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FINAL REPORT

PROJECT NO. US-675-83

**Effects of Food Restriction on Growth, Sexual
Maturity and Reproduction Traits in Chickens:
Genetic and Non-Genetic Aspects**

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EFFECTS OF FOOD RESTRICTION ON GROWTH, SEXUAL MATURITY, AND REPRODUCTIVE TRAITS IN CHICKENS: GENETIC AND NONGENETIC ASPECTS

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C. ABSTRACT

The poultry meat industry is perhaps the most dynamic in animal agriculture. For example, the 3 years since the inception of this project has seen market changes from whole bird - cut up to cut up - further processed products. This shift requires that breeders place more emphasis on growth and that broilers be marketed at heavier body weights. Our research involved commercial populations and experimental lines selected for high and low body weight and for high and low abdominal fat. Results obtained in this project determined: (1) the interface of minimum thresholds for age, body weight and fat to protein ratio in the carcass on onset of egg production in different populations, (2) feasibility of selection for market weight under feed restriction rather than under ad libitum feeding, (3) that all populations tested adapted rapidly to feed restriction (intermittent feeding) in a variety of ways including organ size, enzyme concentration and hormone levels, (4) crosses between populations showed additive genetic variation for most of the adaptations, and (5) that lipid and protein turnover are modified by genotype-environment interactions. These findings and others are discussed in 18 papers that were published or currently are in press in refereed journals. Application of this knowledge by breeders, nutritionists, integrators, producers and processors contribute to improving the overall efficiency of poultry meat production both at the broiler and breeder level.

D. OBJECTIVE

To explore the utilization of feed restriction as a means of improving feed utilization in poultry production.

E. REPORT

1. Description of the Research Problem

A combination of genetic and nongenetic factors has contributed to dramatic increases in broiler growth and body weight. Concomitant to these responses have been changes in food consumption and metabolic patterns which can result in excessive adiposity in broilers which is energetically costly and reduces reproductive efficiency of breeders. The problem of excessive fat may be compounded by greater demands for further processed poultry which, in turn, requires that broilers be marketed at heavier weights. This research project provided a multidisciplinary approach using biochemical, genetical, nutritional, and physiological techniques to examine mechanisms determining the efficiency of feed utilization in chickens. The overall objective was to improve the efficiency of broiler production.

Research generally followed the project proposal with activities and locations consistent with the time schedule outlined in the work plan.

2. Selection for growth under restricted feeding (Jerusalem).

Theoretical studies suggested that selection for body weight under uniform restricted food intake had a more positive effect on feed efficiency than selection under ad libitum feeding. Lacking, however, were data to evaluate this theory as well as information concerning

correlated responses of reproductive traits and responses under ad libitum and restricted uniform feeding.

Three experiments were conducted as part of a general experimental program aimed at investigating the presence of genetic variation in feed efficiency under conditions of uniform food intake. Breed and strain comparisons were conducted with respect to uniform feed intake and with respect to the more usual measure of feed efficiency under ad libitum feeding. In each case the stocks compared were chosen a priori on the basis of indications of possible differences in feed efficiency.

In the first series of experiments broiler lines were compared in a series of experiments. Lines included White Rock-female and Cornish-male lines from Breeder A, White Rock-female and Cornish-male lines from Breeder B and high and low abdominal fat lines developed by Cahaner of the Hebrew University, Faculty of Agriculture. Comparisons involved measuring feed efficiency under ad libitum and uniform feed intake in these stocks. Uniform feed intake was achieved by feeding chickens a restricted amount of feed that was somewhat below ad libitum intake of that population. The thesis was that such restriction while precluding excessive feed intake would meet maintenance requirements and the partition function between lean and adipose tissue. Differences between lines in feed efficiency under uniform-restricted food intake and under ad libitum feeding were observed in the first replication (involving stocks from Breeder A) with Cornish more efficient than White Rocks. Differences were not found under either feeding regime in the second

