

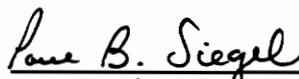
FEED INTAKE IN CHICKENS: GENETIC AND SOCIAL FACTORS

by

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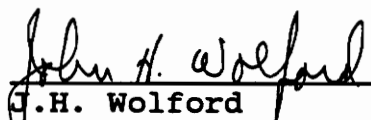
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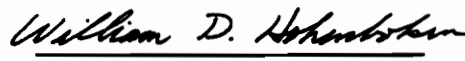
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(ABSTRACT)

The effects of genetic and social factors influencing ingestive behaviors, growth, livability, and dietary self-selection were investigated in three experiments. In Experiment I, ingestive behaviors, livability, and body weight were measured in lines of White Plymouth Rock chickens selected for high (HW) and low (LW) juvenile body weight reared in cages and floor pens as line-separate (S) and line-intermingled (I) flocks in three replicated trials. Body weights of Line HW chicks in cages, livability of Line LW chicks in cages, and ingestive behaviors of Line LW chicks in floor pens were higher in I than S flocks. Experiments II and III were designed to determine the ability of young chicks to discriminate among diets differing in amino acid content. In Experiment II, growth, feed intake, and feed preferences for diets varying in content of lysine, methionine, or tryptophan were measured in Line HW and a line of White Leghorns (HA) selected for high antibody response to sheep erythrocytes. Chicks were fed one of seven diets which were either balanced (Diet A),

or slightly (1) or moderately (2) deficient in lysine (L), methionine (M), or tryptophan (T) for seven days. Chicks were then offered a choice between Diet A and the diet fed for seven days (3 to 10 days of age). Line HW chicks eventually showed a consistent preference for Diet A to all but Diet L1. For diet preference, interactions between time and diet were common in Line HW and the causes of these interactions were discussed. Line HA chicks preferred Diet A to M2, but otherwise did not choose between diets. Growth of Line HW chicks was reduced by feeding Diets L2, L1, and M2, but growth was not affected in Line HA. In Experiment III chicks from Lines HW, HA, and LW were provided a choice among diets with .85, .58, and .44 % methionine from one day of age. Line HW discriminated among diets with different methionine content from five days of age, but chicks did not make a consistent choice until after a period of deficiency. After a period of deficiency, Line HW chicks consistently chose the diet with .85 % methionine. Line HA chicks consumed more of the diet in slight excess of their methionine requirement and the reason for this is not clear. Line LW chicks did not discriminate among diets at any time during the trial. These results indicate that several factors interact to influence ingestive behaviors, growth, livability, and dietary self-selection in different genetic lines of chickens.

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INTRODUCTION

The production of commercial poultry for meat and eggs continues to become increasingly intensified. Standard husbandry practices include feeding specialized diets, using environmentally controlled housing, and reducing the incidence of infectious diseases and parasites through use of feed additives and specific immunization programs. Parallel to the development of these practices has been the development of breeding programs designed to produce specialized stocks for production of meat and eggs.

The ability of these stocks to respond optimally to changing environments is important for maximization of performance. It is generally accepted that meat-type chickens eat at or near gut capacity, yet "starve-outs" persist, and variation exists among and within populations for nutrient needs. The research reported in this thesis is designed to (1) examine the effect of social facilitation on growth and behavior in populations of chickens which differ in eating behavior and growth potential and (2) evaluate the ability of chickens from different populations to discriminate among diets varying in amino acid content.

LITERATURE REVIEW

Effects of Selection.

The genetics of growth in poultry has received

considerable study with regard to modes of inheritance and response to selection. Reviews on this topic specific to chickens (Siegel and Dunnington, 1987; Chambers, 1990), turkeys (Buss, 1990), waterfowl (Pingel, 1990), and other galliformes (Marks, 1990) have appeared in recent literature. From these reviews, it can be concluded that body weight is moderately to highly heritable, shows little heterosis, and is correlated with numerous other traits of which reproductive performance (Nestor, 1984) and feed consumption (McCarthy and Siegel, 1983) are among the more pronounced. The review presented in this thesis will give primary attention to feed intake behavior, social facilitation, and dietary self-selection within and between populations.

Feed Intake Behavior.

Feed intake behavior can be influenced by a number of factors including photoperiod and genotype. White Leghorns (Siegel and Guhl, 1956) and broilers (Siegel et al., 1962) exhibited diurnal rhythms of feeding activity under a 16-hour light:8-hour dark lighting regime. When the effects of photoperiod were removed and feed was available at all times, broilers did not exhibit periodicity of feed consumption (May and Lott, 1992). Using dwarf and nondwarf genotypes of White Rocks selected for eight-week body weight, Barbato et al. (1980) reported that nondwarf chicks

exhibited more periodicity of feed consumption than dwarf chicks. Both groups were reared under natural photoperiod.

Masic et al. (1974) reported that although broilers spent half as much time feeding as White Leghorns, broilers ate more meals of shorter duration than Leghorns. They suggested that Leghorns spent more time in nonconsummatory feeding behavior, which was associated with lower feed efficiency. Activity budgets showed that broilers spent less than 3 to 5% of their time eating (Bessei, 1992), which was somewhat less than the 11% reported by Murphy and Preston (1988). In both studies, locomotor activity decreased while resting, sitting, and lying increased towards the end of the growing period.

Meat and egg type chickens responded differently to intragastric intubation of tryptophan and tyrosine, both of which are precursors of brain neurotransmitters (Lacy et al., 1982). Although tyrosine increased feed intake of White Leghorns within 30 minutes of intubation, it had no effect on feed intake of broilers. Tryptophan decreased feed consumption in both stocks. Using lines of White Rocks divergently selected for body weight at Virginia Tech, Burkhardt et al. (1983) found that ventromedial hypothalamic lesions increased feed consumption in the line selected for low body weight. Hyperphagia was not observed in the line selected for high body weight. They concluded that

selection for increased body weight had altered feed intake mechanisms such that, when feed was available ad libitum, "normal" feed intake of that line resembled that which was surgically induced in the low line. Some individuals in the low line exhibit anorexia (Zelenka et al., 1988), suggesting other alterations in brain centers associated with feed intake behavior.

Dwarf and nondwarf chickens from the same lines investigated by Burkhart et al. (1983) were used by Gidlewski et al. (1982) to measure feed consumption when liquid intake was provided as 0, 10, or 20% solutions of glucose. Although normal and dwarf chickens responded similarly within a line, time required to achieve isocaloric intake was 15 days in the low and 30 days in the high line.

Selection for body weight, in addition to altering appetite, modifies feeding rhythms. Broilers, but not White Leghorns, eat to near gut capacity (Nir et al., 1978). Using the Virginia Tech body weight lines, Barbato et al. (1980) observed that differences in body weight closely paralleled differences in feed consumption. Although meal size was similar for the selected lines, chicks from the high line ate more meals and spent less time in nonconsummatory feeding behavior than those from the low line. Differences in feeding behavior and feed consumption between these lines were present at hatch, suggesting major

genetic differences between the lines for these characteristics (Barbato et al., 1983; O'Sullivan et al., 1992a). Response of chickens from these divergently selected weight lines and their F₁ crosses to feed restriction regimes was also studied (Dunnington et al., 1987). Low weight line chicks were less able to compensate for feed restriction than cross or high weight line chicks, which were similar to each other and showed less periodicity for eating and drinking.

A condition observed in the line of chickens selected for low body weight discussed above is delayed sexual maturity, with the frequency of females exhibiting this condition varying among generations of selection (Siegel and Dunnington, 1987). Pullets which had not reached sexual maturity by 240 days of age were randomly assigned to one of two groups: one was force-fed (intubated to capacity two times per day) and the other was fed ad libitum (Zelenka et al., 1988). At an age when only 47% of the pullets fed ad libitum had entered lay, 92% of those force-fed had commenced egg production. They concluded that reduced feed consumption was the major cause of delay in achieving sexual maturity.

Behavioral responses of two commercial broiler parent lines to different dietary energy levels and to either ad libitum or alternate-day feeding were investigated by Boa-

Amponsem et al. (1991). Chicks from the faster growing line ate more often and exhibited less periodicity of feed consumption than those from the slower growing line. Meal size, however, was similar. Chicks of the two lines also responded differently to feed restriction. At five days of age, contents of the gastrointestinal tract were greater in the faster than the slower growing line when fed a higher nutrient density diet. There was no difference between the lines fed a lower nutrient density diet.

From the above literature, it is evident that variation exists among and within populations for feed intake behavior. These changes may occur as correlated responses to selection for growth and are evident throughout life.

Social Facilitation.

Social facilitation is "...a form of allelomimetic behavior in which the beginning of an activity or increased activity by one individual leads to similar behavior of others" (Craig, 1981). Effects of group size and social facilitation on feeding behavior have been studied within lines of chickens. White Leghorn chicks reared as pairs consumed more feed than those reared singly (Tolman, 1964). When tested under various conditions of social contact (isolation, visual contact, partial contact), chicks in complete contact with their companion consumed the most feed. Further investigation showed that beak pecking, a

behavior where the chick pecks at the beak of a feeding companion, was a key behavior in social facilitation. When a companion dropped some of its feed, the feed was consumed by its penmate. Beak pecking may also be elicited by tapping a pencil, which apparently creates a response similar to that of a companion. In a subsequent study with White Leghorns, Tolman and Wilson (1965) observed that the feeding behavior of a chick was influenced by the feed deprivation state of its companion. Although satiated chicks ate in the presence of a feed-deprived companion, their feeding behavior was not further influenced by increasing the number of deprived companions. When deprived and satiated chicks were paired, the former consumed no less feed than when paired with another deprived companion. In another study, Tolman (1968) observed that feeding behavior could be stimulated by nonfeeding activity of a companion. While visual contact was sufficient to elicit social facilitation, the extent was less than for complete social contact. Franchina et al. (1986) reported that White Leghorn chicks drank more in the presence of companions than alone, regardless of whether or not the companions were drinking. These results agree with the findings of Tolman (1968) on the influence of flockmates on eating behavior.

Effects of social facilitation on eating behavior, body weight, and livability have been studied among stocks of

chickens and classes of poultry. When broilers and White Leghorns were reared in the same flock, body weights of broilers were heavier and those of White Leghorns were lighter than those reared in stock-separated flocks (Savory, 1975a). Method of rearing modified behaviors of both stocks with broilers consuming meals of longer duration and Leghorns resting more in intermingled than stock-separated flocks. When turkeys and broilers were reared together, turkeys were heavier in intermingled than in separated flocks at four weeks, but not at older ages (Savory, 1982). Body weights of broilers were similar in intermingled and separated flocks. Intermingling had no influence on livability of either broilers or turkeys.

The influence of social facilitation on feeding behavior has been questioned by Hughes (1971) and Savory (1975b). Studying broilers housed in individual cages, Hughes (1971) observed that they performed the same behaviors at the same time (allelomimetic behavior) including feeding. Hughes did not attribute the allelomimetic behavior to social facilitation because he felt the cause was an external factor; i.e., the photoperiod. Feeding behavior and growth of Brown Leghorn chicks and chicks obtained from a cross of Rhode Island Red by Light Sussex were measured by Savory (1975b). Chicks from both stocks reared in groups of 2, 4, or 8 grew faster

to 42 days of age than those reared in single cages. He attributed this difference to superior feed efficiency, not to feed intake as was proposed from studies with White Leghorns (Tolman, 1964). Yet, chicks reared in groups of 8 consumed more feed to 42 days of age than those reared as pairs which, Savory suggested, could be due to social facilitation. Also, chicks tended to eat as a group rather than separately, and this he attributed to allelomimetic behavior rather than to social facilitation. Meunier-Salaun and Faure (1984) investigated the influence of flock size during rearing, previous acquaintance, and partitioning of feeder space on feeding behavior of White Leghorn hens. Social attraction played an important role in the feeding behavior, however, whether or not this was due to social facilitation was not discussed.

Because chickens are social animals, behaviors exhibited by an individual are not necessarily independent of those exhibited by its flockmates. From the previous discussion, it is evident that there is a lack of consensus among investigators on the roles of learning and innate behavior on social facilitation. Also, genetic variability within and between populations may complicate interpretation of stimulus-response interactions.

Sense of Taste.

Ingestive behavior can be influenced by the

palatability of feed and fluids. Flavor perceptions of humans and chickens do not necessarily correspond (Kare et al., 1957); and although chickens have only 24 taste buds (Kare and Beauchamp, 1984), their gustatory acuity is considerable (Kare and Medway, 1959). When chicks from a cross of Rhode Island Red by Barred Rock were offered a choice between water and a flavored solution, preference appeared to be more closely associated with presence rather than concentration of the test flavor. Appetite is also associated with taste preferences and ability to discriminate among different solutions. Gentle (1972) observed considerable individual variation in thresholds for discrimination among concentrations of glucose solutions for Brown Leghorns. Kare and Pick (1960) reported that Rhode Island Red by Barred Rock cross chicks exhibited greater sensitivity to flavors in fluids than in feed. Previously, using the same cross, Kare and Medway (1959) observed the use of faculties (e.g., osmotic pressure) other than what we consider as the sense of taste to discriminate between flavors. Acceptance or rejection of a carbohydrate depended more on the carbohydrate itself than on human perceptions of sweetness.

