Effects of feed restriction on efficiency of egg production

by Edmund Guenthner

A THESIS Submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of Master of Science in Animal Industry
Montana State University

Abstract:
Individual records of feed consumption, egg production, egg weight, body weight, and age at first egg were compiled on 115 Cornell Randombred Strain of White Leghorn pullets during non-restricted and restricted feeding periods of 121 days each.

Analysis of fifteen multiple regression equations for estimating feed consumption, calculated with different combinations of the observed independent variables, during non-restricted and restricted feeding, indicated that egg production and body weight were the major factors influencing feed consumption.

The significance of the mean differences between gross efficiency and adjusted efficiency coefficients, calculated for each pullet during non-restricted and restricted feeding, indicated that gross efficiency coefficients were more satisfactory measures of efficiency than adjusted efficiency coefficients.

A comparison of the mean gross efficiency coefficients, during non-restricted and restricted feeding, indicated that restricting feed intake 25 percent of predicted feed consumption significantly reduced efficiency. The gross observed reduction was 29 percent. Restricting feed intake 12 1/2 per cent or feeding at the rate of predicted feed consumption did not significantly reduce efficiency of egg production.

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ABSTRACT

Individual records of feed consumption, egg production, egg weight, body weight, and age at first egg were compiled on 115 Cornell Randombred Strain of White Leghorn pullets during non-restricted and restricted feeding periods of 121 days each.

Analysis of fifteen multiple regression equations for estimating feed consumption, calculated with different combinations of the observed independent variables, during non-restricted and restricted feeding, indicated that egg production and body weight were the major factors influencing feed consumption.

The significance of the mean differences between gross efficiency and adjusted efficiency coefficients, calculated for each pullet during non-restricted and restricted feeding, indicated that gross efficiency coefficients were more satisfactory measures of efficiency than adjusted efficiency coefficients.

A comparison of the mean gross efficiency coefficients, during non-restricted and restricted feeding, indicated that restricting feed intake 25 percent of predicted feed consumption significantly reduced efficiency. The gross observed reduction was 29 percent. Restricting feed intake 12½ per cent or feeding at the rate of predicted feed consumption did not significantly reduce efficiency of egg production.

INTRODUCTION

The data supporting this paper were taken from a genetic project in which hens were being selected for efficiency in egg production. This study was a preliminary investigation of components and measures of efficiency which were to be used as the basis for selection under ad libitum and restricted feeding programs.

The efficiency with which feed is converted into eggs is of utmost importance to the poultryman because feed accounts for 50 to 60 percent of the total cost of producing eggs (Titus 1955). A reduction of 20 percent in feed cost will therefore result in a 10 to 12 percent saving in total production cost. Such a difference may determine whether or not a profit or loss is sustained.

Restricting feed intake is a device used in certain segments of the industry to reduce feed costs (Singsen et al. 1958). This technique apparently has benefit when applied to broiler type breeding hens and in the growing of replacement pullets. Only a limited amount of information is available concerning this application of feed restriction to egg-type hens.

The purpose of this study was to obtain information concerning factors which influence feed consumption and efficiency, to evaluate different measures of efficiency, and to observe effects of feed restriction on efficiency of egg production.

REVIEW OF LITERATURE

Components of Efficiency

According to Titus (1955), most of the feed a laying hen consumes is used for growth and maintenance and a relatively small portion is used for egg production. He considers that efficiency is primarily influenced by rate of production, body size, and quantity of feed consumed. He found that a Leghorn pullet weighing 3.5 pounds required .14 pounds feed for daily maintenance and an additional .0888 pounds of feed to produce a 2-ounce egg. He also reported that a Leghorn pullet will consume 7.7 to 8.7 pounds of feed per dozen eggs when producing 100 eggs per year, but only 4.4 to 4.9 pounds of feed per dozen eggs when producing 200 eggs per year.

Brody *et al.* (1938) arrived at the following formula for feed consumption:

$$\text{Feed} = .692(\text{egg}) + .300M^{.73} + 1.1 \text{ change in } M$$

This formula indicates that .692 grams feed are expended in producing 1 gram of egg; .300 grams feed are used for maintenance per gram body weight raised to the .73 power; and 1.1 grams feed are expended per gram change in body weight. This equation incorporates the Brody *et al.* (1934) formula for estimating maintenance requirements of animals as a function of body weight.

