the cold and hot environment respectively, while ration digestibility was less severely depressed by 7 and 5% ($P<.05$).

Increasing feed consumption within the thermoneutral environment by force-feeding resulted in a linear ($P<.05$) increase in live weight gain (Table 3) up to the level of the *ad libitum* consumption, and failed to elicit a significant response above this level though feed consumption increased 15%. In the cold environment, birds gained more weight ($P<.05$) up to the *ad libitum* consumption level but declined 17% thereafter as feed consumption increased 6.6%. However, under heat stress conditions, increasing feed consumption resulted in live weight gain increasing quadratically. When feed consumption as a percent of body weight increased by 16%, a 33% weight gain increase resulted ($P<.05$). Increasing feed consumption by 34% above *ad libitum* consumption resulted in a 17% increase in weight gain.

Carcass gain closely paralleled live weight gain, however in the hot environment the significant increase noted in live weight gain at

TABLE 2. Intake, ration digestibility, body weight gain, carcass gain and feed efficiency of ad libitum fed birds

	7.2C	23.9C	35C	Pooled SEM
Intake (% body wt/day)	12.1[a]	9.4[b]	8.5[c]	.66
Ration digestibility (%)	68.6[c]	73.8[ab]	72.0[b]	3.3
Body weight gain (g)	499[b]	675[a]	386[c]	121.13
Carcass gain (g)	362[b]	549[a]	339[b]	106.12
Body wt gain/feed	.42[c]	.61[a]	.48[bc]	.107

[a,b,c]Means in rows having different superscripts differ (P<.05)

TABLE 3. Live gain and carcass gain for force-fed birds at three temperatures

Intake (% body wt per day)	7.2C		23.9C		35C	
	Live gain	Carcass gain	Live gain	Carcass gain	Live gain	Carcass gain
6.5	-37.6[h]	-3.4[i]	319.1[f]	271.1[def]	304.3[f]	246.3[ef]
8.3	140.1[g]	106.3[h]	534.0[e]	439.7[bc]	419.3[def]	335.9[cde]
9.6	192.9[g]	147.4[gh]	651.6[ab]	517.4[ab]	557.8[bc]	403.8[c]
11.1	377.9[ef]	272.9[def]	709.0[a]	546[a]	490.6[cde]	348.6[cde]
12.9	314.5[f]	207.7[fg]	--	--	--	--
Pooled SEM	121.3	106.12				

[a,b,c,d,e,f,g,h,i] Means in columns having different superscripts differ ($P<.05$)

16% above ad libitum consumption intake only approached significance (P<.1) for carcass.

Production efficiency (Table 4) as measured by live gain/feed and carcass gain/feed was not affected by feed intake within the thermoneutral and hot environments (P>.1), however under cold conditions, both measures of efficiency increased quadratically. Dry matter digestibility was found to be inversely related to feed intake in the thermoneutral and hot environments with values at 11.1% feed intake levels significantly lower than at 6.5% feed intake levels. While ration digestibility in the cold environment was significantly lower than that at corresponding feed intake levels in the higher temperatures, there was no difference in the values obtained at consumption levels below ad libitum consumption. There was, however, a sharp decline in digestibility when ad libitum consumption levels were exceeded.

The mean hematocrit and plasma protein values for ad libitum fed birds at each environmental temperature tested are presented in Table 5. Plasma protein values were 13% higher (P<.05) for birds reared in the 7.2C environment than 23.9C while similar values were observed as 23.9 and 35C. These values tended to be higher than those obtained by Deaton et al. (1969) but followed the same pattern when temperatures were compared. Mean hematocrit values were 15% higher at 7.2C than at 23.9C, however the low trend continued up to 35C, the difference between values at 23.9C and 35C was not significant. The hematocrit pattern obtained in our study closely paralleled those observed by Deaton et al. (1969) who reported significantly higher values for broilers reared at 7.2C than for birds reared at 32C and reported no consistent differences in values for birds reared at 23.9C and 32.2C,

TABLE 4. Feed efficiency, carcass efficiency and ration digestibility of force-fed birds at three temperatures

Intake (% body wt/day)	7.2C Live gain per feed	7.2C Car. gain per feed	7.2C Dig.	23.9C Live gain per feed	23.9C Car. gain per feed	23.9C Dig	35C Live gain per feed	35C Car. gain per feed	35C Dig.
6.5	$-.08^{g}$	$-.0006^{e}$	70.4^{def}	0.52^{abcd}	0.443^{a}	75.9^{a}	0.52^{abcd}	0.415^{ab}	76.4^{a}
8.3	$.20^{f}$	$.151^{d}$	70.7^{cdef}	0.58^{ab}	0.473^{a}	74.8^{ab}	0.54^{abc}	0.432^{a}	74.0^{abc}
9.6	$.25^{f}$	$.198^{d}$	70.1^{def}	$.59^{a}$	$.465^{a}$	73.2^{abcd}	0.56^{abc}	0.405^{ab}	71.8^{bcde}
11.1	0.38^{e}	0.284^{c}	70.4^{def}	$.57^{abc}$	$.433^{a}$	71.5^{acde}	$.46^{cde}$	$.331^{bc}$	67.8^{fg}
12.9	0.29^{f}	0.191^{d}	65.4^{g}	--	--	--	--	--	--
Pooled SEM	0.107	0.094	3.32						

a,b,c,d,e,f,g Means in the same column having different superscripts differ (P> .05)