Effects of domestication on taste and feed intake indicate that while broilers show no preference for sucrose, Jungle Fowl prefer sucrose to water and are more adept at

regulating caloric intake than broilers (Kare and Maller, 1967). These results suggest that ability to regulate caloric intake has been altered during domestication. The alteration may be in modifications of thresholds because the Virginia Tech lines of White Rocks divergently selected for high and low body weight differed in sensitivity thresholds to dextrose and quinine sulfate (Barbato et al., 1982). Chickens from the high line were less sensitive to lower concentrations of dextrose and quinine sulfate in water than those from the low line. Crosses between these selected lines were intermediate in the threshold for which they showed an aversion to quinine sulfate or a preference for dextrose. These results imply that additive genetic effects were mainly responsible for preferences exhibited at intermediate levels of dextrose and quinine sulfate. Selection for high body weight appeared to elevate thresholds while, with selection for low body weight, thresholds were decreased.

Dietary Self-Selection.

Protein-energy. In commercial poultry production, it is common to feed a complete diet in the form of mash or pellets. This practice precludes the opportunity for individuals to select and balance their diets other than by altering total consumption. Leeson and Summers (1978) offered growing male turkeys a complete diet per NRC (1984)

recommendations or high energy/low protein and high protein/low energy split diets. To four weeks of age protein intake on the split diet was 36%, compared to 28% for the complete diet. Thereafter, consumption of protein was similar to NRC (1984) recommendation. There were no consistent effects on growth, feed efficiency, or carcass fat between the complete or split diet feeding regimes.

Broiler males were fed either a complete diet, a split diet of a high protein/low energy diet and a low protein/high energy diet, or the two split diets mixed together (Kaufman et al. 1978). Broilers fed split diets grew at nearly the same rate as those fed the complete diet, suggesting that the protein-energy intake system involves more than growth. Cowan and Michie (1978) fed broiler males and females a complete diet, split diets of whole wheat and a complete diet with the wheat removed, or split diets of whole wheat and a complete diet with all cereal grains removed. Broilers fed the complete diet were heavier than those fed split diets, even though levels of protein and energy intake were similar for both groups. These results were consistent with those of Kaufman et al. (1978) who showed that factors in addition to growth were involved in dietary self-selection of chickens.

Summers and Leeson (1978) fed broilers and White Leghorn pullets a complete diet or split diets of high

protein/low energy and low protein/high energy. Broilers fed the complete diet were heavier than those fed split diets. Although overall feed conversion was similar for both feeding regimes, efficiency of converting dietary protein to carcass protein was superior for the split than the complete diet. As with broilers, growth of White Leghorn pullets was more rapid under the complete than the split diet. They proposed that a slower more constant growth on the split diet than the complete diet better prepared the pullets for lay.

Effects of feeding a separate protein concentrate with a high or low energy diet have been studied with laying hens. Hens provided a choice consumed more energy and protein than those fed a low energy diet or a high energy diet alone (Balnave and Abdoellah, 1990). Egg mass was greater with a feeding regime of a protein concentrate with a high energy diet than for regimes with a protein concentrate with a low energy diet or a complete high energy diet.

In a long-term replicated selection experiment, Darden and Marks (1988) selected Japanese quail for high or low body weight on either split or complete protein/energy diets. Quail selected on the complete diet were heavier at four weeks of age than those selected on the split diet, implying that the complete diet was superior in allowing

expression of genetic potential for growth. Quail selected on the split diet laid heavier eggs in the 10th and 11th generations of selection and had a higher percentage of hatchability than those selected on the complete diet. When all lines were reared on the complete diet, those which had been selected on the complete diet were heavier than those selected on the split diet. When all lines were reared on the split diet, body weights were similar for the high lines, while for the low lines, quail selected on the complete diet were heavier than those selected on the split diet.

Self-selection of protein and energy in the Virginia Tech high and low body weight lines was observed by Huey et al. (1982). Chickens from the high line consumed more protein and those from the low line consumed more energy when provided a split rather than a complete diet. There was periodicity for protein consumption in the high line, and periodicity for energy consumption in the low line. In a subsequent study with these lines, Brody et al. (1984) measured dietary self-selection in the presence of either a glucose solution or water. High-line chickens consumed more feed on an absolute basis, but less on a metabolic basis than those from the low line. When fed complete diets, high-line chickens consumed less feed when the fluid offered was glucose rather than water. A glucose versus water

effect on feed consumption was not evident in the low line. Although chickens from the low line preferred glucose to water, there was no preference by high-line chickens at the concentration used. In addition, low-line chickens ate less protein on a split than on a complete diet, which was consistent with results reported by Huey et al. (1982).

Minerals. Presence of an egg in the oviduct influences calcium intake. Although mechanisms involved are not known, calcium intake increases during the period of shell formation (Hughes and Wood-Gush, 1971a). Therefore, it was not surprising that when laying hens were offered diets differing in levels of calcium, discrimination among diets was almost immediate (Holcombe et al., 1975). Previously, Hughes and Wood-Gush (1971a) proposed that calcium appetite was a learned behavior and that taste cues alone were sufficient for discrimination. Visual cues such as supplementing calcium via oyster shells may complicate recognition of different diets.

Hughes and Wood-Gush (1973) measured stereotypic activity in White Leghorns fed diets deficient in either calcium or sodium chloride. Hens fed deficient diets transversed the cages more, exhibited more air pecks, and pecked more at novel objects than those fed the adequate diets. Use of stereotypies to diagnose nutrient deficiencies was questioned by Cherry et al. (1984) who

concluded that behavioral responses in White Leghorn males which may be interpreted as being symptomatic of nutrient deficiencies also occurred when no overt deficiency was present. Previously, Hughes and Wood-Gush (1971b) investigated dietary choices for sodium chloride and thiamine in White Leghorns. Hens fed diets deficient in thiamine exhibited an appetite for thiamine when presented with a choice of an adequate and deficient diet. They proposed that appetite was a learned behavior. Hens fed sodium-deficient diets did not show a preference for sodium in the diet and avoided sodium in drinking water when water without sodium was available.

Amino Acids. Appetites for specific amino acids have been investigated mainly in rats. Rogers and Harper (1970) fed rats a diet adequate in all amino acids except histidine. Within three days of being offered a choice between water and a histidine solution, rats drank more of the histidine solution than water. When offered a choice between a histidine-HCl solution and a hydrochloric acid solution, there was a preference for the former, but only after five days, suggesting that taste cues play a role in the choice process. Leung et al. (1968) reported that rats rejected a threonine-deficient diet in favor of a protein-deficient diet. They proposed that consuming an amino acid imbalanced diet produced an unfavorable effect on the rat

and that the response to the imbalanced diet appeared to be learned.

Ability of broilers to balance lysine intake was investigated by Newman and Sands (1983), who found that, although chicks detected a deficiency, they did not balance their diet when offered the needed ingredients in crystalline form. In contrast, after being fed methionine-deficient diets, broilers effectively discriminated among diets differing in methionine content (Steinruck et al., 1990a). Learning appeared to play a role in the preference, because broilers maintained in groups were better able to discriminate among diets than those kept in individual cages. In another study, Steinruck et al. (1990b) measured the effect of changing feeder position on the ability of broilers to discriminate among diets varying in methionine content. Broilers were given a choice between adequate and methionine-deficient diets, and periodically, feeder positions were changed. Evidence was obtained showing some reliance on spatial memory aids or cues.

Hens from the Virginia Tech body weight lines consumed more of a diet low in methionine than a diet with medium or high levels of methionine (Cherry and Siegel, 1981). This pattern was observed within the first week of the experiment in normal and dwarf hens. Even though they consumed more feed, hens fed the low methionine diet did not have heavier

body weights, lay larger eggs, or have higher egg production than those fed the other diets. In contrast, light laying hybrid hens required eight weeks to discriminate between diets based on the dietary content of methionine (Roth et al., 1990). Preference for the adequate diet was not evident until after the appearance of deficiency symptoms.

Excessive amounts of amino acids in the diet influenced weight gain, feed consumption, gain-to-feed ratio, and dietary preference in New Hampshire by Columbian cross chicks (Edmonds and Baker, 1987). Growth was reduced when diets containing 4% additional methionine, phenylalanine, or tryptophan were fed. When given a choice among diets, chicks chose a 4% excess lysine over the basal diet, which was preferred over the other diets with excess amino acids. When offered a choice between either a 4% excess of lysine or 4% excess of leucine, chicks showed no avoidance of either diet. They concluded that cross breed chicks discriminated among diets based on dietary amino acid content.

The literature just reviewed shows that there is considerable variation in dietary self-selection both among and within genetic stocks of chickens. There is also variation for preference of specific nutrients, which is modified by prior experience and nutritional state. Because of this complexity, research should be multifaceted to

delineate between specific and generalized results.

Genotype by Nutrition Interactions.

Genotype by environment interactions occur when strains or breeds perform differently, relative to each other, in differing environments (Craig, 1981). Environments may be very general such as location, or more specific such as nutritional regimes. This thesis will discuss genotype by nutrient interactions, especially amino acids.

Marks et al. (1969b) reported that although stock by dietary protein level interactions were significant for several egg production traits, their importance to breeding programs was minimal, because they accounted for less than 7% of the variation. In broilers, stock by dietary protein level interactions were not significant and accounted for less than 2% of the variation (Marks et al., 1969a). Using normal and dwarf populations of the Virginia Tech body weight lines, Cherry et al. (1978) studied the effect of the sex-linked dwarfing gene, genetic background, and nutrient density of the diet on egg formation. Genotype (normal versus dwarf) by nutrient density interactions were minor for egg component traits, while significant for egg weight. Feeding the high density diet reduced egg weights in normal pullets, while increasing egg weights in dwarf pullets.

In a study of eight broiler stocks fed either a diet high or low in methionine and lysine, stock by diet

interactions were generally not significant for growth associated traits (Siegel et al., 1984). When two broiler crosses were fed five levels of lysine (Acar et al., 1991), there were stock by lysine level interactions for abdominal fat, breast fillet yield, and tenders (*Pectoralis minor*) yield. Stock 1 had higher breast fillet yield, higher tenders yield, and less fat than Stock 2 when the lysine level of the diet was .85%. With lysine as 1.15% of the diet, there were further increases in breast fillet and tenders yield and a decrease in abdominal fat in Stock 1 with an opposite effect in Stock 2. In a similar study, differences were found among eight broiler stocks for live performance, further-processing yield, and response to additional dietary lysine (Bilgili et al., 1992). Differences in response to dietary lysine among stocks were attributed to one stock having a much greater increase in weight gain when fed a .95% than a .85% lysine diet than the other stocks. Differences in live performance and further-processing yield were attributed to differences in growth rate and body weight at market age.

Genotype by nutrition interactions vary in importance depending on stocks or lines, nutrients in question, and husbandry practices. For this reason, what is "best" or "optimum" should be qualified by production goals and circumstances at the time.

EXPERIMENT I. INGESTIVE BEHAVIOR AND GROWTH WHEN CHICKS
FROM LINES DIFFERING IN FEED CONSUMPTION
ARE REARED SEPARATELY OR
INTERMINGLED

INTRODUCTION

Factors which may influence growth and ingestive behaviors of chicks include social facilitation (Craig, 1981). In chickens with similar growth potential, social facilitation may increase ingestive behaviors (Tolman, 1964; 1968; Tolman and Wilson, 1965; Meunier-Salaun and Faure, 1984; Mills and Faure, 1989), or its effects may be minimal (Hughes, 1971; Savory, 1975a). Genetic variation exists for feed intake of chickens (Marks, 1991). Feeding behaviors differ among genetic lines selected for differences in body weight (Barbato et al., 1980), with broilers but not Leghorns eating at near gut capacity (Nir et al., 1978). Comparing growth and behaviors of broilers and Leghorns reared in stock-separate and stock-intermingled flocks, Savory (1975a) reported that broilers consumed meals of longer duration and Leghorns rested more in intermingled than stock-separate flocks. He also observed that intermingling increased body weights of broilers and decreased those of Leghorns.

In commercial turkey flocks, some poults fail to eat and/or drink. Savory (1982) reared poults and broilers together and separately. At four weeks, but not at older ages, turkeys reared with broilers were heavier than those not reared with broilers. There was no effect on body weights of broilers in intermingled or separate flocks

(Savory, 1982). Intermingling had no influence on livability of either broilers or turkeys.

Lines of White Plymouth Rocks selected for high and for low juvenile body weight differed in feeding behavior and feed consumption at hatching and at older ages (Barbato et al., 1980; 1983; O'Sullivan et al., 1992a) with some individuals in the low line being anorexic (Zelenka et al., 1988). Although electrolytic lesioning of the ventromedial hypothalamus resulted in increased feed intake in the low line, such did not occur in the high line, suggesting altered satiety mechanisms (Burkhardt et al., 1983). Information on the influence of intermingling chicks with such behavioral differences in the same flocks is lacking. The experiment reported here measured effects of separate and intermingled rearing on livability, body weight, and ingestive behaviors of such genetic stocks in floor pens and in cages.