For comparative purposes, if the Brody formula is applied to a hen weighing 1720 grams, producing 37 grams egg per day, the hen would consume 94.9 grams of feed and have a gross efficiency of .3898. The Titus formula applied to a similar hen would result in 95.4 grams feed consumption and a gross efficiciency of .3877. When these coefficients are converted to "pounds feed per dozen 2-ounce eggs" the results become 3.85 and 3.86 respectively.

Card (1946) expressed the annual feed requirements of hens weighing between 4 and 8 pounds by the following formula:

$$F = 25 + 8W + E/7$$

where F represents the total feed, W the average body weight, and E is the number of eggs produced in one year.

King (1956) using random sample test data for light breeds developed the following regression equation for predicting feed consumption:

$$Y = -10.214 + .114X_1 + 8.915X_2 + 1.416X_3$$

where X_1 is the hen day egg production, X_2 the body weight in pounds, and X_3 the egg weight in ounces per dozen.

Byerly (1941) found the annual feed requirement for maintenance of a 3-pound hen to be 46.8 pounds, and each 100 eggs required an additional 14.2 pounds of feed. Bhuwan et al. (1949) reported that hens laying at a rate of 72 percent used 71 percent of the feed for maintenance, 27 percent for egg production and 2 percent for increase in body weight. Glazener and Blow (1954) observed that body weight and rate of production were the most important factors in efficiency of egg production. Miller and Quisenberry (1959) considered body size, rate of production and inherent differences in feed conversion as the most important factors affecting efficiency.

Effects of Feed Restriction

Heywang (1940) found that restricting feed intake of hens $12\frac{1}{2}$ and 25 percent reduced egg production 31 and 54 percent respectively. The daily feed allowances of the restricted groups were determined by deducting the appropriate amount from the daily feed intake of a control group which was being fed ad libitum.

Singsen et al. (1948) compared restricted and non-restricted feeding of high and low energy rations to broiler type breeding hens. Egg production was unsatisfactory when low energy diets were fed on a restricted basis. Egg production was maintained and a saving of 22 to 29 percent in feed resulted when high energy diets were restricted.

In a trade journal article, Fisher (1958) remarked that caged hens on high energy diets ate 10 to 15 percent in excess of their calculated requirements for maintenance and egg production, and that hens on rations restricted 10 to 15 percent may actually lay more eggs than non-restricted hens.

Fuller (1958) reported that restricted feeding of Leghorn pullets during the growing period reduced body size and delayed sexual maturity. When feed restrictions were removed, normal body size was quickly attained, early egg size was increased, and most of the saving in feed that occurred during restriction was lost. An interesting and beneficial side effect was observed. The pullets subjected to feed restriction during the growing period suffered a smaller death loss in the laying pens, and thus produced more eggs than those grown on full diets.

In this review of literature a very limited amount of information was found pertaining to restricted feeding of egg-type hens. In most of the literature, restricted feeding was applied to special conditions involving the use of special diets, heavy-type hens, and growing pullets prior to egg production.

PROCEDURES AND METHODS

Definition of Efficiency

In the terminology of the industry and much of the scientific literature, gross efficiency is usually expressed as the pounds of feed consumed per dozen eggs produced. Frequently this expression is qualified by specifying that the eggs are of standard weight, i.e., 24 ounces per dozen. Expressing efficiency in this manner has a serious disadvantage. When the efficiency of individual hens is calculated by this method, it is found that the efficiency of a hen producing no eggs approaches infinity, and cannot be given a numerical value. In reality, the efficiency of such a hen is zero. For these reasons, gross efficiency will be expressed, in this paper, as grams of egg produced per gram of feed consumed.

$$\text{Gross efficiency} = \frac{\text{observed output}}{\text{observed input}}$$

When this expression is reduced to grams of egg per gram of feed, the resulting coefficient falls between 0 and 1. Thus when a hen is not laying, the efficiency is 0; the larger the coefficient, the better the efficiency. The coefficient of efficiency can readily be converted to the term "pounds of feed per dozen 2-ounce eggs" by dividing the constant 1.5 by the efficiency coefficient.

$$\text{Pounds feed per dozen 2-ounce egg} = \frac{1.5}{\text{Efficiency coefficient}}$$

The constant 1.5 is used because a dozen 2-ounce eggs are equal to 680.40 grams, and 680.40 divided by 453.59 (grams per pound) equals 1.5.