TABLE 5. Plasma protein, hematocrit, digesta retention time viscera weight and body temperature of ad libitum fed birds

	7.2C	23.9C	35C	Pooled SEM
Plasma protein (g/100 ml)	4.17^{ab}	3.69^{c}	3.9^{bc}	.36
Hematocrit	36.6^{a}	31.7^{b}	29.9^{bc}	4.1
Retention time (min)	192	178	187	24.0
Viscera wt (g)	201	195^{ab}	146^{c}	29.9
Body temp. (C)				
0	41.4^{bcd}	41.4^{bcd}	42.0^{a}	.25
1.5	41.8^{b}	41.6^{bc}	42.3^{a}	.25
3	41.5^{bcde}	41.4^{de}	42.2^{a}	.26

^{a,b,c,d,e}Means in rows having different superscripts differ (P<.05) but was not consistent with the results of Huggins and Lewis (1978) who did not observe any differences in hematocrit values for broilers reared at 4.4, 12.7, and 23.9C. Within the thermoneutral and hot environments there was a tendency for plasma protein to be influenced by ration dry matter consumption, however, at 7.2C level of feed intake had no effect ($P>.1$) on plasma protein. Across all temperatures, hematocrit values were not influenced by increased feed intake.

The digesta retention times of the ad libitum fed birds (Table 5) were not influenced by changes in environmental temperature. Although feed intake has been shown to modify digesta retention time in other species (Rice et al. 1967, Wilson et al. 1980) in this study, different intake levels (Table 7) had no significant effect. Viscera weight was highly and positively correlated ($r^2 = .83$) with dry matter consumption but only slight negative correlation existed with retention time. Similarly only slight but significant ($P<.05$) negative correlation ($r^2 = -.15$) existed between dry matter consumption and digesta retention time. Across all temperatures, gastrointestinal tract mass increased linearly (Table 7) with intake and accounted for up to 36% of body weight gain.

The mean temperature of birds in the cold environment (Table 5) did not differ ($P<.05$) from those held at 32.9C, while high environmental temperature significantly elevated the body temperature above that recorded under thermoneutral conditions. Increasing feed intake did not significantly alter rectal temperature of the birds under any of the three environmental temperature regimes, however, in all cases a trend toward elevation of body temperature was noted 1.5 hours after birds had been given a meal which subsequently returned close to the

TABLE 6. Plasma protein and hematocrit values for birds force fed at three temperatures

Intake (% Body wt/day)	7.2C Plasma Protein	7.2C Hematocrit	23.9C Plasma Protein	23.9C Hematocrit	35C Plasma Protein	35C Hematocrit
6.5	4.10^{ab}	40.4^{a}	3.93^{c}	35.0^{bcde}	3.96^{bc}	30.2^{fg}
8.3	4.26^{ab}	38.6^{ab}	4.04^{abc}	34.4^{bcde}	3.96^{bc}	32.0^{efg}
9.6	4.16^{ab}	36.8^{abc}	4.09^{ab}	35.5^{bcde}	4.24^{ab}	33.7^{cdefg}
11.1	4.22^{ab}	37.5^{abc}	4.20^{ab}	36.8^{abc}	4.37^{a}	32.3^{defg}
12.9	4.29^{ab}	37.9^{abc}	--	--	--	--
SEM	.36	4.12				

^{a,b,c,d,e,f,g}Means in columns having different superscripts differ ($P<.05$)

TABLE 7. Digesta retention time and viscera weights of force fed birds

Intake (% Body wt/day)	7.2C RTM (min)	7.2C Viscera wt (g)	23.9C RTM	23.9C Viscera wt (g)	35C RTM	35C Viscera wt (g)
6.5	203^{a}	97.7^{e}	178^{bcd}	137.8^{d}	193^{abc}	125.6^{d}
8.3	173^{bcd}	131.3^{d}	159^{bc}	178.6^{b}	169^{bcde}	148.2^{cd}
9.7	172^{bcd}	128.4^{d}	159^{de}	197.4^{ab}	170^{bcde}	175.8^{bc}
11.1	147^{e}	179.3^{b}	174^{bcd}	216.3^{a}	164^{cde}	176.7^{bc}
12.9	172^{bcd}	180.3^{b}	--	--	--	--
SEM	24.0	29.9				