MATERIALS AND METHODS

Three trials were conducted using White Plymouth Rock chicks from lines that had undergone 33 generations of divergent selection for high (HW) or low (LW) body weight at eight weeks of age (Dunnington and Siegel, 1985). In each trial, chicks were reared in light-proof pens on wood shavings litter in floor pens or on wire floors in battery

cage units. Within a trial there were six floor pens: two with Line HW chicks, two with Line LW chicks, and two where chicks from the lines were intermingled. There were 12 pens within each cage trial: four with Line HW chicks, four with Line LW chicks, and four where chicks from the two lines were intermingled. Trials 1, 2, and 3 were conducted in March-April, June-July, and December-January, respectively.

For each trial, parents of chicks of both lines were the same age. At hatch, chicks were vaccinated for Marek's disease, wingbanded, and assigned to flocks. Twenty-four chicks were assigned to each floor pen in Trials 1 and 2 and 20 in Trial 3. Respective numbers for the cage pens were 12 and 10. Equal numbers of HW and LW chicks were started in the intermingled flocks. Prior to being placed in the intermingled pens, the body plumage of HW chicks was dyed to allow identification of lines during behavioral observations. Previous trials using this procedure showed no effect of dye on behaviors, growth, or livability. Moreover, there was no need to dye the feathers a second time for an experiment of this length.

Chicks were fed a corn-soybean diet consisting of 24% protein and 3146 kcal of ME/kg of feed. Lighting was continuous and feed and water were available at all times. At 20 days of age, chicks in cages were transferred to larger cages in the same room. Timing of routine care of

the chicks was varied to reduce the probability that chicks would perceive a time schedule and exhibit periodicity. The feed supply was adequate so that chicks did not have to be fed daily. Flocks were located in remote sections of buildings to minimize contact with humans.

Chicks were individually weighed to the nearest g at 9, 20, and 30 days of age. The number of chicks eating and drinking was recorded in each pen at 0700, 0730, 1300, 1330, 1700, and 1730 hours at 3, 7, 14, and 28 days of age. Where lines were intermingled, data were obtained for each line. The measurement unit was the average for two observations taken at 30-minute intervals (e.g. 0700 and 0730). Chicks which died were weighed and sex was determined by gonadal examination. Sex of survivors was determined at the conclusion of each trial.

Prior to analysis, body weights were transformed to common logarithms and eating and drinking percentages were transformed to arc sine square roots. For each line within floor pens and within battery cages, body weights and ingestive behaviors were analyzed with separate vs. intermingled (flock), age, trial, and interactions among them as sources of variation. When interactions were significant, analyses were conducted within each main effect. For eating and drinking, time of day was included in the analysis. Livability to 30 days of age was analyzed

by Chi square within each line-housing environment subset. Significance was considered at $p \leq .05$.

RESULTS

Because interactions of age with the other main effects were significant for eating, drinking, and body weight, subsequent analyses were made within each age.

Livability.

Livability of HW chicks was similar in line-separate (S) and line-intermingled (I) flocks regardless of whether they were reared in cages (98 vs. 99%) or in floor pens (97 vs. 99%). While livability of Line LW chicks was similar for S and I flocks reared in floor pens (95 vs. 90%), in cages it was less for the S than for I flocks (82 vs. 94%).

Eating and Drinking.

There was no time of day effect for percentage of chicks eating or drinking, nor did time of day interact with the other main effects. For cage housing the percentage of Line HW chicks eating was similar for S and I flocks on Days 3, 14, and 28 days of age (Table 1). On Day 7, however, there was a trial by flock interaction due to a greater percentage of chicks eating in I than in S flocks in Trial 1, but not in Trials 2 or 3 (Table 2). For Line LW, the percentage of chicks reared in cages eating was similar for S and I flocks at 3 and 28 days of age. At 14 days,

however, the percentage of chicks eating was higher in the I than S flocks. As with Line HW chicks, there was a trial by flock interaction on Day 7 caused by more chicks eating in I than S flocks in Trial 1 with no difference in Trials 2 and 3.

For floor housing, the percentage of Line HW chicks eating was similar in S and I flocks at all ages (Table 1). In contrast, for Line LW chicks it was greater in I than S flocks on Days 3, 7, and 14 with a trial by flock interaction on Day 28. This interaction resulted from more chicks eating in the I than in the S flocks in Trial 1, but not in Trials 2 or 3 (Table 2).

In both lines percentages of cage-reared chicks drinking were similar in S and I flocks on Days 3, 14, and 28 with trial by flock interactions significant on Day 7 (Table 3). The cause of the interactions was the same for both lines with a higher percentage of chicks drinking in the I than in the S flocks in Trial 1, but not in Trials 2 or 3 (Table 4).

For chicks reared on the floor, percentages drinking were similar in S and I flocks on Days 3, 14, and 28 for Line HW and Days 3 and 28 for Line LW. On Day 14 a higher percentage of LW chicks were drinking in I than S flocks. Significant trial by flock interactions for both lines at 7 days were caused by a higher percentage of chicks drinking

in I than in S flocks in Trial 3, but not Trials 1 or 2.

Body Weights.

Body weights of cage-reared HW chicks were heavier at all ages in I than in S flocks (Table 5). For Line LW chicks in cages, body weights were similar in S and I flocks on Day 30 with trial by flock interactions present at Days 9 and 20. The interaction on Day 9 resulted from chicks in I flocks being heavier in Trial 3, similar in Trial 1, and lighter in Trial 2 than those in S flocks (Table 6). On Day 20 the interaction was caused by a lack of difference between S and I chicks in Trials 1 and 2 with those in I flocks heavier than those in S flocks in Trial 3 (Table 6).

For floor housing, body weights were similar regardless of whether or not chicks were in S or I flocks. The exception was HW chicks on Day 9 where a trial by flock interaction was caused by chicks from I flocks being heavier in Trial 1, lighter in Trial 2, and similar in Trial 3 to chicks in S flocks (Table 6).

DISCUSSION

Chicks are precocial at hatch (Craig, 1981), and social facilitation in seeking and consuming feed should have an important function under natural conditions. A chick pecks where its mother pecks, thus enhancing feeding behavior (Wood-Gush, 1971). In the absence of a hen, chicks rely

primarily on visual cues from other chicks and secondly on auditory cues (Tolman, 1967). In the present experiment efforts were made to minimize external influences that may contribute to periodicity in eating and drinking behaviors.

The lack of a time of day effect was consistent with results obtained in environmental chambers under continuous light and feed availability (May and Lott, 1992). Thus, behavioral modifications would mainly come from effects among flock mates. Chicks from Line HW have more meals and consume more feed than those from Line LW, while Line LW chicks exhibit more nonconsumatory feeding activity than Line HW chicks (Barbato et al., 1980). The probable reason that the percentage of chicks eating or drinking was equal to or greater in I than S flocks in all comparisons was social facilitation among genetic stocks.

Trial by S vs. I flock interactions were generally significant on Day 7, but not on Days 3, 14, or 28. It is of interest to speculate on why these interactions were prevalent at this age and not the other ages. The nutrient source of the developing chick embryo is the egg with the vitelline residue essentially utilized by three days posthatch (Nitsan et al., 1991). At hatching the chick has primarily a lipid-based metabolism and when placed on external sources of feed, there is a shift to a primarily carbohydrate-based metabolism (Duke, 1984). Also, shortly

posthatch dynamic changes occur in the digestive system (Nitsan et al., 1991, O'Sullivan et al., 1992b), allomorphic growth (Katanbaf et al., 1988; O'Sullivan et al., 1992b), immune response (Zander and Mallinson, 1991), and in thermoregulation (Dunnington and Siegel, 1984). Differences among genetic stocks in the maturation of these systems and differences among trials during this critical period could result in interactions among variables which may alter behaviors of chicks.

In this experiment, essentially all mortality was in Line LW, a line known to have individuals that are anorexic at older ages (Zelenka et al., 1988). Although feed and water were available at all times, the main reason for deaths was starvation, suggesting that anorexia may be present in some chicks at hatch. Percentages of Line LW chicks eating and drinking in S and I flocks were similar in cages, but on the floor, a consistently higher percentage of Line LW chicks were observed eating in I than S flocks. This indicates that social facilitation for ingestive behaviors may have been more prevalent in floor than in cage housing.






Cage-rearing broilers with Leghorns altered meal patterns of both stocks, increased body weight in broilers, and decreased it in Leghorns (Savory, 1975a). In the present experiment, intermingling of lines in cages, while

not influencing the percentages of chicks eating and drinking or body weights of Line LW chicks, resulted in heavier body weights of Line HW chicks. Intermingling of lines in floor housing had no influence on body weight, a result inconsistent with those obtained in cages in the present experiment or in those reported by Savory (1975a, 1982). There was, however, a higher percentage of Line LW chicks eating and drinking in I than in S flocks which was consistent with Savory's (1975a) observations of social facilitation. Perhaps the discrepancies in cage and floor housing in the experiments presented here were due to differences in initial space allowances (245 to 294 cm² per chick in cages and 1116 to 1340 cm² on the floor), which in turn influenced proximity to feed and water. These differences in area allowed Line HW chicks more absolute space per unit weight in I than in S flocks and in floor than cage housing. The differences may have been magnified by mortality because as Line LW chicks died in I flocks, more space was available for HW chicks. The results of this experiment show that ingestive behaviors, livability, and body weight may be affected by rearing lines of chickens with different eating behaviors either together or separately. These responses, however, are not independent of age, housing environment, and genetic stock.

SUMMARY

Ingestive behavior, livability, and body weight were measured in lines of chickens selected for high (HW) and low (LW) juvenile body weight and reared as line-separate (S) and line-intermingled (I) flocks in cages and floor pens. Percentages of chicks eating and drinking were similar or greater in I than S flocks. There were no trial by I vs. S flock interactions for these behaviors at 3, 14, and 28 days of age. On Day 7, however, several of these interactions were significant and possible causes for them are discussed. Line HW chicks reared in cages were heavier in I than in S flocks, whereas this treatment had no influence on body weights under floor rearing for Line HW or for Line LW chicks. Mortality for Line HW chicks was very low. Anorexia has been reported in Line LW, and death from starvation was greater in that line for S than I flocks in cages. This difference in mortality was not observed in floor pens. The results of this research suggest that ingestive behavior, livability, and growth may be influenced by intermingling chicks from genetic lines that differ in eating behaviors. The degree of influence, however, is not independent of age, housing environments, or genetic stock.

Table 1. Percentage of chicks eating at 3, 7, 14, and 28 days of age in line-separate and line-intermingled flocks by housing environment.

Housing	Line ¹	Flock ²	Age (days)			
			3	7	14	28
Cage	HW	S	8		12	7
		I	13		12	7
	LW	S	8		6*	10
		I	11		14	10
Floor	HW	S	3	4	5	6
		I	6	5	7	6
	LW	S	1	4	3	
		I	* 5	* 9	* 9	
Pooled S.E.M.			1	1	1	1

¹HW=high body weight line, White Plymouth Rocks; LW=low body weight line, White Plymouth Rocks.

²S=line-separate; I=line-intermingled.

Boxes denote significant trial by flock interactions (see Table 2).

*Adjacent percentages in a column are different ($p \leq .05$).

Table 2. Percentage of chicks eating where trial by flock interactions were significant.

Age	Housing	Line ¹	Flock ²	Trial		
				1	2	3
7	Cage	HW	S	8 ^a *	6 ^a	6 ^a
			I	32 ^a	6 ^b	6 ^b
		LW	S	15 ^a *	5 ^b	8 ^{ab}
			I	28 ^a	4 ^b	4 ^b
28	Floor	LW	S	2 ^b *	4 ^{ab}	8 ^a
			I	12 ^a	7 ^a	10 ^a

¹HW=high body weight line, White Plymouth Rocks; LW=low body weight line, White Plymouth Rocks.

²S=line-separate; I=line-intermingled.

*Adjacent percentages in a column are different ($p \leq .05$).

^{a-b}Percentages in a row with the same letter do not differ ($p > .05$).

Table 3. Percentage of chicks drinking at 3, 7, 14, and 28 days of age in line-separate and line-intermingled flocks by housing environment.

Housing	Line ¹	Flock ²	Age (days)			
			3	7	14	28
Cage	HW	S	4	□	4	1
		I	2	□	4	1
	LW	S	2	□	4	2
		I	1	□	4	1
Floor	HW	S	4	□	2	2
		I	6	□	3	3
	LW	S	2	□	1	0
		I	3	□	3*	1
Pooled S.E.M.			.3	.4	.3	.2

¹HW=high body weight line, White Plymouth Rocks; LW=low body weight line, White Plymouth Rocks.

²S=line-separate; I=line-intermingled.

Boxes denote significant trial by flocking interactions (see Table 4).

*Adjacent percentages in a column are different ($p \leq .05$).

Table 4. Percentage of chicks drinking where trial by flocking interactions were significant at seven days of age.