Experimental Materials

The Cornell Randombred Strain of White Leghorns was used in this study. This strain was selected because it was developed specifically for experimental purposes, and is being maintained as a random breeding and genetically stable population (King *et al.*, 1959). Thus the parent flock becomes a base against which selected populations can be measured for change.

Experimental Procedures

Eggs obtained from the randombred flock at the North Central States Regional Poultry Breeding Laboratory were hatched March 30, 1958. The chicks were grown in one pen so that all were subjected to similar environmental conditions. At 14 weeks of age, 120 pullets were divided at random into four groups and placed in individual cages equipped with individual feeders and egg trays. Ambient temperatures in the laying house ranged from 40 to 88°F. during the trial. After production began, the pullets received 14 hours of light daily.

The individual record of each pullet began on the day she produced her first egg. Individual records were kept on feed consumption, body weight, number of eggs, and egg weight.

An all-mash, barley based laying ration, shown in Appendix Table XIII, was fed throughout the trial. During the first four months, the pullets were fed ad libitum. On the day a pullet produced her first egg, the initial body weight was recorded and 400 grams of feed weighed into the feeder. Thereafter feed was added in increments of 400 grams as needed. During the following four-month production period, different rates of feed restriction were applied to the four groups. The following feeding rates applied:

Group a. Predicted feed consumption minus 25%
Group b. Predicted feed consumption minus 12½%
Group c. Ad libitum
Group d. Predicted feed consumption

Statistical Methods

The main statistical methods employed in this study were those of correlation and tests for differences between means set forth by Snedecor (1959); the analysis of variance for multiple regression, and the estimating equation given by Ostle (1958):

$$\hat{Y} = b_0 + b_1X_1 + \ldots. + b_kX_k$$

The estimating equation would serve several useful purposes. With the estimating equation, the predicted feed consumption could be calculated for each hen. Upon this basis, feed restrictions could be calculated which take into consideration variables in the equation upon which feed consumption are dependent. With information gained from the estimating equation it would also be possible to adjust feed consumption and the efficiency of the hens to a common rate of egg production and body size. These adjusted measures might be useful in comparing hens differing in egg production and body weight.

The adjusted daily feed consumption indicates the amount of feed a pullet would consume if her daily egg production were 37 grams and her body weight 1720 grams. All of the adjusted values in this study were adjusted to this constant rate of egg production and body weight. The formula given by Ostle (1958) for finding adjusted Y values is:

$$\text{adj } Y = Y - b_1(X_1-\bar{X}_1) - b_2(X_2-\bar{X}_2)$$

In this case, 37 and 1720 were substituted for $\bar{X}_1$ and $\bar{X}_2$ respectively.

Gross efficiency was calculated by dividing the daily egg production by the daily feed consumption. The adjusted efficiency was found by dividing the constant 37, to which daily egg production was adjusted, by the adjusted daily feed consumption.

SYMBOLS

The following symbols are used in the text and table headings of this paper:

- adj E - adjusted efficiency coefficient, adjusted to constant $X_1 = 37$, $X_2 = 1720$
- Gr E - gross efficiency coefficient
- X_1 - egg production in grams
- X_2 - body weight in grams
- X_3, X_4 - other variables, defined in text
- Y - observed feed consumption
- $\hat{Y}$ - predicted feed consumption
- adj Y - adjusted feed consumption, adjusted to constant $X_1 = 37$, $X_2 = 1720$
- ** - highly significant ($P < .01$)
- * - significant ($P < .05$)
- Efficiency - grams of egg produced per gram of feed consumed

RESULTS AND DISCUSSION

Components of Efficiency

Five exploratory equations for estimating feed consumption were calculated. These equations are shown in Table I. Equations 1, 2, and 5 were derived from data taken after the hens had been in production for an average of 86 days. Equations 3 and 4 were calculated from data covering an average production period of 121 days.