replication using stocks from Breeder A or in a third replication using stocks from Breeder B. Similarly, one of three trials involving the high and low fat lines, showed an advantage in favor of the low over the high fat line under both feeding regimes. Thus, in two of six trials significant differences in feed efficiency were found and in both cases the differences were expected on the basis of a priori considerations. In both cases, when significant differences were found, they were in the same experiment and for both feeding programs suggesting that differences were biological rather than sampling. The results support the thesis of genetic variation in gross efficiency under both feeding regimes and that the two traits are related. They also suggest that nongenetic factors may mask the genetic differences under either regime. Moreover, they demonstrate genetic variation for maintenance requirements and partitioning of lean and fat.

A second series of experiments involved the White Rock lines developed for high and for low abdominal fat by Cahaner. The experiments were designed to estimate heritability of weight gain under uniform-restricted food intake and weight gain and feed efficiency under ad libitum feeding. Also calculated within each line were genetic correlations of these traits with abdominal fat deposition. Results with respect to growth related traits under ad libitum feeding were as expected from the literature, lending credence to those with the more novel uniform-restricted feeding. These included a moderate heritability for body weight, feed efficiency and fat depositions and positive genetic

correlations of body weight with fat deposition and with feed efficiency. They suggest that selection under the novel procedure might reduce fat deposition under ad libitum feeding have little effect on ad libitum feed efficiency and have a negative effect on growth. Overall, these experiments suggest that real, though small, differences between genetic populations in feed efficiency occur under both uniform food intake and ad libitum food intake. They infer that poultry breeders can make progress in improving feed efficiency and reducing fat deposition under either regime with concomitant increases in body weight by development of appropriate indices for selection.

3. Restricted feeding, feed efficiency, and organ weight changes (Rehovot and Blacksburg).

Experiments were conducted to evaluate the hypothesis that feed restriction during growth decreases fat deposition and enhances overall feed efficiency. Comparisons included different intermittent feeding programs and ad libitum feeding of commercial and experiment stocks, including closed populations and appropriate crosses. Such comparisons are essential in determining whether behavioral, anatomical, and physiological adaptations to feeding programs are general or population specific, i.e., the presence or absence of genotype by feeding regime interactions.

During the initial year of the project, comparisons involving progeny from a White Rock line selected for high body weight mated to a White Rock line selected for low body weight and to a White Leghorn line

showed that the background genome, rather than small body size per se, of the parental population influenced the adaptive responses to intermittent feeding. Time activity budgets showed that chicks quickly habituated to intermittent feeding regimes. This habituation contributed to general anatomical adaptations in the upper gastrointestinal tract. Variation in the lower tract appeared to be influenced mainly by the type of feed restriction which was used. Analyses of pancreatic digestive enzymes showed physiological adaptation to feeding regimes and reflected further variability dependent on food availability. Similar responses were indicated by analyses of liver and adipose depot lipids, muscle protein, and concentrations of growth and thyroid hormones in the blood. These data have been analyzed and the research published (reprints from Poultry Sci. 66:1-40 are included as part of this report).

The above observations provided a basis for research on genetic analyses of responses to feeding regimes which were conducted in Blacksburg and are reported in the Katanbaf et al. papers. Also, intermittent feeding programs and relationships of water and feed intake were studied in concomitant experiments conducted at Rehovot. These results are in the Pinchasov et al. papers.

4. Body weight at sexual maturity (Jerusalem and Blacksburg).

As stated earlier, selection for rapid growth of broiler chickens has resulted in correlated responses in adult body weight and obesity in breeder and broiler populations. Not only are large obese parents energetically inefficient, but obesity can reduce reproductive potential.

Feed restriction programs have become routine in poultry production. Benefits of such programs include reduced feed consumption, lower body weight, and improved fecundity of breeder flocks. Collaborative research at Jerusalem and in Blacksburg showed that chickens will not enter lay below a given body weight and/or age. Subsequent studies suggested that a balance of fat to protein was also needed for the onset of lay. Minimum weight and age as well as fat to protein balance vary among populations and it appears that genetic variation exists for all of these traits. Studies at Blacksburg showed that genetic variation was additive for weight at sexual maturity and nonadditive for age at sexual maturity. The mode of inheritance for carcass composition followed that for body weight.