Age	Housing	Line ¹	Flock ²	Trial		
				1	2	3
7	Cage	HW	S	4 ^a *	5 ^a	2 ^a
			I	15 ^a	4 ^b	1 ^b
		LW	S	2 ^a *	2 ^a	3 ^a
			I	11 ^a	6 ^{ab}	2 ^b
	Floor	HW	S	4 ^a	2 ^a	2 ^a
			I	7 ^{ab}	3 ^b	10 ^a *
		LW	S	3 ^a	1 ^a	1 ^a
			I	4 ^b	1 ^b	9 ^a *




¹HW=high body weight line, White Plymouth Rocks; LW=low body weight line, White Plymouth Rocks.

²S=line-separate; I=line-intermingled.

*Adjacent percentages in a column are different ($p \leq .05$).

^{a-b}Percentages in a row with the same letter do not differ ($p > .05$).

Table 5. Mean body weights at 9, 20, and 30 days of age in line-separate and line-intermingled flocks by housing environment.

Housing	Line ¹	Flock ²	Age (days)			
			9	20	30	
Cage	HW	S	112 *	311 *	611 *	
		I	119	338	652	
	LW	S			124	
		I			121	
	Floor	HW	S		300	614
			I		302	612
LW		S	44	68	105	
		I	44	68	105	
Pooled S.E.M.			1	5	10	

¹HW=high body weight line, White Plymouth Rocks; LW=low body weight line, White Plymouth Rocks.

²S=line-separate; I=line-intermingled.

Boxes denote significant trial by flocking interactions (see Table 6).

*Adjacent means in a column are different ($p \leq .05$).

Table 6. Mean body weights of chicks where trial by flock interactions were significant at 9 and 20 days of age.

Age	Housing	Line ¹	Flock ²	Trial		
				1	2	3
9	Cage	LW	S	42 ^b	46 ^a	43 ^b
			I	44 ^b	43 ^b *	49 ^a *
	Floor	HW	S	107 ^b	124 ^a	113 ^b
			I	119 ^a *	117 ^a *	109 ^b
20	Cage	LW	S	75 ^a	77 ^a	78 ^a
			I	72 ^b	74 ^b	90 ^a *

¹HW=high body weight line, White Plymouth Rocks; LW=low body weight line, White Plymouth Rocks.

²S=line-separate; I=line-intermingled.

*Adjacent means in a column are different ($p \leq .05$).

Means in a row with the same letter do not differ ($p > .05$).

EXPERIMENT II. SHORT TERM FEED INTAKE
ADJUSTMENT OF CHICKS TO
A DEFICIENCY OF
LYSINE, METHIONINE, OR TRYPTOPHAN

INTRODUCTION

In the development of commercial chickens, geneticists emphasized either high egg production or rapid growth. At the same time, nutritionists formulated complete diets specifically for age classes of egg and meat stocks. Chickens (e.g., Cowan and Michie, 1978; Summers and Leeson, 1978; Kaufman et al., 1978; Huey et al., 1982; Balnave and Abdoellah, 1990), turkeys (Leeson and Summers, 1978), and Japanese quail (Darden and Marks, 1988) can discriminate between diets varying in protein and energy content. In his review, Hughes (1984) reported that individual variation, palatability, learning and prior experience, social factors, location of feeders, and metabolic and nutritional requirements played a role in dietary self-selection.

Information on feed preferences of chickens is generally lacking with few investigations involving specific amino acids (eg., Newman and Sands, 1983; Edmonds and Baker, 1987, Steinruck et al., 1990a; 1990b; Roth et al., 1990), with essentially none designed to detect genetic variation for diet choice. Picard (personal communication) demonstrated that, when effects of palatability were minimized, broilers were able to discriminate between a balanced diet and one deficient in lysine, methionine, and tryptophan. The experiment reported here measures the discriminatory, feed intake, and growth responses to diets varying in content of lysine, methionine, or tryptophan in

two genetic lines of chickens.

METHODS AND MATERIALS

Diets, Stocks, and Husbandry.

Raw ingredients and synthetic amino acids of diets (Table 7) followed those described by Picard (personal communication). Diet A, considered the balanced control diet, was supplemented with synthetic amino acids at the expense of corn starch to meet NRC (1984) recommendations for broiler starter diets. Diets L1 and L2 were considered balanced except for being slightly (~ 15%) and moderately (~ 30%) deficient in lysine, respectively. Similarly, Diets M1 and M2, and T1 and T2 were slightly and moderately deficient in total sulfur-containing amino acids (hereafter referred to as methionine) and tryptophan, respectively, but otherwise balanced. In contrast for layer chicks, Diets L2, M2, and T2 would be balanced for their respective amino acids and Diets L1, M1, T1, and A in excess of NRC (1984) requirements for layer starter diets.

The lines used in this experiment were White Plymouth Rocks (HW) that had undergone 33 generations of selection for high body weight at 56 days of age (Dunnington and Siegel, 1985) and White Leghorns (HA) selected for 17 generations for high antibody response to sheep erythrocytes (Martin et al., 1990). Parents of chicks used in the experiment were age-contemporaries reared under similar

husbandry. Chicks were removed from the hatcher, wingbanded, and randomly assigned by lines to pens in electrically heated brooder batteries. There were four replicate pens of each line-diet subclass for a total of 56 pens with six chicks per pen. Floor space allowance was 495 cm² per chick. Lighting was continuous with feed and water available at all times. Sufficient feeder space was allowed (10.5 cm per chick before a choice of feeds was offered and 5.5 cm per chick after a choice of feeds was offered) so that all chicks in a pen could eat simultaneously.

A corn soybean diet of 24% crude protein and 3146 kcal of ME / kg of feed was fed to Day 3, after which chicks were fed one of the seven diets described in Table 7 until Day 10. On Day 10, chicks that had been fed a deficient diet were given a choice between it and Diet A. The choice was presented by assigning at random one of the diets to one feeder and the other diet to the other feeder in that pen. Chicks reared on Diet A were offered that diet in two feeders. Location of feeders within a pen on Day 10 was not changed.

Traits Measured and Statistical Analyses.

Body weight of each chick was obtained at hatching and at 3, 10, and 16 days of age. Weight of feed consumed by each pen of chicks was obtained for the period from 3 to 10 days of age. Starting on Day 10 feeders were weighed at 0, 2, 4, 6, 12, 24, 48, 72, 96, 120, and 144 hours after the

chicks were given the choice of diets. Just prior to the time when feeders were weighed, the number of chicks eating from each feeder was recorded.

Body weights at three days of age were analyzed by analysis of variance with line as the main effect. At 10 and 16 days of age, line, diet, and the interaction between them were sources of variation. Feed consumption and feed efficiency (body weight on Day 10 divided by weight of feed consumed for the period from Day 3 to 10) were also analyzed by analysis of variance. When interactions between lines and diets were significant, comparisons were made within each line and within each amino acid. For these analyses, the same Diet A chicks were used in comparisons with diets deficient in each of the amino acids. Prior to analysis, weights were transformed to common logarithms and ratios to arc sine square roots.

To measure feed preferences when chicks were given a choice between two diets, feed intake was measured and the weight of each diet consumed during a fixed period was expressed as a ratio of total consumption; i.e., 50% would represent no preference. Comparisons were made within each line-amino acid subclass. Percentages were transformed to arc sine square roots and analysis of variance conducted within each line and amino acid with sources of variation being period (0-2, 2-4, . . . , 120-144), level of amino acid (deficient vs. balanced), and the interaction between them.

To measure feeding behavior, percentages of chicks eating from the feeders in each pen were transformed to arc sine square roots and analysis of variance conducted with time, level of amino acid (deficient vs. balanced), and the interaction between them as sources of variation. Significance was considered at $p \leq .05$.

RESULTS AND DISCUSSION

Body Weight, Feed Consumption, and Feed Efficiency.

When fed the corn-soybean starter diet, chicks from Line HW were heavier than those from Line HA (58 vs. 42 g) at three days of age. Chicks were then fed one of the diets described in Table 7. At 10 days of age the line by diet interaction was significant for body weight. Comparisons among levels of amino acid within lines showed that this interaction was due to similarity of body weights among diets for HA, but not for HW chicks (Table 8). Body weight rankings in Line HW were $L2 < L1 < A$ for lysine, $M2 < (M1 = A)$ for methionine, and $T2 = T1 = A$ for tryptophan. Regardless of diet, Line HW chicks were heavier than Line HA chicks.

Because feed efficiency involved body weight, analyses of feed efficiency and feed consumption were conducted within lines and amino acids. In all comparisons, feed consumption and feed efficiency were greater in Line HW than in Line HA (Table 8). Within Line HA, feed consumption was

lower for Diet L2 than L1 and A, and lower for T2 than T1 and A. There were no differences in feed consumption among levels of methionine in either line, nor were there differences in intake among either lysine or tryptophan levels for Line HW chicks. While level of tryptophan had no influence on feed efficiency of chicks from either line, responses of the lines differed for lysine and methionine. That is, while level had no effect in Line HA, feed efficiency was inferior for Line HW chicks fed Diets L2 and M2.

Differences between lines for body weight were also evident on Day 16, which was six days after chicks were given a choice of Diet A and the diet which they had been fed previously. Means were 246 and 114 g for Lines HW and HA, respectively. Again, there was no effect of diet on body weight in Line HA chicks (Table 9). For Line HW chicks, there was no difference between Diets L2 and L1 apparently because of the accelerated growth of chicks previously fed Diet L2. During this period their increase in body weight was 91% while those for Line HW chicks fed Diets L1 and A were 80 and 78%, respectively.

The results showed that the effect of slight to moderate reductions in dietary methionine, lysine, and tryptophan had different effects depending on genetic line. Using body weights, feed consumption, and feed efficiency as measurement criteria, the results are consistent with the

involvement of tryptophan in feed intake, lysine in protein synthesis, and methionine on various metabolic pathways including protein synthesis.

Feed Preferences.

Two procedures were used to measure feed preferences. In one, feed intake of Diet A was expressed as a proportion of total consumption for a specific period in each pen; i.e., 50% would indicate no preference. For the other procedure, the observational unit was the percentage of chicks in a pen eating from a feeder. Analyses were made within lines for each of the six choice situations (i.e., each deficient diet and the balanced diet). The results from both procedures were in general agreement.

For feed intake in Line HA chicks, there was no period effect, no period by diet interaction, and the only diet effect was between between M2 and A (Table 10) where preference for Diet A was 55%. In contrast, for Line HW the diet by period interactions were significant in 5 of 6 analyses (Table 10), implying that expression of preferences between diets was not consistent across periods. Accordingly, preference comparisons were made within each period and periods were compared within diets. These analyses revealed period effects and dietary preference effects. Overall preferences were 60 and 54% for Diet A with Diets L2 and L1, 56 and 56% for Diet A with M2 and M1, and 63 and 66% for Diet A with T2 and T1, respectively.

When viewed across periods (Figure 1), a general pattern emerged for Line HW for the three amino acids and the level of each in the diet. During the first few hours, chicks preferred the diet higher in the amino acid (Diet A). This was followed by either a lack of preference or, in the case of M2, L1, and L2, a preference for the deficient diet. Then there was a return to a preference for Diet A which persisted in all cases except for L1. These data suggested that adjustment to the deficiency was rapid with overconsumption, followed by compensation. Such adaptation required approximately 48 hours for lysine and tryptophan and 72 hours for methionine. Deficient levels of both methionine and tryptophan followed similar patterns. For lysine, the longer term effect appeared to differ in that at the slightly deficient level (L1) there was a lack of preference while at the moderately deficient level (L2) there was a preference for balanced Diet A.

The lack of preference by Line HA chicks and a preference by Line HW chicks probably reflected differences in nutrient requirements of Leghorns and faster growing White Rocks. Nir et al. (1978) reported that meat, but not Leghorn stocks, ate at near gut capacity. Preference patterns based on feed intake of Line HW chicks were consistent with those observed in broilers fed a diet deficient in lysine, methionine, and tryptophan (Picard, personal communication). Namely, after being fed a

deficient diet there was overconsumption of the balanced diet, followed by compensation with gradual adaptation. The rate and degree of adaptation may be variable depending on the role of the amino acid and the degree of deficiency. That is, lysine is mainly involved with protein synthesis (Scott et al., 1982), methionine acts on various metabolic pathways including protein synthesis (Scott et al., 1982), and tryptophan is mainly associated with neuromediators and hence dietary choices (Shea et al., 1991).

Also the general pattern of dietary preferences over time involves the metabolic state of the chick and its previous experience. In the choice setting, chicks were presented with both a familiar but nutritionally deficient diet and another diet which, while unfamiliar, met a physiological need. Although the physiological need for the amino acid may be stronger initially than neophobia of the unfamiliar diet, once the need is met, neophobia may again briefly come into play. By the end of 48 hours (lysine and tryptophan) or 72 hours (methionine), the chicks are addressing physiological needs and consuming less of the diet with the lower level of amino acid.

A lack of time by diet interactions for percentage of Line HA chicks eating (Table 11) was consistent with the lack of such interactions when amount of feed consumed was the measurement criterion for preference. Also, there were no diet effects with the exception that the percentage was

greater for Diet M1 than A (Table 12). Time effects for percentage of chicks eating were present in 4 of 6 cases (Table 11). These differences may be attributed to periodicity in feeding behavior and suggest that feed consumed during a period of time is a more reliable measure in experiments of this type than number of chickens exhibiting ingestive behavior at a specific point in time.