Equations 1 and 2 differ only in the body weights used for variable X_2. The mid-body weight in equation 1 was an average (a) the weight of the pullet on the day of the first egg and (b) the weight at the end of the 86 day production period. The final body weight in equation 2 is that observed at the end of the 86 day period. The remaining variables in these equations were the total feed consumption, the total weight of eggs produced, and the number of days the pullets were in production.

All of the partial regression coefficients of equations 1 and 2 were statistically highly significant. As shown in the lower portion of Table I, the use of the final body weight of the pullets improved the estimating equation. The standard deviation of equation 2 was reduced, and the R^2 and F values improved. This improvement in the estimating equation was probably due to the fact that the pullets were gaining weight,

Table I. COMPARISON OF ESTIMATING EQUATIONS FOR FEED CONSUMPTION, USING DIFFERENT COMBINATIONS OF VARIABLES

Variables:

	Feed, gr.	Eggs, gr.	Body wt., gr.	Other Variables	
	Y	X_1	X_2	X_3	X_4
1.	Total feed	Total eggs	Mid	Days in Lay	-
2.	Total feed	Total eggs	Final	Days in Lay	-
3.	Feed/day	Egg/day	Final	Days in Lay	-
4.	Feed/day	Egg/day	Final	-	-
5.	Feed/day	Egg/day	Mid	Gain/day	Age 1st egg

Estimating equations:

		b_0		$b_1 X_1$		$b_2 X_2$		$b_3 X_3$		$b_4 X_4$
1.	$\hat{Y}$ =	-4824.27	+	.9140**	+	2.6905**	+	81.64**		-
2.	$\hat{Y}$ =	-4451.40	+	.9407**	+	2.5025**	+	78.69**		-
3.	$\hat{Y}$ =	33.4226	+	.7270**	+	.0303**	-	.0221		-
4.	$\hat{Y}$ =	33.1867	+	.7270**	+	.0303**		-		-
5.	$\hat{Y}$ =	32.0100	+	.8214**	+	.0281**	+	1.4645*	+	.0102

Means, s, R^2, F values:

	Y	X_1	X_2	X_3	X_4	s	R^2	F
1.	9707.21	3207.42	1676.08	86.86		1006.4	.78	131.43**
2.	9707.21	3207.42	1720.78	86.86		972.3	.79	143.50**
3.	114.69	37.76	1728.99	121.51		6.9	.62	62.37**
4.	114.69	37.76	1728.99			6.9	.62	94.37**
5.	112.37	37.05	1676.31	.78	166.14	8.1	.56	36.45**

** Significant beyond .01 probability level
* Significant beyond .05 probability level

and thus the final weight was a better basis for the estimation of feed consumption.

Equations 3 and 4 differ from 1 and 2 in that daily feed consumption and daily weight of eggs produced were used as variables Y and X_1, and the observation period covered 121 days of production. By converting variables Y and X_1 to a rate per day basis, variable X_3, days in production, might be omitted without seriously affecting the estimating equation. The resulting equations show that there were no changes in the partial regression coefficients associated with egg production and body weight. These coefficients were highly significant. The partial regression coefficient for days in production, in equation 3, was non-significant. In the lower portion of Table I, it will be seen that the s and R^2 values for equations 3 and 4 were the same. The F values, however, changed because of the difference in degrees of freedom resulting from the deletion of one variable. Omitting days in production did not significantly affect the estimating qualities of the equation. In comparing equations 1 and 2 with 3 and 4, it was found that the R^2 values were reduced from .78 to .62. Apparently extending the observation period from 86 to 121 days adversely affected the estimation.

The improvement of estimating equation 2 over equation 1, by increasing the body weight, suggested that change in body weight was a factor which affected feed consumption. Therefore average daily change in body weight was introduced as a variable in equation 5. The other variables were daily feed consumption, daily weight of egg produced, mid body weight, and age at first egg. The partial regression coefficients associated with egg production and body weight again were highly significant. The partial regression coefficient for the average daily gain in weight was significant. The partial regression coefficient for age at first egg was not significant. Comparing equations 3 and 4 with equation 5, it was found that the standard deviation in equation 5 was greater, and the R^2 and F values obtained were lower than in equations 3 and 4. The means of the variables are shown in Table I. Analysis of variance tables of multiple regression equations 1 through 5 are shown in Table II.

