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GRENINGER, THOMAS JOSEPH

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ENERGETICS OF EGG PRODUCTION

by

Thomas J. Greninger

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Energetics of Egg Production

BY

Thomas J. Greninger

APPROVED	DATE
Dr. James A. DeShazer	9/23/80
Dr. Thomas L. Thompson	9/23/80
Dr. Earl W. Gleaves	9/23/80
Dr. Dennis Schulte	9/23/80
Dr. Thomas Sullivan	9/23/80

SUPERVISORY COMMITTEE

GRADUATE COLLEGE **UNIVERSITY OF NEBRASKA**

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INTRODUCTION

The Agricultural Engineering Yearbook (Anomynous, 1980) has specified the environmental temperature requirement for the laying hen to be 13C. The trend in the poultry industry has been to increase the laying house temperature from 10-20C for maximum egg production to 20-30C for feed savings. The higher environmental temperature saves feed by decreasing the energy maintenance requirement. The higher temperature can be obtained by reducing the heat loss through the ventilation system. Quantifying the affects of this increase in environmental temperatures on the production of the laying hen is important to the agricultural engineer in developing new environmental control design criteria.

One step in developing laying house temperature criteria is to determine the amount of energy, protein and other nutrients required per unit of egg produced as a function of environmental temperature. The relationships between energy and protein needed and egg production level and environmental temperature should be put in mathematical form to quantify existing trends and organize relationships.

In order to investigate this the literature was reviewed to get some of the relationships needed for some of the requirements. Then an experiment was designed and run to obtain more information. A model was then developed. Verification of the model was done and some results using the model are presented.

OBJECTIVES

The objectives of this research were to determine the energy, protein, and calcium required by a laying hen under different production levels, and environmental temperatures.

The ultimate goal was to develop a production simulation computer model for predicting the performance of laying hens under a wide range of input conditions. This model should then be able to adequately determine the performance of the laying hen under actual laying conditions.

BACKGROUND

Computer Simulation

In the area of computer simulation of egg production there has not been much work done. Only one paper was found that dealt with computer simulation as it pertains to egg production. This was developed by Brown (1976). He developed a model that would predict percent hen lay and average egg weight as a function of varying environmental temperature and varying energy, protein, and calcium levels in the diet for birds ranging in age from 28 to 80 weeks.

Heat Loss and Metabolic Rate

The effect of factors such as age, laying condition of the hen, and environmental temperature on heat loss and metabolic have been studied. O'Neill et al. (1971) kept mature cockerels at 21°C to 23°C for 15 mounths and found age had little effect on starving metabolic rate, if their weight was held constant. Waring and Brown (1967) supported this finding.

Gerhartz (1914) noted that the metabolic rate of laying hens was 30 percent higher than that of non-laying hens. Waring and Brown (1967) found the difference to be 19 percent, while Tasaki and Sasa (1970) found it to be 26 percent. Lesson and Porter (1970) found an increase in metabolic rate of 23 percent in laying hens after peak production was reached.

O'Neill et al. (1971) measured the heat production of adult cocks at 15,22,25,29 and 34°C after conditioning the cocks at these temperatures for 28 days. They reported a decrease in heat production with increasing temperatures. The studies of Van Kampen and Romijn

(1970) found a best fit line for heat production as a function of ambient temperature from -5^{o}C to 40^{o}C. Their equation was,

$$H=0.2453T^2 - 18.90T + 803.3 \quad ,$$

where H = Heat production in kJ/kg$^{0.75}$ /day

T = ambient temperature in degrees centigrade. Davis et al.(1973) studied the influence of temperature on energy utilization in the laying hen. They regressed heat production against ambient temperature as follows:

$$H = -4.6T + 631.6$$

where H is heat production in kJ/kg$^{0.75}$/day

T is the ambient temperature. Emmans(1974) studied the effect of temperature on the performance of laying hens. He estimated the maintenance requirement for white strains in kJ/kg-day to be:

$$ME = -8.4T + 585.6$$

Balnave et al.(1978) analyzing data of other researchers came up with the following expression for ME in kJ/kg$^{0.75}$.

$$ME = 388(EXP(0.027(22-T)))$$

Tasaki and Sakurai (1969) using spring-hatched crossbred cockerels observed under natural conditions the starving metabolic rate was highest in the winter and lowest in the summer. Also the starving metabolic rate was lowest at higher ambient temperatures. Mehta et al.(1972) observed the feed consumption of White Leghorn layers for one year. They found a decline in feed intake in the summer, which was accompanied by a drop in egg production. These data were taken under natural conditions giving averages for feed intake, egg production and egg weight for 12 months.

Daily Requirements

The daily requirements (energy, protein and calcium) of the laying hen have also been studied. Also the relationship between feed intake and egg production has been studied.