For Line HW chicks, there were no time by diet interactions (Table 11), a result consistent with that observed for Line HA chicks, but different from that obtained for Line HW chicks when preference was measured by feed intake. As with Line HA chicks, time had an effect on percentage of chicks at the feeder (Table 10) and reflected periodicity. There was a general pattern based on diet preference for percentage of Line HW chicks eating, with the percentage of chicks at the feeder containing the balanced diet, the same (2 of 6 comparisons) or greater (4 of 6 comparisons) than at the feeder with the lower level of amino acid (Table 12). These results are consistent with the greater overall consumption of the high amino acid feed.

General Comments.

The two lines used in this experiment responded differently in growth, feed consumption, feeding behavior, and preference choices to an adequate diet and diets deficient in lysine, methionine, or tryptophan. Responses were most evident in the faster growing White Rock Line HW.

The only indication of dietary deficiencies in White Leghorn Line HA was reduced feed consumption when fed diets moderately deficient in lysine (Diet L2) and tryptophan (Diet T2). Failure of Line HA chicks to discriminate among diets in choice feeding may not reflect an inability to discriminate between diets. Rather, the amino acid content of the so-called deficient diets may have been balanced for them as evidenced by a lack of differences in body weight when fed these diets from 3 to 10 days of age. Crossbred chicks are known to discriminate against amino acid excesses in the diet (Edmonds and Baker, 1987).

Although literature is limited, our results with breed differences tend to corroborate previous studies. Eight weeks were needed before light hybrid laying hens fed diets deficient in methionine chose the diet higher in methionine (Roth et al., 1990). By that time, deficiency symptoms had appeared. In contrast, White Rock laying hens adjusted their feed intake to varying levels of methionine within one week (Cherry and Siegel, 1981). White Leghorn Line HA chicks used in this experiment appeared to have neither sufficient time nor deficiency symptoms to exhibit dietary choices.

Broilers chose a diet higher in methionine without a period of deficiency, but chicks which were fed a deficient feed chose a higher ratio of the feed with more methionine (Steinruck et al. 1990b). Previously, Steinruck et al.

(1990a) reported that while broilers generally followed gustatory cues, they also relied somewhat on spatial memory aids. Picard (personal communication) observed with monofeeding that broilers consumed more of a balanced diet than a diet deficient in lysine, methionine, and tryptophan during the first 24 hours posthatch. Although broilers could select between diets based on lysine content (Newman and Sands, 1983), they could not balance their needs when offered crystalline lysine. This may be due to a palatability factor (Hughes, 1984). The experiment reported here, however, attempted to preclude palatability as a factor, thus making the nutrient state of the animal and its previous experience the major factors in diet choice.

SUMMARY

Growth, feed intake, and feed preference were measured in two experimental lines of chickens fed diets varying in content of lysine, methionine, or tryptophan. Lines were White Leghorns selected for high antibody response to sheep erythrocytes and White Rocks selected for high eight-week body weight. Diet A was balanced for all amino acids, while the remaining six diets were slightly (~ 15%) or moderately (~ 30%) deficient in either lysine, methionine, or tryptophan. All chicks were fed a balanced commercial broiler starter diet to three days of age. Chicks were then fed one of the experimental diets from 3 to 10 days of age,

at which time a choice was offered between Diet A and the diet that was fed previously.

Body weight and feed efficiency of White Leghorns at 10 days of age were not affected by diet. In contrast, deficiencies of lysine or methionine had a negative effect on these traits in White Plymouth Rocks. Tryptophan deficiency reduced feed intake of White Leghorns, but not White Plymouth Rocks. With choice feeding from Day 10 to 16, there were considerable differences between lines. While preferences were minimal in White Leghorns, they were evident in White Rocks with an almost immediate preference for the balanced diet, followed by a lack of preference or a preference for the deficient diet. By 72 hours for lysine and tryptophan, and 96 hours for methionine, the preference for the balanced diet over the moderately deficient diet became consistent. Among slightly deficient diets, a preference for the balanced diet was expressed for methionine and tryptophan, but not lysine. The data suggest that in some genetic stocks there is rapid adjustment to deficiencies in these amino acids with overconsumption, followed by compensation and fine-tuning for the preference of the balanced diet. The results indicate that the nutrient state of the animal and its previous experience are major factors in diet choice.

Table 7. Experimental diets¹.

Ingredients	Composition (g/kg) ²						
	A	L2	L1	M2	M1	T2	T1
Ground corn	667						
Peanut meal	180						
Gelatin	50						
Soybean oil meal	40						
Limestone	11						
Dicalcium phosphate	23						
Salt	3						
Vitamin mix ³	5						
Trace mineral mix ⁴	1						
L-threonine	2.5						
L-isoleucine	2						
L-valine	1						

Corn starch	2.3	7.0	4.6	5.1	3.7	3.0	2.6
L-lysine HCL	7.0	2.3	4.7	7.0	7.0	7.0	7.0
DL-methionine	4.2	4.2	4.2	1.4	2.8	4.2	4.2
L-tryptophan	1.0	1.0	1.0	1.0	1.0	.3	.7
<u>Analyzed nutrient content (g/kg)</u>							
Crude protein	201	205	205	205	205	206	204
Lysine	12.9	9.2	11.1				
Methionine	8.5			4.4	5.8		
Cystine	2.3			2.3	2.2		
Tryptophan	2.3					1.7	1.8

¹A=balanced diet; L, M, and T represent diets moderately (2) and slightly (1) deficient in lysine, methionine, or tryptophan, respectively.

²Composition of diets above the dashed line is the same for all diets.

³Vitamin mix provided per kg of diet: vitamin A, 10,000 IU; cholecalciferol, 1500 IU; vitamin E, 15 IU; vitamin B₁₂, .008 mg; thiamine, .5 mg; riboflavin, 4 mg; d-pantothenic acid, 8 mg; niacin, 25 mg; pyridoxine, 1 mg; folic acid, .2 mg; biotin, .1 mg; menadione sodium bisulfite complex, 5 mg; and choline chloride, 500 mg.

⁴Trace mineral mix provided per kg of diet: manganese, 110 mg; iron, 35 mg; zinc, 100 mg; copper, 9 mg; iodine, 1.3 mg; cobalt, .9 mg; and selenium, .15 mg.

Table 8. Mean body weights at 10 days of age and feed consumption and efficiency from 3 to 10 days of age by line¹ and diet².

Diet	Body Weight ³		Feed consumption		Feed efficiency	
	HA	HW	HA	HW	HA	HW
L2	72 ^a	123 ^c	357 ^b	558 ^a	.37 ^a	.59 ^b
L1	76 ^a	130 ^b	416 ^a	604 ^a	.36 ^a	.63 ^a
A	74 ^a	141 ^a	441 ^a	652 ^a	.33 ^a	.65 ^a
M2	74 ^a	133 ^b	432 ^a	662 ^a	.35 ^a	.61 ^b
M1	74 ^a	144 ^a	445 ^a	734 ^a	.36 ^a	.65 ^a
A	74 ^a	141 ^a	441 ^a	652 ^a	.33 ^a	.65 ^a
T2	72 ^a	136 ^a	372 ^b	633 ^a	.36 ^a	.65 ^a
T1	71 ^a	138 ^a	459 ^a	634 ^a	.31 ^a	.65 ^a
A	74 ^a	141 ^a	441 ^a	652 ^a	.33 ^a	.65 ^a

¹HA = high antibody line, White Leghorns; HW = high body weight line, White Plymouth Rocks.

²A = balanced diet; L, M, and T represent diets moderately (2) and slightly (1) deficient in lysine, methionine, or tryptophan, respectively.

³Line by diet interaction was significant for body weight but not for feed consumption or feed efficiency.

^{a-c}Means within a line-amino acid subclass with the same letter do not differ ($P > .05$).

All differences between lines were highly significant ($P \leq .01$).

Table 9. Mean body weights at 16 days of age and % change in body weight between 10 and 16 days of age by line¹ and diet².

Diet	Body Weight (g)		% change in Body Weight ³	
	HA	HW	HA	HW
L2	111 ^a	235 ^b	54 ^a	91 ^a
L1	118 ^a	235 ^b	55 ^a	80 ^b
A	112 ^a	251 ^a	51 ^a	78 ^b
M2	117 ^a	244 ^b	58 ^a	84 ^a
M1	115 ^a	259 ^a	55 ^a	80 ^a
A	112 ^a	251 ^{ab}	51 ^a	78 ^a
T2	112 ^a	245 ^a	56 ^a	80 ^a
T1	111 ^a	252 ^a	56 ^a	82 ^a
A	112 ^a	251 ^a	51 ^a	78 ^a

¹HA= high antibody line, White Leghorns; HW = high body weight line, White Plymouth Rocks.

²A = balanced diet; L, M, and T represent diets moderately (2) and slightly (1) deficient in lysine, methionine, or tryptophan, respectively.

³(Day 16 body weight - Day 10 body weight) / Day 10 body weight.

^{a-b}Means within a line-amino acid subclass with the same letter do not differ (P > .05).

All differences between lines were highly significant (P < .01).

Table 10. Analyses of variance for feed preference as measured by feed consumed during specific time periods for each line and diet comparison.

Line ¹	Source of variation	Amino acid		
		Lysine	Methionine	Tryptophan
HA	Diet ²	NS	*	NS
	Period	NS	NS	NS
	Interaction	NS	NS	NS
	Diet ³	NS	NS	NS
	Period	NS	NS	NS
	Interaction	NS	NS	NS
HW	Diet ²	**	**	**
	Period	NS	NS	NS
	Interaction	**	**	NS
	Diet ³	NS	**	**
	Period	NS	NS	NS
	Interaction	**	**	**

¹HA= high antibody line, White Leghorns; HW= high body weight line, White Plymouth Rocks.

²Moderately deficient vs. balanced diet.

³Slightly deficient vs. balanced diet.

* $P \leq .05$; ** $P \leq .01$; NS = $P > .05$.

Table 11. Analyses of variance for feed preference as measured by % of chicks eating at specific times for each line and diet comparison.

Line ¹	Source of variation	Amino acid		
		Lysine	Methionine	Tryptophan
HA	Diet ²	NS	NS	NS
	Time	**	*	NS
	Interaction	NS	NS	NS
	Diet ³	NS	**	NS
	Time	NS	**	**
	Interaction	NS	NS	NS
HW	Diet ²	NS	*	**
	Time	**	NS	**
	Interaction	NS	NS	NS
	Diet ³	*	**	NS
	Time	**	*	**
	Interaction	NS	NS	NS

¹HA= high antibody line, White Leghorns; HW= high body weight line, White Plymouth Rocks.

²Moderately deficient vs. balanced diet.

³Slightly deficient vs. balanced diet.

* $P \leq .05$; ** $P \leq .01$; NS = $P > .05$.

Table 12. Percentage of chicks from each line observed eating in a paired choice situation: Diet A and a diet lower in content of either lysine, methionine, or tryptophan by line¹.

Comparison ² with Diet A	Line					
	HA			HW		
L2	13	NS	13	16	NS	15
L1	12	NS	10	20	**	14
M2	7	NS	10	20	*	13
M1	6	**	14	16	*	10
T2	11	NS	7	20	**	11
T1	12	NS	10	16	NS	14

¹HA= high antibody line, White Leghorns; HW= high body weight line, White Plymouth Rocks.

²For each pair comparison the percentage for Diet A is given first. A = balanced diet; L, M, and T represent diets moderately (2) and slightly (1) deficient in lysine, methionine, or tryptophan, respectively.

*P ≤ .05; ** P ≤ .01; NS = P > .05.

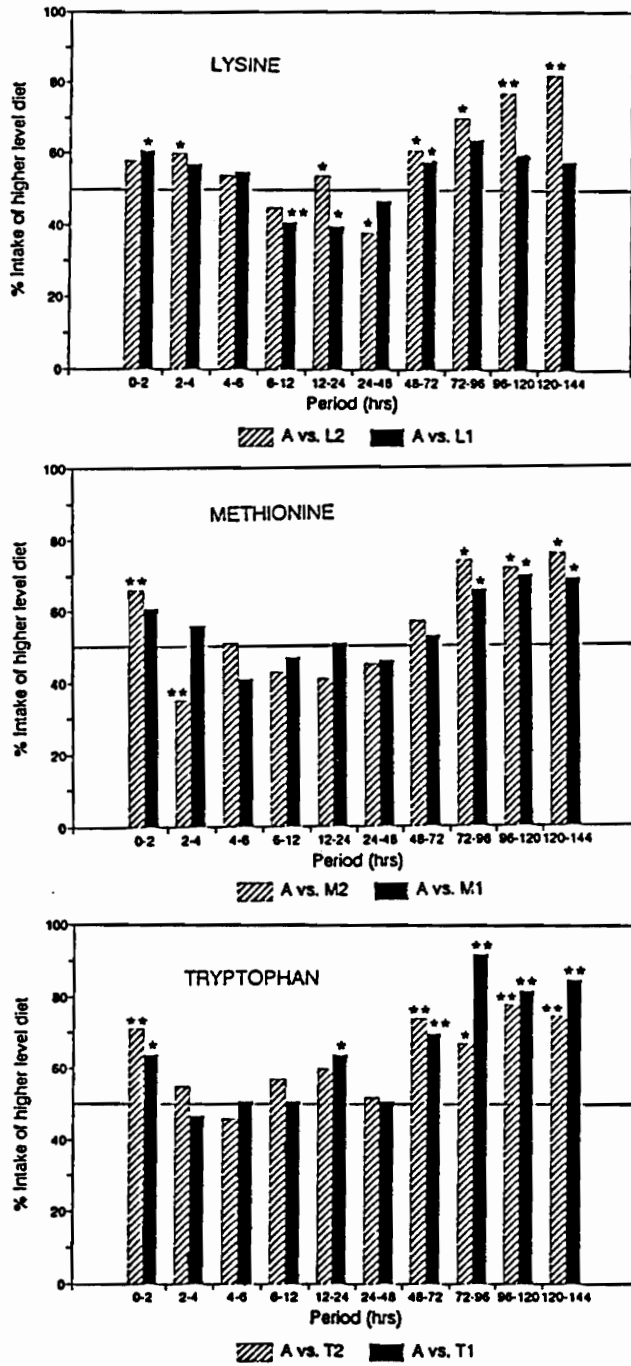


Figure 1. Preference in Line HW (high body weight line, White Plymouth Rocks) for the balanced diet (A) to those slightly (1) or moderately (2) deficient in lysine (L), methionine (M), or tryptophan (T) (* $p < .05$; ** $p < .01$).