The individual records of the pullets from which equations 1, 2, and 5 were calculated are shown in Appendix Tables I, II, III, and IV. In addition to the daily feed consumption, Y; the daily egg production, X_1; and body weight, X_2; which were used in calculating the estimating equations; the predicted feed consumption, $\hat{Y}$; the adjusted feed consumption, adj Y; the gross efficiency, Gr E; and the adjusted efficiency, adj E; are shown on a daily basis for each pullet. The records

Table II. ANALYSIS OF VARIANCE OF MULTIPLE REGRESSION EQUATIONS 1, 2, 3, 4, and 5

	Source	d.f.	SS	MS	s	R^2	F
1.	Regression	3	399407508	1333135836.0	1006.4	.78	131.43**
	Deviation	114	115471770	1012910.3			
	Total	117	514879278				
2.	Regression	3	407087180	135695726.6	972.3	.79	143.50**
	Deviation	114	107792098	945552.4			
	Total	117	514879278				
3.	Regression	3	9056.25	3018.75	6.9	.62	62.37**
	Deviation	111	5371.65	48.39			
	Total	114	14427.90				
4.	Regression	2	9055.27	4527.63	6.9	.62	94.37**
	Deviation	112	5373.07	47.97			
	Total	114	14428.34				
5.	Regression	4	9580.06	2395.02	8.1	.56	36.45**
	Deviation	113	7423.11	65.69			
	Total	117	17003.37				

** Significant beyond .01 probability level

from which equations 3 and 4 were calculated are shown in Appendix Tables V, VI, VII, and VIII.

At the end of the non-restricted feeding period, a set of feed consumption estimating equations was calculated covering 121 days of production. The set of equations include an over-all equation which was based on the total observations and four individual equations, one for each group of hens. At the end of the restricted feeding period, a similar set of equations was calculated on the data accumulated during that period. Both sets of equations are shown in Table III. It will be noticed that equation 6 is the same as equation 4 in Table I and serves as the over-all equation of the four groups 6, a, b, c, and d during the non-restricted feeding period of 121 days. The data from which equations 6, a, b, c, and d were calculated are shown in Appendix Tables V, VI, VII, and VIII. The headings of these tables show the estimating equation used in calculating the predicted feed consumption of each hen. The predicted feed consumption of each hen was then used as a basis for calculating the daily feed allowance for the hen during the restricted feeding period. Equations 7, a, b, c, and d were calculated from Appendix Tables IX, X, XI, and XII. The daily feed consumption, Y, in these tables indicates the amount of feed allowed each hen during the restricted feeding period.

Table III. ESTIMATING EQUATIONS, OVER-ALL AND BY GROUPS, 121 DAY PRODUCTION PERIODS, NON-RESTRICTED AND RESTRICTED FEEDING

Estimating equations, non-restricted feeding

		b_0		b_1X_1		b_2X_2
6.	$\hat{Y}$ =	33.1867	+	.7270**	+	.0303**
a.	$\hat{Y}$ =	38.9816	+	.9216**	+	.0229**
b.	$\hat{Y}$ =	35.1551	+	.3164**	+	.0387**
c.	$\hat{Y}$ =	21.7647	+	1.0897**	+	.0285**
d.	$\hat{Y}$ =	25.3619	+	.7782**	+	.0325**

Estimating equations, restricted feeding. Feeding rates: a. $\hat{Y}$-25%, b. $\hat{Y}$-12½%, c. ad libitum, d. $\hat{Y}$

		b_0		b_1X_1		b_2X_2
7.	$\hat{Y}$ =	12.4204	+	.8876**	+	.0368**
a.	$\hat{Y}$ =	34.5142	+	.4465**	+	.0242**
b.	$\hat{Y}$ =	23.6048	+	.5754**	+	.0333**
c.	$\hat{Y}$ =	38.8166	+	.8442**	+	.0276**
d.	$\hat{Y}$ =	23.3975	+	.7154**	+	.0338**