Gleaves et al.(1973) studied the effect of composition of feed on the egg production of laying hens. They studied the effect of different levels of feed protein and feed energy on egg weight and feed consumption, and found that as the egg production decreased the effect of energy on feed consumption decreased. They also found that as dietary protein was increased egg production increased.

Ivy et al.(1976) studied the minimum protein and energy requirements of the hen at different production levels. They found that as egg production increased feed intake increased. They estimated the energy and protein requirements of different production levels (Table 1).

Table 1. Requirements of the Laying Hen(1700g), Ivy et al. (1976)

Actual egg production levels,%					
	4.2(0)*	29.8	49.1	70.5	100*
Daily feed consumption,grams					
	87	108	118	128	---
Protein requirement,grams					
Total/day	6.5	11.4	12.5	13.5	15.0
Maintenance	6.1*	20.5	12.4	8.7	6.1
Egg above maint.	---	17.8	13.0	10.5	8.9
Total/egg	---	38.3	25.4	19.2	15.0
Energy requirement,KJ M.E.					
Total/day	696*	951	1048	1227	1253
Maintenance	654*	2220	1332	909	654
Egg above maint.	---	1006	800	670	599
Total/egg	---	3226	2133	1580	1253

*Calculated values

Gardner et al.(1972) studied the effect of dietary protein and energy levels on egg weight and component parts. They found that as dietary protein was increased from 12 to 18 percent the egg weight increased (table 2). Also the percentage of the weight attributed to the yolk and albumen increased with increasing protein levels.

Table 2. Effect of dietary protein and energy on egg weight, yolk weight,albumen weight and shell weight, Gardner et al.(1972)

Dietary Protein	Egg Wt.	Yolk Wt.	Albumen Wt.	Shell Wt.
	(gm)	(gm)	(gm)	(gm)
12%	59.13a*	16.07a	37.14a	5.92a
14%	63.47bc	17.92b	39.41bc	6.14b
16%	63.12b	18.07b	38.97b	6.08b
18%	64.04c	18.02b	39.95c	6.07b
Dietary Energy				
8.728KJ/Kg	62.21a	17.39a	38.72a	6.10a
9.242KJ/Kg	62.67a	17.64b	39.02a	6.01b

*Values not showing the same letter differ significantly at the .05 level of propability.

Singh et al.(1974) studied the growth and egg production of hens as it varied with the levels of energy in the mash. There was no significant difference in egg production with varying levels of feed energy. However there was a significant increase in growth with higher energy levels.

Chauhan et al.(1969) studied the effect of type of feed and energy level on egg production. They found no significant difference in egg production or egg weight with increasing energy levels although there was a rising tendency with increasing energy.

Auckland et al.(1973) studied the effect of dietary energy concentration on voluntary intake of Metabolizable energy and egg production. They found no significant effect of feed energy on egg production and a small increase in egg weight with increasing energy levels. They found the hens would over-consume ME (Metabolizable Energy) with the higher concentrated feeds.

Gleaves et al.(1977) studied the effect of dietary calcium, protein and energy on hen performance, and found that egg production was significantly influenced by dietary protein, energy and calcium. They found average egg production to be best for diets containing 19 g protein, 840 KJ M.E., and 5.4 g calcium per day.

Matner et al.(In Preparation 1978) studied the influence of rate of egg production on the energy requirement of hens. They found the energy requirement to be greater during the egg laying period than the non-laying period for the 75 percent production level, but not for the 50 percent production level.

Florescu et al.(1975) studied the effect of varied levels of calcium in the feed on the performance of the laying hen. They found that the average egg production decreases by 17 percent and that the daily intake of feeds increases by 22 percent in the feeds with lower calcium levels.

Balnave (1974) analyzed data from research at Queen's University and found that very little energy is needed for egg formation. He found about a 25 KJ difference in heat production between hens that failed to lay on a given day than ones that did, but the transfer of nutrients probably still occurred in the hens that failed to lay.

Effect of Temperature

The effect of temperature on egg production has been studied by Smith et al.(1972). They studied the effect of environmental temperature on egg production and egg weight. They found a decrease in production with higher temperatures. At temperatures of 21, 32 and 38°C, 79,72 and 41 percent of the hens laid eggs on any particular day respectively. Egg weights also decreased with higher temperatures. Mueller (1961, and 1967) kept hens in environmental chambers at different temperatures. He had chambers at 13C and 32C and found that the hens at 32C had reduced egg production by about 30 percent.

Emmans(1974) reviewed the research of others and concluded that rate of egg lay and egg weight is independent of temperature between 5C and 30C for equal intake of energy and other nutrients. The main problem encountered with higher environmental temperatures is that of reduced intake of feed.

Zimmerman (1974) found that egg production and egg size is unaffected by temperature in the range of 15C to 27C. He also found that feed intake will decrease by 0.5 percent for each 1F (about 0.5C) rise in temperature.