EXPERIMENT III. SELF-SELECTION AMONG DIETS DIFFERING
IN METHIONINE CONTENT BY CHICKENS
OF DIFFERENT LINES

INTRODUCTION

After a period of deficiency, discrimination between a balanced diet and diets deficient in either lysine, methionine, or tryptophan was observed in a White Plymouth Rock, but not a White Leghorn line (Experiment II). The experiment reported here expands on these results by measuring the discriminatory responses of the same White Leghorn (HA) and White Plymouth Rock (HW) lines and in a second line of White Plymouth Rocks (LW) to three levels of methionine used in the previous experiment. In Trial 1, rather than use a deficient diet initially, Line HA and Line HW chicks were offered a choice of three diets differing in methionine content from 1 through 7 days of age. From 8 to 10 days of age some flocks continued to receive dietary choices, while others were monofed each diet. In Trial 2, chicks from Lines HW, HA, and LW were offered a choice of three methionine diets from 1 through 13 days of age. They were then monofed the diet lowest in methionine for six days, after which they were again offered a choice of three diets for four days.

METHODS AND MATERIALS

Trial 1. Diet, Stocks, and Husbandry.

Ingredients and synthetic amino acids used in the diets fed in this experiment were the same as Diets A, M1, and M2

in Experiment II (Table 7). Chicks from Lines HW and HA (described in Experiment II) were removed from the hatcher, wingbanded, and randomly assigned to pens in electrically heated brooder batteries with wire floors. There were eight pens of each line (16 pens total) with six chicks per pen. Floor space was 495 cm² per chick, waterer space was 5 cm per chick, and three feeders in a row provided a total of 8.5 cm of feeder space per chick.

Chicks were fed a corn-soybean diet of 24% protein and 3146 kcal of ME / kg of feed on the day of hatch. From 1 through 7 days of age, chicks in each pen were offered a choice of Diets A, M1, and M2. From Day 8 to 10, two pens of chicks from each line were fed either Diet A, M1, or M2, while two pens continued to have a choice of three diets.

Traits and Analyses- Days 1 through 7.

Feed consumption of each pen of chicks was obtained daily for seven consecutive days. Feeders were weighed between 0800 and 0830 hours and their location changed. The procedure involved randomly assigning a position to the feeder containing each diet in a pen the first day and then rotating its position clockwise each time the feed was weighed. Dietary preferences were analyzed by analysis of variance as daily intake of each diet. Sources of variation were line, day, diet (level of methionine), and the interactions among them. When interactions were

significant, data were analyzed within each main effect. When a main effect was significant, comparisons among means were made using Duncan's multiple range test. Feed intake was transformed to common logarithms prior to analysis. Daily total feed and total methionine intake, as well as intake of each diet were regressed on days.

Traits and Analyses- Days 8 and 9.

Feed intake was measured for the 48 hours after the feeding regimes were changed. Data were analyzed by analysis of variance with feeding regime (choice and each diet monofed), line, and the interaction between them as the sources of variation. For pens which continued on choice feeding, intake was also analyzed with level of methionine (diet), line, and the interaction between them as sources of variation. Body weights were obtained at 8 and 10 days of age and the change in body weight during this period was analyzed by analysis of variance with feeding regime, line, and the interaction between them as sources of variation. Weight change and feed intake were transformed to common logarithms prior to analysis. When a main effect was significant, comparisons among means were made using Duncan's multiple range test.

Trial 2. Diets, Stocks, and Husbandry.

Diets and husbandry used in this trial were the same as in Trial 1. In addition to Lines HA and HW, a White

Plymouth Rock line (LW) selected for low body weight at eight weeks of age (Dunnington and Siegel, 1985) was included. At hatch, chicks from each line were wingbanded and randomly assigned to nine pens (27 pens total) with six chicks per pen.

After receiving the same corn-soybean diet as in Trial 1 on the day of hatch, chicks were offered a choice of Diets A, M1, and M2 from 1 through 13 days of age. On Day 14, only Diet M2 was fed for six days after which the choice of the three diets was offered for four days (to 24 days of age).

Traits and Analyses.

Intake of each diet was measured daily by pen, with feeders weighed between 0800 and 0830 hours and rotated as in Trial 1. For Days 1 through 13, and 20 through 23, intake was analyzed by analysis of variance with line, day, diet, and interactions among them as sources of variation. For Days 14 through 19 when chicks were fed only Diet M2, sources of variation were line, day, and the interaction between them. Prior to analysis, data were transformed to common logarithms. When interactions were significant, analyses were made within each main effect. When a main effect was significant, comparisons among means were made using Duncan's multiple range test. Polynomial regression models were fitted for feed and methionine intake. Model

selection was based on r^2 values and the significance levels of the regression coefficients.

RESULTS

Trial 1.

Because preliminary analyses of variance revealed several significant interactions between line and other main effects, subsequent analyses were conducted within each line. There was no preference among diets by Line HA chicks from Days 1 through 7 (Table 13). Regressions of daily feed intake on days were similar for all diets and were significantly different from zero. Regressions of methionine intake for each diet were also significant. The similarity among diets to this age is an artifact because differences among diets were becoming greater.

In contrast to Line HA chicks, day by diet interactions were significant for feed intake of Line HW chicks. These interactions resulted from chicks exhibiting no preferences among diets to five days of age and inconsistent preferences thereafter (Table 14). There was also a significant interaction of day by diet for methionine intake. This was due to the consistently higher intake for Diet A and day to day fluctuations for Diets M1 and M2. Regressions of daily methionine intake on days were all positive, different from zero and from each other.

During Days 8 and 9, when some pens were not given a choice but were monofed one of the three diets, there were no differences among diets for either feed intake or change in body weight of HA chicks (Table 15). Also during these days, there was no preference for any diet for chicks from this line which continued on choice feeding (data not shown). While feed intake was similar among feeding regimes for Line HW chicks, methionine intake and body weight change differed (Table 15). Chicks monofed Diet A consumed more methionine than those offered a choice, or those monofed Diets M2 or M1. Although the latter two groups were similar, intake of methionine was less than when allowed a choice of diets. Chicks monofed Diet M1 gained less weight on Days 8 and 9 than those on the other regimes. Chicks which continued to have a choice of diets consumed more of Diet A than Diets M1 or M2 (data not shown).

Trial 2.

As in Trial 1, data in this trial were analyzed within each line because of significant interactions between lines and other main effects. Through day 13, day by diet interactions for feed intake were significant for HW, but not HA and LW chicks. The day by diet interaction for HW chicks was caused by their exhibiting a choice among diets for Days 5, 6, 7, 9, 10, and 11, but not on other days (Figure 2). The choice of diets however, was not consistent

on days when choice was available. No preferences among diets were observed through Day 13 for Line HA and LW chicks. All chicks were fed Diet M2 for six days commencing on day 14. When given a choice, Line HA chicks avoided Diet M2 and preferred Diet M1 with Diet A intermediate to Diets M2 and M1 (Figure 2). There was no preference among diets for Line LW chicks.

Regressions of daily feed intake on days were significant (Figure 3) with r^2 values being .97, .83, and .85 for Lines HW, HA, and LW, respectively. The response for methionine intake was curvilinear with a significant cubic component in all lines (Figure 4). The r^2 values were .92, .79, and .76 for Lines HW, HA, and LW, respectively.

DISCUSSION

In Experiment II, White Plymouth Rock (HW) and White Leghorn (HA) chicks were fed a diet deficient in methionine from 3 to 10 days posthatch. When chicks were then given a choice between methionine deficient and balanced diets, no preference was evident for Line HA chicks. By contrast, Line HW chicks exhibited an almost immediate preference for the balanced diet (within 2 hours), followed by either a preference for the deficient diet or no dietary preference to 72 hours, and then a consistent preference for the balanced diet until the conclusion of the experiment at 144

hours. Trial 1 of the experiment presented here used the same genetic lines and diets as in Experiment II; however, choices among diets commenced on Day 1 posthatch (i.e., no exposure to a deficient diet). Trial 2 extended the length of the initial choice among diets from the 7 days in Trial 1 to 13 days. The design also included feeding a deficient diet for six days (to day 20), before again providing a choice.

In both trials of this experiment, differences between Line HA and Line HW chicks were consistent when chicks were provided choices among diets starting at one day of age. Namely, HA chicks showed no preference among diets, while HW chicks commenced showing preferences when five days of age. Preferences, however, were not consistent from day to day. After being fed a deficient diet for six days (14 through 19 days of age) and then given a choice, within four days HW chicks exhibited a preference for the balanced diet. Line HA chicks preferred Diet M1 to M2 with the balanced diet being intermediate and not different from M1 or M2. Chicks from Line LW, which are extremely slow growing never exhibited a dietary preference.

These results and those obtained in Experiment II show consistency among these two genetic stocks in exhibiting preferences for diets differing in methionine content. They also imply that differences in response may be influenced by

previous diet, with day to day initial variation, perhaps reflecting compensating mechanisms in dietary self-selection. That is, without a period of depletion, there is little evidence of deficiency and therefore no physiological compensation for choosing a balanced diet for broiler stocks (NRC, 1984). After a period of depletion, however, chicks chose the balanced diet.

In the experiment presented here, a preference among diets became evident in Line HW chicks at five days of age. Importance of this age in the development of supply organs and digestive enzyme systems of this line has been reported (Katanbaf et al., 1988; Nitsan et al., 1991). Also by five days the vitelline residue has become negligible (Nitsan et al., 1991). Genotype by environment interactions for feed intake behavior were common at seven days of age in a trial involving Lines HW and LW (Experiment I). At hatching the chick has primarily a lipid-based metabolism and when placed on external sources of food, there is a shift to a primarily carbohydrate-based metabolism (Duke, 1984). Also, shortly after hatch dynamic changes occur in the digestive system (Nitsan et al., 1991; O'Sullivan et al., 1992b), in allomorphic growth (Katanbaf et al., 1988), in immune response (Zander and Mallison, 1991), and in thermoregulation (Dunnington and Siegel, 1984). Differences among genetic stocks in the maturation of these systems

during the first two weeks after hatch could result in the differences in dietary self-selection among genetic lines. As selection can alter dietary self-selection for protein and energy (Huey et al., 1982), it may also have altered mechanisms which control dietary self-selection based on amino acid content.

SUMMARY

Two trials were conducted to compare genetic lines of chickens for discrimination among diets containing .85, .58, and .44% methionine. In Trial 1, chicks from a fast-growing White Plymouth Rock (HW) and a slow-growing White Leghorn line (HA) were offered a choice of three diets from 1 through 7 days of age. From 8 to 10 days of age, they were monofed one of the three diets or continued to have a choice of diets for two days. In Trial 2, a slow-growing line of White Plymouth Rocks (LW) was used in addition to the lines used in Trial 1. All chicks were offered a choice of three diets from 1 through 13, and 20 through 23 days of age. From 14 through 19 days of age all chicks were monofed the .44% methionine diet. In both trials, Line HW chicks first exhibited a preference among diets at five days of age. This preference was not consistent until after a period of deficiency. Line HA chicks did not discriminate among diets in either trial when given a choice from day one. They did,

however, show a preference starting on Day 20 in Trial 2 after being fed a deficient diet. No dietary preferences were noted in chicks from Line LW. Results of these trials show that self-selection among diets varying in methionine content is influenced by genotype, age, nutritional state of the chick, and interactions among these variables.

Table 13. Mean feed and methionine intake per chick for Line HA¹ by day and diet² from 1 through 7 days of age, Trial 1.

