BD

BARD

FINAL REPORT

PROJECT NO. US-976-85

Optimization of Growth Trajectory, Feed Composition, and Carcass Quality of Broiler Chickens

P. Sharpe, H. Talpaz, S. Hurwitz

35

630.72
BAR/SHA
2nd copy

1990

32942

000000151405

000000000000

000000000000

Date: January 23, 1990

BARD

P.O.Box 6

Bet Dagan, ISRAEL 50250

BARD Project No. US-976-85

Title of Project:

Optimization of Growth Trajectory, Feed Composition and Carcass Quality of
Broiler Chickens

Name of Investigators

Principle Investigator:

P. J. H. Sharpe

Cooperating Investigators:

H. Talpaz

S. Hurwitz

הספריה המרכזית
למדעי החקלאות
בית-17

Name and Address of Affiliated Institutions

Principle Institution:

Biosystems Research Division, Texas A&M University
College Station, Texas 77843 USA.

Cooperating Institution:

Department of Statistics, and
Institute of Animal Science
Agricultural Research Organization
The Volcani Center
P. O. Box 6, Bet Dagan, 50250 ISRAEL.

Project Starting Date: November 2, 1986.

Type of Report: Final.

Signatures:

Principle Investigator

Peter J. H. Sharpe

Institution Authorizing Official

630.72
BAR / SHA

2nd copy

1 636.5 ; 636.508.5

b. TABLE OF CONTENTS

c. ABSTRACT	3
d. OBJECTIVES	4
e. RESEARCH REPORTS	5
1. Economic Optimization of a Growth Trajectory for Broilers	6
2. Modeling of the Dynamics of Accelerated Growth Following Feed Restriction in Chicks	15
3. Optimization of a Growth Trajectory, Feed Composition and Carcass Quality of Broiler Chickens. Ph.D Thesis Abstract	29
f. COOPERATION	32
g. EVALUATIONS AND CONCLUSIONS	33
h. PUBLICATION LIST	37

c. ABSTRACT

A model which describes normal growth and compensatory growth in chicks resulting from an early-age feed-restriction has been constructed. Normal growth is described by a Gompertz equation whereas for description of compensatory growth, growth rate is proportional to a compensation factor, dependent on the severity of feed restriction, and a time-dependent exponential term. The model was fitted to experimental results obtained in male and female broiler chicks, with the aid of an iterative nonlinear algorithm. The standard errors for the estimated parameters were less than 3% of their respective values. Also, the deviations of the predicted from the observed values did not exceed 4% and were, in most cases less than 2% of the observed values.

A dynamic model was constructed aimed at selecting the economically optimal growth trajectory of broilers and computing the feeding schedule designed to satisfy the nutritional requirements along this trajectory. The optimal trajectory is solved for by a Reduced-Gradient nonlinear programming algorithm. The model calculates the daily optimal growth rates along with the corresponding requirements of total protein, amino acids and energy in obtaining the optimal diets. A substantial increase in profits can be achieved by following this methodology.

A dual responsive dynamic broiler growth model was constructed. It investigates the growth response as affected by various diets. This model is based on the Integrated Rate Method (IRM) which uses continuous time Markov theory as its foundation. This model can be used for investigating various diets on the body composition in terms of fat.

d. OBJECTIVES

1. Build a simulation model to describe the compensatory growth process.
2. Formulate and test a computer model which would define the optimal management practices, specifically;
 - a) composition of diets along the growth trajectory,
 - b) define the amount of feed to be provided at any time,
 - c) optimize for different seasons or desired environmental temperatures,
 - d) determine optimal marketing age.
3. Increase the scope of economic optimization to consider carcass quality.

f. COOPERATION

1. The optimization models have been developed by Talpaz and Hurwitz in Israel. Phase I was completed in early 1988. While validation experiments were conducted as components of BARD project I-735-84, a major task to reprogram the optimization system was taken by the Israeli team.
2. The US team, headed by Sharpe have modeled the growth process via the CTM (Continuous Time Markov) mathematics. Talpaz traveled to Texas A&M in 1987 and joined Sharpe and his Ph.D student - de la Torre in the effort to estimate the CTM model parameters. Subsequently, de la Torre has completed his Ph.D thesis on that subject.
3. The results of the validation experiments yielded led to a novel concept of compensatory growth. Remodeling was started by the Israeli team and continued recently at Texas A&M where Talpaz spent a 5 months sabbatical period, in which a fraction of it was devoted to this project working together with Sharpe and Wu on the new compensatory model. Therefore, Sharpe's visit to Israel has been cancelled.
4. During Talpaz's two visits to Texas A&M, and throughout the project duration, experimental results, computer programs, and model simulation results have been exchanged and discussed by the two teams via Bitnet and FAX.

g. EVALUATIONS AND CONCLUSIONS

1. DEVELOPMENT OF HOLISTIC FRAMEWORK (The US team)

The greatest challenge encountered in this portion of the project was to develop explicit relationships between diet and body composition. The lack of a generally accepted theoretical mathematical foundation for coupling multiple inputs to an integrated metabolic process, is a major drawback in the formulation of adequate animal production models. To investigate whether such a framework could be developed, a graduate student dissertation (de la Torre, 1987) was completed which developed a theoretical foundation for a dynamic broiler growth model capable of predicting growth and body composition(fat, feathers and carcass protein). The growth model is based on the integrated rate method which uses continuous time Markov (CTM) theory as its foundation.