Effect of Age

Gavora et. al. (1971) tested the applicability of an egg production model, developed for Drosophila Melangaster (McMillan, 1970) to fowl. They found it to be practical to apply it to poultry. This model was as follows:

equation 1) $N(t) = M(1-EXP(-z(t-t^0)))EXP(-at)$

where $N(t)$ = number of eggs layed on day t

M = potential maximum daily egg production

t^0 = the initial day of egg laying

z = rate of increase in egg laying

a = rate of decrease in egg laying

For sufficiently large t equation 1 reduces to

equation 2) $N(t) = M(EXP(-at))$

Then taking logs of each side $\ln(N(t)) = \ln(M) - at$

Estimates of M and a can then be approximated by log-linear regression analysis.

Now letting-

$F(t) = M(1-\exp(-z(t-t^0)) = N(t)EXP(at)$

then

$\ln((m-F(t))/M) = zt^0 - zt$

Now z and t^0 can be estimated by regression.

EXPERIMENTAL PROCEDURE

An experiment was performed to determine the effect of borderline high environmental temperatures on the performance of laying hens. Producers have in the past kept house temperatures in the range of 15C-20C, but with rising feed costs they have increased the house temperature to 20C-30C. Knowing the effect of this increased temperature on performance of laying hens is neccesary to develop new environmental design criteria.

Environmental chambers were chosen as a method to study the effect of temperature on hen performance since chambers provide a repeatable thermal environment. The experiment utilized two insulated environmental chambers, each being 2.1m wide by 3.0m long by 2.1m high. Each chamber contained two rows of cages on three tiers. Each cage measured 41cm deep by 21cm wide by 41cm high. Each row contained 8 cages, thus each chamber had 48 cages. The temperature in each chamber was controlled to either 25C or 29C plus or minus 1C, using Partlow model RFC-15 temperature controllers. The dew point temperature of both chambers was controlled to 18C.

White leghorn layers (Hyline W36 hybrids) were placed in each cage when they were 48 weeks old, one to a cage. They were randomly assigned to each of the two temperature treatment environments that were randomly assigned to the chambers. They were fed using a ration containing 32.7% milo, 31.3% corn, 22.4% soybean meal, 2.5% dehydrated alfalfa, 7.9% limestone, 2.3% dicalcium phosphate, and .9% trace mineral and vitamin premix. The nutrient analysis is shown in Table 3.

The number of eggs per hen and average weight of each hen's eggs produced each week were measured and recorded. Feed intake was measured using the the cup method where each cup of feed was about 85.5g. The feed was measured daily by recording each cup fed. Lighting was on a 14 hour on 10 hour off cycle. Hen body weights were measured every four weeks by used a suspending scale.

Sub sampling of heat losses was done each week using a partitional gradient layer calorimeter as described by DeShazer et al.(1970). The hen was suspended in a cage inside of the calorimeter. A dropping pan filled with oil was placed below the hen so that the droppings would be covered to prevent evaporation. The inside dimensions of the calorimeter were 1m long by .7m wide and .7m high. Air was pumped through the calorimeter at 30 l/min, and was preconditioned to a dew point temperature of about 12C and a dry bulb equal to the outlet air temperature of the calorimeter. This prevented any sensible heat loss leaving in the air. The sensible heat loss was measured using a thermopile to sense the temperature difference across the walls as first described by Benzinger(1949). The Latent heat losses were measured using an infrared moisture analyzer which measured the moisture difference between the incoming and outgoing air. This analyzer was calibrated using an ethane nitrogen synthetic span technique as described by Olson et al.(1974). The calorimeter had been relocated and was not fully operational until the end of the study, so measurements of heat loss were not possible until the 15th week.

After 16 weeks the temperatures in the two chambers were switched without moving the hens and performance and heat loss data were taken

for another two weeks. This was done to determine if acclimation had taken place and was causing the 29C hens to perform better than the 25C hens.

A split plot statistical analysis was conducted on the data. The experiment was designed to test week and week(x)temperature interactions but not to test temperature differences since the experimental unit for temperature was a chamber. The experimental unit for the week and week(x)temperature interaction was the individual hen.

Table 3. Nutrient Composition of Experimental Feed

FEED INGREDIENT	PERCENT OF RATION
MILO	32.7
CORN	31.3
SOYBEAN MEAL	22.4
DEHYDRATED ALFALFA	2.5
LIMESTONE	7.9
DICALCIUM PHOSPHATE	2.3
TM+VIT PREMIX	0.9

NUTRIENT	PERCENT OF RATION
PROTEIN	16.76
ENERGY	11501kJ/kg
CALCIUM	3.59
PHOSPHOROUS	0.73
LYSINE	0.89
METHIONINE	0.27
METHIONINE+CYSTINE	0.53
TRYPTOPHAN	0.20
THREONINE	0.62