^{a,b,c,d,e}Means in columns having different superscripts differ ($P<.05$)

TABLE 8. Body temperatures of birds pre and post feeding

Intake (% body wt per day)	TIME[1] 72C			23.9C			35C		
	0	1.5	3	0	1.5	3	0	1.5	3
6.5	41.2^{c}	41.3^{bc}	41.3^{bc}	41.3^{bc}	41.6^{a}	41.7^{a}	41.2^{c}	41.6^{a}	41.5^{b}
8.3	41.3^{bc}	41.7^{a}	41.5^{b}	41.4^{bc}	41.7^{a}	41.7^{a}	41.5^{b}	41.7^{a}	41.8^{a}
9.6	41.3^{bc}	41.6^{a}	41.4^{bc}	41.4^{bc}	41.6^{a}	41.5^{b}	41.5^{b}	41.7^{a}	41.7^{a}
11.1	41.4^{bc}	41.6^{a}	41.6^{a}	41.2^{c}	41.5^{b}	41.5^{b}	41.5^{b}	41.5^{b}	41.8^{a}
12.9	41.6^{a}	41.7^{a}	41.6^{a}	--	--	--	--	--	--
SEM	0.25	0.25	0.26						

[1] 0 = temperature prior to feed; 1.5 and 3 = 1.5 and 3 hrs post feed respectively

[a,b,c] Means in columns having different superscripts differ ($P<.05$)

prefeeding temperature at 3 hours post feeding. The yield of selected carcass parts of ad libitum fed birds (Table 9) was directly proportional to the carcass weight. Birds reared under thermoneutral conditions produced heavier drumsticks, thighs and breasts than those reared in the extreme temperature conditions ($P<.05$). Increasing feed intake by force feeding resulted in a linear increase in the weight of the carcass parts (Table 10) in the thermoneutral environment and a quadratic response at 7.2 and 35C. Maximum response was achieved at ad libitum consumption in the cold environment while feeding birds at 16% above ad libitum intake in the hot environment resulted in highest yield of carcass parts. Abdominal fat gain increased linearly ($P<.05$) with feed intake across all temperatures. However, birds reared in the cold environment deposited significantly less than those in the hot and thermoneutral conditions.

The data from this experiment permits a comparison of the effect of increased feed intake on broiler chicks at temperatures above, within and below the zone of thermoneutrality. It should be noted that at 7.2C maximum production and efficiency of production is achieved at or about ad libitum intake level (12.1% of body weight), and that when dry matter intake is forcibly increased there is a sharp decline in production, probably due to the correspondingly sharp drop in ration digestibility. In this experiment sufficiently high levels of intake above normal consumption was not achieved in the thermoneutral environmental environment to allow definite conclusions as to the effect of increased intake above ad libitum consumption. The results obtained here however agreed with the observations of Teeter et al. (1983, submitted) that feeding this type of broiler chicks

TABLE 9. Yield of drumstick, thigh, breast and abdominal fat of ad libitum fed birds

	7.2C	23.9C	35C	Pooled SEM
Drumstick (g)	96.8	137.6[a]	103.2	20.16
Thigh (g)	111.4	152.2[a]	113.1	22.51
Breast (g)	155.8	203.4[a]	137.8	29.35
Abdominal fat (g)	1.50[a]	11.5	7.6	4.76

[a] Means in rows having different superscripts differ ($P<.05$)

TABLE 10. Yield of drumstick, thigh, breast and abdominal fat of force fed birds

Intake	7.2C				23.9C				35C			
(% Body wt/day)	Drum (g)	Thigh (g)	Breast (g)	Ab Fat (g)	Drum (g)	Thigh (g)	Breast (g)	Ab Fat (g)	Drum (g)	Thigh (g)	Breast (g)	Ab Fat (g)
6.5	54.6^{f}	59.0^{i}	80^{g}	$.1^{f}$	97.1^{ac}	104.3^{def}	147^{bcd}	5.3^{cde}	94.0^{cd}	98.3^{defg}	137^{cde}	3.8^{frg}
8.3	68.0^{ef}	80.1^{ghi}	106^{fg}	$.8^{ef}$	$121.^{ab}$	134.9^{bc}	185^{a}	7.1^{bcd}	96.5^{cd}	105.1^{def}	138^{cde}	6.9^{bcd}
9.6	59.8^{f}	69.7^{hi}	98^{fg}	$.5^{ef}$	130.2^{a}	150.6^{ab}	175^{ab}	11.2^{ab}	110.5^{bc}	120.9^{ed}	152^{bcd}	9.3^{abc}
11.1	81.8^{de}	96.2^{efg}	126^{cdef}	1.3^{ef}	130.2^{a}	158.2^{a}	190^{a}	12.8^{a}	91.2^{cd}	110.2^{de}	124^{def}	11.4^{ab}
12.9	70.7^{ef}	84.7^{fgh}	110^{ef}	$.7^{ef}$	--	--	--	--	--	--		--
SEM	20.16	22.51	29.35	4.76								