The holistic framework has the advantage that it has the potential to capture the interdependence of several internal biophysical processes of the bird. A change in one factor alters all the transitions between growth states, resulting in changes in the probabilities associated with each state. As a result, a change in any one resource level alters the growth response with respect to all the remaining resources. In the dissertation, several simulations of the model were performed to investigate the effect of various diets, including the optimum diets calculated by the optimization procedure. These simulations were designed to test the effects of energy and protein concentration, energy intake, protein intake, and feed intake on body composition. The effects of varying periods and severity of feed restrictions on compensatory growth and final body composition were also tested.

The disadvantage of the approach is that an intense and detailed data set is required to adequately parameterize the model, especially when a period of early feed restriction stimulates a compensatory growth response.

Recognizing this possibility, we stated in the original proposal that we would consider both the CTM and other approaches, such as compartmental analysis. We also stated that we would select the modeling approach which was most efficient for developing and testing a model for predicting both compensatory growth and fat content, given the existing data base for the project.

Working with different models and approaches, considerable insight into the data requirements for each approach has emerged. It became evident that to parameterize the CTM model would require fat and protein body composition values for each growth interval (daily or even weekly). Such information is currently not available. An intermediate level modeling approach was selected, using insights gained from each of the different approaches.

Even at the intermediate level of model complexity, the data available was only just sufficient for developing an adequate model.

The more sophisticated models point to the need for further experimental research to monitor changes in fat and carcass protein as a function of diet over the course of the growth experiments. Such experiments could include combinations of the extremes of high and low protein, and high and low energy dietary inputs. Of interest is how diet composition interacts with carcass composition during growth following a feed restriction. Future experiments need to determine what dietary trajectories of energy and protein minimize final fat content during compensatory growth.

2. THE ECONOMIC OPTIMIZATION ALGORITHM (The Israeli team)

The combination of growth dynamics, subject to accelerated (or compensatory) growth with a nonlinear optimization routine as reported in the Talpaz et. al. (1988) paper, has been highly successful in computing the optimized growth path, daily diets, feed intake and dietary energy concentration. The algorithmic approach taken has proven to be highly flexible and while achieving a fast rate of convergence to the optimal solution. Since the optimizer treats the simulation component as a "Black Box", maximum flexibility prevails which allows access to the simulation program only when changes are required. Such was the case with respect to the new accelerated growth function which was needed following the validation experiments.

The procedure, developed to estimate the parameters of normal growth and those of the *overcompensation* model have proved successful and efficient. Such estimation handles a system of extremely nonlinear equations, a task failed to be carried by the famous SAS Inc. computer procedures.

On the biological side, the discovery of the *overcompensation* phenomenon was an unexpected favorable surprise, since instead of a trade off between a loss of body weight and a saving of feed, we now have a beneficiary effect of early-age feed restriction on body weight at marketing time.

Once implemented, the benefits to the growers are three fold: saving of feed, gain in final market body weight, improved carcass quality together with its price. Therefore, the new system developed in this study may lead to the concurrent feed saving of 1 - 2%, an increase of 2 - 3% in body weight, and a decrease of 10 -15% in carcass fat which is desirable in the market due to consumer health leading to higher product price. This translates to approximately \$5 - \$15 million annual increase in

profits to the industry in Israel, and about \$200 - 300 million to the industry in the USA. Such implementation requires that the findings related to the new compensation form (Talpaz *et al.*, 1990) will be integrated with the optimization algorithm developed earlier (Talpaz *et al.*, 1988).

The methodology developments for optimization and parameter estimation techniques can be implemented in a wide range of applications in biological research.

h. PUBLICATION LIST

de la Torre, J. R. L. (1987) "Optimization of Growth Trajectory, Feed Composition and Carcass Quality of Broiler Chickens," Ph.D Dissertation, Texas A&M University.

Talpaz, H., S. Hurwitz, J.R. de la Torre, and P. J. H. Sharpe (1988), "Economic Optimization of a Growth Trajectory for Broilers," *American Journal of Agricultural Economics* , 70 :382-390.

Talpaz, H., P. J. H. Sharpe, H. I. Wu, I. Plavnik, and S.Hurwitz (1990), "Modeling of the Dynamics of Accelerated Growth Following Feed Restriction in Chicks". Submitted for publication .