Means, s, R^2, F values

	$\bar{Y}$	$\bar{X}_1$	$\bar{X}_2$	s	R^2	F
6.	114.69	37.76	1728.99	6.9	.62	94.37**
a.	112.48	37.31	1704.55	7.3	.57	17.25**
b.	117.53	38.15	1814.06	7.8	.53	15.54**
c.	116.42	39.31	1818.21	5.8	.65	23.46**
d.	112.21	36.38	1795.71	5.5	.82	57.69**
7.	99.46	24.85	1761.53	7.4	.83	281.04**
a.	79.41	13.79	1599.24	3.0	.89	106.69**
b.	96.60	25.06	1755.56	4.1	.77	45.52**
c.	117.85	32.36	1895.25	7.8	.71	31.11**
d.	104.92	28.57	1802.32	5.1	.89	111.63**

** Significant beyond .01 probability level

In Table III, it is seen that the constant, b_0, of the over-all equation 6 falls within the range of the constants of its groups a, b, c, and d. Similarly the partial regression coefficients for egg production, b_1, and body weight, b_2, fall within the range of the corresponding group coefficients. In contrast, the b_0 of over-all equation 7 falls below the range of the constants in its corresponding group equations, and the partial regression coefficients b_1 and b_2 are greater than corresponding coefficients in the group equations. In the non-restricted feeding period, equation 6 appeared to be an "average" of the group equations, but during the restricted feeding period, when some of the variables were controlled, this did not seem to pertain.

The F values, shown in the lower portion of Table III, obtained for the over-all equations 6 and 7 are greater than the corresponding values in their respective groups, indicating as may be expected, that the greater number of observations tend to reduce error. Examination of the R^2 values, however, indicated that the over-all equations were not always the best estimating equations when compared with the R^2 values of their own groups. This would indicate, that although the over-all equations contain less error, the equations for the individual groups may be more realistic. The analysis of variance for the multiple regression equations 6, a, b, c, d, and 7, a, b, c, and d appear in Table IV.

The estimating equations in Table I and IV show that all the partial regression coefficients associated with the variables egg production and body weight were highly significant. This applied whether the hens were being fed ad libitum or restricted rations. This would indicate that, of the independent variables considered in this study, egg production and body weight are the major factors affecting feed consumption. This agrees with the findings reported in the review of literature.

Measures of Efficiency

The adjusted efficiency coefficients might be useful measures for comparing the efficiencies of hens which differed in rate of production and body size. A comparison of gross efficiency coefficients and adjusted efficiency coefficients is shown in Table V. Part 1 shows a comparison of the average gross efficiency versus the average adjusted efficiency of four groups of hens during the non-restricted feeding period. It was found that the mean differences between these measures were non-significant. Correlations between the means of gross efficiency and adjusted efficiency all were positive and ranged from .21 to .53. It would appear that, because of the non-significant mean differences, gross efficiency and adjusted efficiency estimated the same measure.

Table IV. . ANALYSIS OF VARIANCE OF ESTIMATING EQUATIONS, 6, a, b, c, d, AND 7, a, b, c, d

	Source	df	SS	MS	s	R^2	F
Non-restricting feeding							
6.	Regression	2	9055.27	4527.63	6.9	.78	131.43**
	Deviation	112	5373.07	47.97			
	Total	114	14428.34				
a.	Regression	2	1881.59	940.79	7.3	.57	17.25**
	Deviation	26	1417.65	54.52			
	Total	28	3299.24				
b.	Regression	2	1920.28	960.14	7.8	.53	15.54**
	Deviation	27	1667.18	61.74			
	Total	29	3587.46				
c.	Regression	2	1608.16	804.07	5.8	.65	23.46**
	Deviation	25	856.69	34.26			
	Total	27	2464.85				
d.	Regression	2	3646.60	1823.30	5.5	.82	57.69**
	Deviation	25	790.10	31.60			
	Total	27	4436.70				
Restricted feeding							
7.	Regression	2	31912.04	15956.02	7.4	.83	281.04**
	Deviation	112	6358.59	56.77			
	Total	114	38270.63				
a.	Regression	2	1947.72	973.86	3.0	.89	106.69**
	Deviation	26	237.31	09.12			
	Total	28	2185.03				
b.	Regression	2	1595.93	797.96	4.1	.77	45.52**
	Deviation	27	473.26	17.52			
	Total	29	2069.19				
c.	Regression	2	3842.13	1921.06	7.8	.71	31.11**
	Deviation	25	1543.29	61.73			
	Total	27	5385.42				
d.	Regression	2	5767.26	2883.62	5.1	.89	111.63**
	Deviation	25	645.77	25.83			
	Total	27	6413.03				