[a,b,c,d,e,f,g,h,i] Means in columns having different superscripts differ (P<.05) above ad libitum consumption does not result in increased productivity under thermoneutral conditions. Increasing feed intake to levels above normal consumption within the hot environment resulted in increased productivity. This increase was sustained up to 113% of ad libitum consumption but declined thereafter. In all three environments ration digestibility at the higher levels appear to play a major part in the production response of the birds examined. The data reported herein indicate that feed intake regulation limits weight gain in heat stressed birds and that probably physiological processes other than feed intake regulation, such as ration digestibility and genetic limitation placed in protein syntheses limit productivity in cold and thermoneutral environments.

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CHAPTER IV

SUMMARY AND CONCLUSIONS

The interaction between environmental temperature feed intake and performance is of utmost importance in the formulation of poultry diets for different climatic conditions and geographical locations, or for the selection of the economically optimal combination of nutrition and environmental temperature. Total productivity and production efficiency of broilers decline as the ambient temperature diverges from the zone of thermoneutrality, substantial decline in productivity result from altered feed consumption and efficiency of feed utilization.

In this study research was conducted to (1) develop a technique for manipulating feed intake and (2) observe the effects of varying feed intake level below, at and above *ad libitum* consumption levels within cold, hot and thermoneutral environments. Two trials utilizing two hundred thirty 4-week-old broiler chicks were conducted at three environmental temperatures--cold, hot and thermoneutral--to investigate the effects of feed intake and diet composition on broiler performance.

In the first trial birds were divided into two experimental groups with one group receiving feed *ad libitum* while the other group was force-fed an amount of feed equal to one-third consumption/body weight of the *ad libitum* group at 1, 5 and 9 hours of the light cycle in a 12-hour light-dark schedule. A mixture of 55% water and 45% feed, which produced a constant dry matter delivery through the force feeding gun, was used.

In the second trial birds were force-fed the experimental diet at levels approximating 69, 88, 103, 116 and 135% of the normal thermoneutral ad libitum consumption while one group of birds was allowed to consume feed ad libitum. Measurements on body weight gain, feed efficiency carcass gain and ration digestibility were determined. Yield determination of the economically important parts of the broiler carcass was carried out.

The force feeding apparatus used in the first trial was found to deliver a constant feed to water ratio throughout the delivery of the gun contents. Feed particle size and dry matter content of the diet to be fed should be designed to permit the resultant mixture to be fed homogeneously. Large particles may become entrapped at the neck of the gun which will increase the pressure needed to force feed out of the gun. Dry matter contents over 50% increase the pressure required for feeding while excess water permits feed-water separation. Since both feed particle size and diet water binding capacity may vary with experimental rations, diets need to be individually tested for optimal feed/water ratios. Equal intakes were attained for the experimental period. Body weight gains, feed efficiency, dressing percentage, diet dry matter digestibility were similar (P>.1) for the two sets of birds. Rate of digesta passage did not differ between treatments although it was 15% faster (P<.1) for birds fed by the new technique. The average time required for two people to force feed each bird was less than 30 seconds per meal. Force fed birds exhibited no signs of discomfort during or after feeding and did not regurgitate food. The simplicity of this procedure should simplify feed intake experiments in the future.

In the second trial birds consuming feed *ad libitum* in the cold and hot environments exhibited reduced body weight gain (26 and 43%), feed efficiency (29 and 21%), and carcass yield (36 and 34%). The cold and hot environments decreased ($P<.05$) carcass abdominal fat by 92 and 16% respectively. Cold elevated voluntary feed consumption by 5% while high temperature reduced ($P<.05$) feed consumption 28%. Increasing feed consumption within an environmental temperature by force feeding increased carcass weight gain linearly ($P<.01$) in the thermoneutral environment and quadratically ($P<.01$) in the hot and cold environments. Carcass yield exceeded the *ad libitum* fed controls within a given environmental temperature only in the case of heat stress. Abdominal fat gain increased linearly ($P<.01$) with feed intake across temperature. Feed efficiency and ration digestibility declined linearly with increased feed intake within each environmental temperature.

The data from this study indicated that (1) with proper force feeding technique, studies can be conducted at desired feed consumption levels with no discomfort to the birds and a drastic reduction in the length of time needed to complete the process, and (2) feed intake regulation limits weight gain in heat stressed birds and that physiological processes other than feed intake regulation such as ration digestibility and genetic limitation placed on protein synthesis limit productivity in cold and thermoneutral environments.

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