Day	Feed (g)			Methionine (g x 10 ⁻³)			
	Total	Diet		Total	Diet		
		A	M1		M2	A	M1
1	4.8	1.3	1.7	1.8	12.1	9.8	8.1
2	5.7	2.2	1.8	1.7	18.0	10.4	7.4
3	7.0	2.8	2.0	2.2	23.9	11.7	9.5
4	7.3	2.2	2.5	2.5	20.0	14.4	10.8
5	8.7	2.7	3.5	2.5	22.7	20.3	10.9
6	9.8	3.0	2.7	4.2	25.3	15.3	18.4
7	11.3	4.2	3.5	3.7	36.0	20.3	15.8

Regression Coefficients ± SE

1.1±.1^a .4±.1^{a*} .3±.1^{a*} .4±.1^{a*} 6.4±.6^{*} 3.0±.7^{a*} 1.8±.4^{a*} 1.7±.4^{a*}

¹High antibody line, White Leghorns.

²Diets A, M1, and M2 contained .85, .58, and .44% methionine, respectively.

* - Regression coefficients are significantly different from zero (p < .05).

^a- Regression coefficients with the same letter were not different among diets (p > .05).

Table 14. Mean feed and methionine intake per chick for Line HW¹ by day and diet² from 1 through 7 days of age, Trial 1.

Day	Feed (g)			Methionine (g x 10 ⁻³)			
	A	M1	M2	Total	A	M1	M2
1	8.3	3.3 ^a	2.2 ^a	53.7	28.3 ^a	12.9 ^b	12.5 ^b
2	7.3	3.3 ^a	2.0 ^a	48.6	28.7 ^a	11.1 ^b	8.8 ^b
3	9.8	3.7 ^a	3.2 ^a	63.4	31.9 ^a	18.6 ^a	12.9 ^a
4	12.3	4.7 ^a	2.9 ^a	77.4	39.7 ^a	16.7 ^b	21.0 ^b
5	14.5	4.0 ^{ab}	3.3 ^b	84.8	33.7 ^a	19.4 ^a	31.7 ^a
6	17.3	6.2 ^a	8.0 ^a	112.7	52.4 ^a	46.6 ^a	13.7 ^b
7	20.7	9.8 ^a	4.5 ^b	137.6	83.8 ^a	26.3 ^b	27.5 ^b

Regression Coefficients ± SE
 2.2±.2^a .9±.3^{a*} .7±.3^{a*} .6±.3^{a*} 14.3±2.0^{*} 7.7±2.3^{a*} 4.0±1.7^{b*} 2.6±1.3^{c*}

¹High body weight line, White Plymouth Rocks.

²Diets A, M1, and M2 contained .85, .58, and .44% methionine, respectively.

* - Regression coefficients are significantly different from zero (p < .05).

^{a,b,c}- Means within each day or regression coefficients with the same letter do not differ (p > .05).

Table 15. Mean feed and methionine intake and weight change of Line HA and HW¹ chicks for days 8 & 9, Trial 1.

Line	Trait	Diet ²			
		Choice ³	Monofed		
HA	Feed intake (g)	A	M1	M2	
	Feed intake (g)	27.0 ^a	22.8 ^a	21.4 ^a	24.0 ^a
	Methionine intake (g X 10 ⁻³)	171.6 ^a	193.4 ^a	124.2 ^b	105.2 ^b
	Weight gain (g)	13.8 ^a	12.2 ^a	10.4 ^a	11.5 ^a
HW	Feed intake (g)	44.0 ^a	44.6 ^a	42.4 ^a	45.0 ^a
	Methionine intake (g X 10 ⁻³)	299.2 ^b	378.6 ^a	246.0 ^c	197.6 ^c
	Weight gain (g)	29.0 ^a	30.1 ^a	23.7 ^b	27.1 ^a

¹HA=high antibody line, White Leghorns; HW=high body weight line, White Plymouth Rocks.

²Diets A, M1, and M2 contained .85, .58, and .44% methionine, respectively.

³Total of Diets A, M1, and M2 consumed.

^{a-c}Means in a row with the same letter do not differ (p > .05).

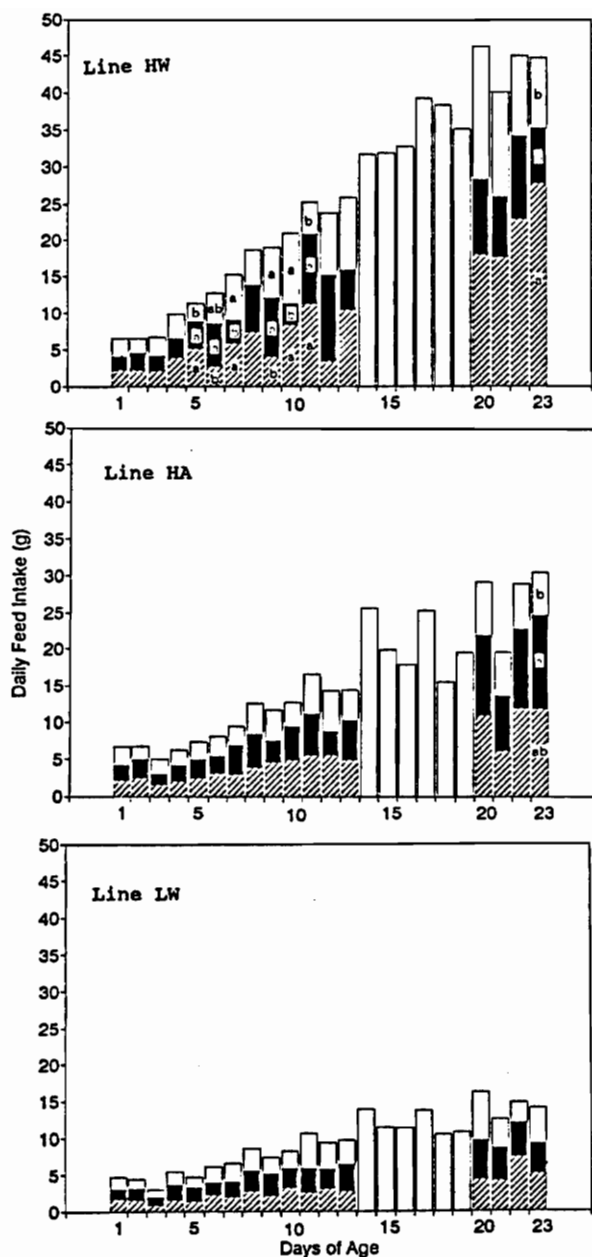


Figure 2. Daily feed intake by line. Line HW (high body weight line; White Plymouth Rocks)- top, Line HA (high antibody line; White Leghorns)- middle, and Line LW (low body weight line; White Plymouth Rocks)- bottom. Diets A (hatched), M1 (black), and M2 (white) contained .85, .58, and .44 % methionine, respectively. Different letters in a bar denote significance at that age. From Days 14 through 19 only Diet M2 was fed.

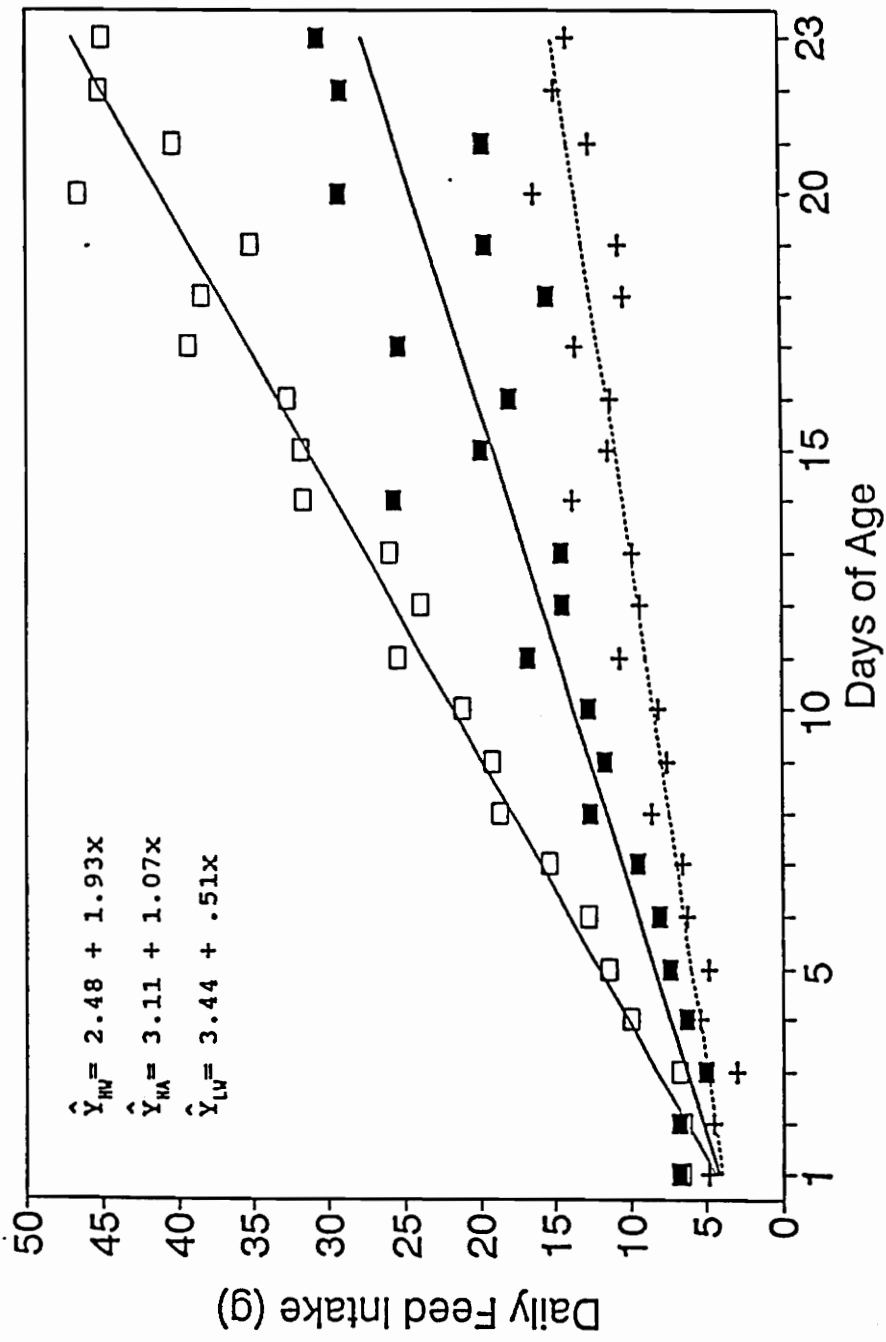


Figure 3. Feed intake regressed on days by line (HW- □ , HA- ■ and LW- +). Description of lines is given in legend for Figure 2.

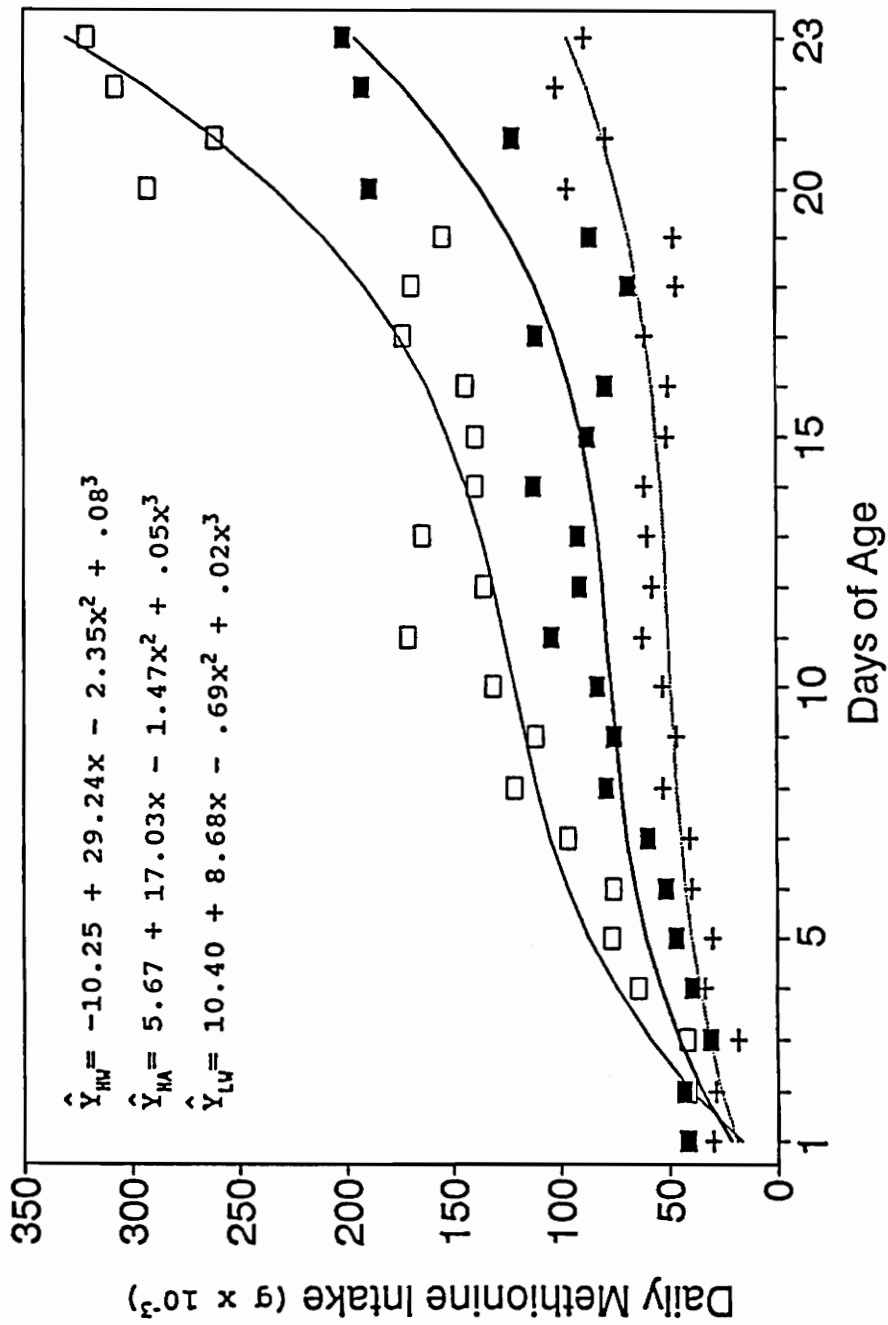


Figure 4. Methionine intake regressed on days by line (HW- □ , HA- ■ , and LW- +). Description of lines is given in legend for Figure 2.