In Jerusalem, two experiments were conducted in which egg number of two lines (selected for 4 and 5 generations for high and low for minimum weight for onset of sexual maturity) were compared under a series of increasing levels of food restriction. Results confirmed the major difference between the lines in body weight at first egg and in subsequent body weights, even under ad libitum feeding. Pullets from the low line entered lay about a month sooner than those from the high line. Even when the first month of lay was removed from consideration, egg number of the low line generally exceeded that of the high line regardless of feeding level. In contrast, egg size was consistently larger for the high than low line. Analyses showed that low line females were smaller than high line females as measured by carcass weight, breast weight and shank

length. They also had a greater absolute weight of abdominal fat and a higher percentage of abdominal fat to body weight. Thus, although feed intake was the same, the low line may be classified as the fatter line. When these lines were reared under ad libitum feeding, results were essentially the same as those observed for the selection regime.

Blacksburg studies included analyses of data concerning carcass composition and body weights of parental lines and F₁ and F₂ generation crosses at the time when 50% of the population had reached lay. Pullets which had reached onset of lay were heavier and had larger fat depots than immature pullets within the same population. Breast tissue appeared to serve as a nutrient store for pullets which had not matured and a nutrient source for those which had commenced lay. Moreover, pullets which had not reached maturity were shown by retrospective analysis to have lower body weights at younger ages. These experiments were reported in the Zelenka et al. papers.

F. DESCRIPTION OF COOPERATION

The investigators have been in contact continuously. This contact has been via several modes including the BITNET system, through joint participation of Nir, Nitsan and Siegel at the European Poultry Congress in 1986, Soller's participation in conferences in the USA in 1987 and Siegel's visit to Israel in 1987. The result has been joint design, minimal duplication and modification of research based on ongoing results and joint publication of manuscripts.

G. EVALUATION OF RESEARCH ACHIEVEMENTS WITH RESPECT TO THE ORIGINAL PROPOSAL AND ITS OBJECTIVES

The experiments conducted during the course of this project were consistent with those outlined in the proposal. Although data obtained during the first year modified the emphasis given to various topics during the subsequent years, changes have been minor. The research has progressed to a point where it not only has direct application in the breeding and husbandry of chickens, but also in the context of a basis for explaining fundamental aspects as well as laying a basis for future studies. Evidence for these statements is provided by the range of refereed journals in which the research has been published. Lastly, several graduate students associated with this research now have positions in both academic and industrial settings involved with scientific and technical aspects of agriculture.

H. PUBLICATIONS

Published or in press in refereed journals

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Cahaner, A., E. A. Dunnington, D. E. Jones, J. A. Cherry, and P. B. Siegel, 1987. Evaluation of two commercial broiler male lines differing in efficiency of feed utilization. Poultry Sci. 66:1101-1110.

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Katanbaf, M. N., E. A. Dunnington, and P. B. Siegel, 1988. Allomorphic relationships from hatching to 56 days of age in parental lines and F₁ crosses of chickens selected 27 generations for high or low body weight. Growth (in press).

Manuscripts in draft form

Anthony, N. B., E. A. Dunnington, and P. B. Siegel, Egg production and egg composition of parental lines, F₁ and F₂ crosses of White Rock chickens selected for 56-day body weight.

Katanbaf, M. N., E. A. Dunnington, and P. B. Siegel, Restricted feeding in early and late feathering chickens. 1. Growth and physiological responses.

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Eitan, Y., and M. Soller, Reproductive performance under various levels of feed restriction in lines selected for high and low minimum body weight for onset of sexual maturity.

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Eitan, Y., and M. Soller, Effect of selection for high and low minimum weight for onset of sexual maturity on minimum age for onset of sexual maturity and in body composition.