GENERAL SYNTHESIS

During the first week posthatch, chicks undergo many changes in the digestive system (Nitsan et al., 1991; O'Sullivan et al., 1992b), in allomorphic growth (Katanbaf et al., 1988; O'Sullivan et al., 1992a), in immune response (Zander and Mallinson, 1991), and in thermoregulation (Dunnington and Siegel, 1984). At hatching, the chick has a supply of vitelline residue which is essentially utilized within the first five days (Nitzan et al., 1991; Chamblee et al., 1992). To utilize this residue, the chick has primarily a lipid-based metabolism and when placed on external sources of food, there is a shift to a primarily carbohydrate-based metabolism (Duke, 1984). Differences exist between genetic stocks in the maturation of the digestive system and in profiles of digestive enzymes over time (O'Sullivan et al., 1992b). In addition, genetic stocks of chickens differ in feed intake behavior at hatch (Barbato et al., 1980; Marks, 1991; O'Sullivan et al., 1992a). With so much happening to the chick at an early age, interactions between genotypes and husbandry factors are not surprising.

Genetic stocks also differ in nutrient requirements as indicated by different responses to low levels of lysine, methionine, and tryptophan in Experiment II. While growth was inhibited in Line HW, it was not affected in the slower

growing White Leghorn Line HA. This confirms different NRC (1984) requirements for broiler and layer starter diets.

Differences among genetic stocks in ontogeny of the dietary self-selection system were observed in Experiment III. These differences appear to be related to nutritional requirements of the genetic lines. The self-selection system in Line HW chicks is able to compensate rapidly for a deficiency in amino acids, as seen in Experiments II and III. Line HA chicks do not respond to excesses in amino acids in their diet in the same way as faster growing stocks. New Hampshire by Columbian cross chicks effectively discriminated against excesses of one of several amino acids (Edmonds and Baker, 1987). In Experiment III (Trial 2), Line HA chicks avoided the diet which met NRC (1984) requirements for total sulfur-containing amino acids in layer starter diets, but only after 20 days of age. The reason for this is not clear, but may be associated with different threshold levels for response.

The results of the experiments conducted in this thesis show that growth, ingestive behaviors, livability, and dietary self-selection are influenced by several factors. These factors include age, genetic line, housing environment, nutritional state, previous experience and learning, social facilitation, and the interactions among these factors. Of these, the changes which occur in the

first week of life were perhaps most critical and most important for us to understand.

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APPENDIX. SELF-SELECTION AMONG DIETS
DIFFERING IN TRYPTOPHAN CONTENT BY
WHITE LEGHORN CHICKENS

INTRODUCTION

Tryptophan is the primary precursor of the neurotransmitter serotonin (Shea et al., 1991) with the effect of tryptophan on feed intake being peripheral rather than central (Denbow, 1989). Infusion of tryptophan into the gut decreased feed intake of White Leghorn and broiler chickens, with response of broilers being slower than that of Leghorns (Lacy et al., 1982). Feed restriction programs to control body weight have become central in the husbandry of broiler breeders. When broiler males maintained on a restricted alternate-day feeding program were fed diets that contained tryptophan at 2, 4, or 8 times NRC (1984) recommended levels, aggressive pecking decreased (Shea et al., 1990). Reductions in agonistic behavior were greater in more dominant than in more subordinate males (Shea et al., 1991).

Chickens may or may not discriminate among diets varying in tryptophan content. Chicks from a New Hampshire by Columbian cross discriminated against a diet with 4% excess tryptophan (Edmonds and Baker, 1987). After one week of being fed either of two tryptophan deficient (.17 and .18%) diets, White Rocks preferred a diet which met the NRC (1984) requirement for tryptophan (.23%) to tryptophan deficient diets used in Experiment II of this thesis. In the same experiment, White Leghorns did not discriminate

against a diet in excess of their NRC (1984) requirement (.23%) after being fed a balanced (.17%) or a slightly excess (.18%) diet for one week. The experiment reported here expands on the trial with White Leghorns by measuring discriminatory and feed intake responses to diets varying in tryptophan content from one day of age.

METHODS AND MATERIALS

Diets, Stock, and Husbandry.

Raw ingredients and synthetic amino acids used were the same as in Experiment II. Diets A, T1, and T2 contained .23, .18, and .17% tryptophan, respectively (Table 7). Diet T2 met the NRC (1984) recommendations for layer starter diets.

Chicks from a White Leghorn line selected for high antibody response to sheep erythrocytes (Martin et al., 1990) were removed from the hatcher, wingbanded, and randomly assigned to pens in electrically heated brooder batteries with wire floors. There were 16 pens with 13 chicks per pen. Lighting was continuous with feed and water available at all times. Floor space was 228 cm² per chick, waterer space was 2.3 cm per chick, and three feeders in a row provided a total of 3.9 cm of feeder space per chick.

A corn soybean diet of 24% crude protein and 3146 kcal of ME / per kg of feed was fed on the day of hatch. From 1

through 7 days of age, chicks in each pen were offered a choice of Diets A, T1, and T2. On Day 8, four of these pens were placed on Diet A, four were placed on Diet T1, four were placed on Diet T2, and four remained on choice feeding. The experiment ended when the chicks were ten days of age.

Traits and Analyses- Days 1 through 7.

Feed consumption was obtained for each diet for each of seven consecutive days. Feeders were weighed daily between 0800 and 0830 hours with their location changed each time using systematic randomization. The procedure involved assigning the locations of the three feeders in a pen at random on the first day and then rotating them clockwise each time the feed was weighed. Preferences among diets were analyzed by analysis of variance as the actual amount of each diet consumed each day. Day, diet (level of tryptophan), and the interaction between them were sources of variation. When significant differences were found comparisons among means were made using Duncan's multiple range test. Feed intake was transformed to common logarithms prior to analysis. Daily total feed intake and total daily tryptophan intake, as well as feed and tryptophan intake from each diet were regressed on days.

Traits and Analyses- Days 8 & 9.

Feed and tryptophan intake were measured 48 hours after the feeding regimes were changed. Data were analyzed by

analysis of variance with feeding regime (choice vs. each of the three diets monofed) as the main effects. Feed and tryptophan intake were also analyzed for the four pens which remained on choice feeding with level of dietary tryptophan being the source of variation. Body weights were obtained at 8 and 10 days of age with body weight change during this period analyzed with feeding regime as the source of variation. Body weight change and feed intake were transformed to common logarithms prior to analysis. When significant differences were found, comparisons among means were made using Duncan's multiple range test.

RESULTS

Choice feeding (1 through 7 days of age).

There were no day by diet interactions for feed or tryptophan intake during the seven days when all pens were given a choice among diets. Chicks exhibited no preference among dietary levels of tryptophan. There were differences among days for total feed intake, with chicks consuming more feed as they became older (Table 16). This pattern was reflected by the significant regression of total daily intake on days. Regression coefficients for each diet on days were similar to each other and different from zero. Daily tryptophan intake closely paralleled feed intake during this period (Table 16). As with feed intake,

regression coefficients, while significantly different from zero, did not differ among the three diets.

Mono and choice feeding (8 and 9 days of age).

There were no differences among feeding regimes for total feed intake (Table 17). Tryptophan intake, however, was lower for the chicks monofed Diet T2 than for the other regimes (Table 17). Although for chicks which continued to have a choice of diets, Diet T2 (5.1 g) was preferred to Diets A and T1 (both 3.6 g), the amount of tryptophan consumed from the three diets was similar (data not shown). Body weight change was greater for chicks that remained on choice feeding than for those monofed regimes of Diet A, T1, or T2.

DISCUSSION

The lack of preferences among diets varying in tryptophan content from 1 through 7 days is consistent with results obtained in Experiment II with the same White Leghorn line. On Days 8 and 9, however, there was a preference for Diet T2. This diet was the one which met NRC (1984) requirements for layer starter chicks, while Diets A and T1 exceeded requirements. The results are consistent with those of Edmonds and Baker (1987), who found that New Hampshire by Columbian cross chicks discriminated against excess tryptophan in the diet. Under monofeeding, feed

intake on Days 8 and 9 was not decreased by excess tryptophan in the diet, which is in contrast to the findings of Lacy et al. (1982) who infused pure tryptophan into the gut.

SUMMARY

This experiment was conducted to study feed intake and dietary preference responses of White Leghorn chicks to diets varying in tryptophan content. Chicks were offered a choice of diets containing .23, .18, and .17 % tryptophan from 1 through 7 days of age. When eight days of age, pens of chicks were randomly assigned to remain on choice feeding, or be monofed one of three tryptophan diets (.23, .18, or .17 %) for 48 hours. There were no preferences for diets through Day 7. After the feeding regimes were changed on Day 8, there were no differences among them for feed intake. Those pens which continued to have a choice of diets on Days 8 and 9 consumed more of the .17 % tryptophan diet than of the other diets. Body weight change on Days 8 and 9 was greater for those chicks who remained on choice feeding than for those monofed the three diets. The results of this experiment are inconsistent in determining the preference and feed intake response of White Leghorn chicks to diets varying in tryptophan content from one day of age.

Table 16. Mean feed and tryptophan intake per chick by diet and day from 1 through 7 days of age¹.

Day	Intake															
	Feed (g)			Tryptophan (g) x 10 ⁻³												
	Total	A	T1	T2	Total	A	T1	T2								
1	3.9 ^c	1.1	1.1	1.6	7.2 ^d	2.5	2.0	2.7								
2	4.9 ^c	1.6	1.7	1.6	9.4 ^c	3.7	3.1	2.7								
3	6.3 ^b	2.2	1.9	2.2	12.2 ^c	5.1	3.4	3.7								
4	6.6 ^b	2.4	2.1	2.1	12.8 ^{bc}	5.5	3.8	3.7								
5	7.3 ^b	2.5	2.3	2.5	14.2 ^{bc}	5.8	4.1	4.3								
6	10.7 ^a	3.4	2.9	4.4	20.5 ^a	7.8	5.2	7.5								
7	11.1 ^a	3.5	4.1	3.5	21.3 ^a	8.1	7.4	6.0								
² Regression Coefficient ± SE ²																
1.2±.2					.4±.1		.4±.1		2.4±.3		.9±.1		.8±.1		.7±.2	

¹Diets A, T1, and T2 contained .23, .18, and .17 % tryptophan.

²Regression coefficients were different from zero and did not differ among each of the diets for feed or tryptophan intake.

Any two means in the total column with the same letter are not different (p > .05).

Table 17. Mean feed intake, tryptophan intake, and body weight change for Days 8 & 9¹.


Feeding regime	Intake		Weight change(g)
	Feed (g)	Tryptophan (10 ⁻³ g)	
Choice	12.3 ^a	23.5 ^a	13.5 ^a
Diet A	10.4 ^a	23.8 ^a	11.7 ^b
Diet T1	11.5 ^a	19.6 ^b	12.0 ^b
Diet T2	11.6 ^a	20.8 ^{ab}	12.1 ^b

¹Diets A, T1, and T2 contained .23, .18, and .17 % tryptophan, respectively.

Any two means in a column with the same letter are not different (p > .05).

VITA

Donald Oscar Noble, the youngest son of Forest and Isabelle Noble, was born on January 31st, 1968 in Mount Vernon, Ohio. He was raised on a farm outside of Chesterville, Ohio in Morrow County. He graduated from Highland High School in June, 1986 and enrolled in The Ohio State University in September, 1986 and was awarded the degree of Bachelor of Science in Agriculture in August, 1990. Noble then enrolled in the Virginia Polytechnic Institute and State University in January, 1991 to persue a Master of Science under the direction of Dr. Paul B. Siegel. Upon graduation, Noble plans to enroll in The Ohio State University and persue a Doctorate of Philosophy under the direction of Dr. Karl E. Nestor. Noble is married to the former Erica Boger.

A handwritten signature in cursive script that reads "Donald O. Noble". The signature is written in black ink and is positioned below the typed text of the biography.