** Significant beyond .01 probability level

Table V. COMPARISON OF GROSS EFFICIENCY AND ADJUSTED EFFICIENCY COEFFICIENTS AS MEASURES OF EFFICIENCY DURING NON-RESTRICTED AND RESTRICTED FEEDING PERIODS

Part 1. Group	Non-restricted mean Gr E	vs.	Non-restricted mean adj E	Mean difference	r
a.	.3315		.3259	.0056	.53
b.	.3264		.3275	.0011	.38
c.	.3382		.3338	.0044	.48
d.	.3242		.3365	.0123	.21

Feeding rates: a. $\hat{Y}$-25%, b. $\hat{Y}$-12½%, c. ad lib. d. $\hat{Y}$

Part 2. Group	Restricted mean Gr E	vs.	Restricted mean adj E	Mean difference	r
a. $\hat{Y}$-25%	.1706		.3979	.2273**	.08
b. $\hat{Y}$-12½%	.2584		.3631	.1047**	.07
c. ad lib.	.2686		.3164	.0478*	.19
d. $\hat{Y}$	.2658		.3432	.0774**	.05

** Significant beyond .01 probability level
* Significant beyond .05 probability level

A comparison of these measures during restricted feeding, in part 2 of Table V, shows the mean differences of groups a, b, and d were highly significant, and the correlation coefficients ranged from .05 to .08. The mean difference between these measures of group c was significant and the correlation coefficient was .19. Relatively small adjustments were made in calculating the adjusted efficiency coefficients in the non-restricted feeding period, while large adjustments were made in the restricted feeding period. The highly significant mean differences and the low correlations in the restricted feeding period indicated that the adjusted efficiency coefficients lost much of their value when extreme adjustments are made. This suggests that gross efficiency coefficients, calculated directly from observed measures, may be more satisfactory than adjusted efficiency coefficients as measures of efficiency.

Feed Restriction and Efficiency

The summary in Table VI shows that feed restriction appeared to affect every measure that was observed. Egg production in group a was reduced from 37.2 grams per day in the non-restricted feeding period to 13.8 grams per day in the restricted period. This was a gross reduction of 63 percent. It is also seen that group c, fed ad libitum in both periods, declined from 39.3 grams to 32.4 grams of egg per day, or a decline of 17 percent, in the same period. This decline is quite possibly due to a seasonal effect normally seen in laying flocks, in which production declines as the flock approaches the end of the production cycle. If it is assumed that group a also declined 17 percent because of seasonal effect, the true reduction attributable to feed restriction may be near 46 percent. A similar deduction made about group b, restricted 12½ percent, would result in a decline of egg production amounting to 17 percent because of restriction. Group d, which received the predicted feed consumption during the restricted feeding period, under the same assumptions would have declined 7 percent.

Table VI. GROUP MEANS AND OVER-ALL MEANS OF ACTUAL AND ADJUSTED VALUES OF FOUR GROUPS OF PULLETS DURING 121 DAYS NON-RESTRICTED AND 121 DAYS RESTRICTED FEEDING

Non-restricted

Group	No.	Y	$\hat{Y}$	adj Y	X_1	X_2	Gr E	adj E
a.	29	112.5	111.6	113.9	37.2	1705	.3315	.3259
b.	30	117.5	117.5	113.4	38.2	1814	.3264	.3275
c.	28	116.4	116.3	111.1	39.3	1818	.3382	.3338
d.	28	112.2	112.0	110.2	36.4	1796	.3242	.3365
Over-all	115	114.7	114.4	112.2	37.8	1782.9	.3300	.3308

Restricted Feeding rates:

a. $\hat{Y}$-25%, b. $\hat{Y}$-12½%, c. ad libitum, d. $\hat{Y}$

Group	No.	Y	$\hat{Y}$	adj Y	X_1	X_2	Gr E	adj E
a.	29	79.4	79.4	93.1	13.8	1599	.1706	.3979
b.	30	96.6	96.6	102.1	25.1	1755	.2584	.3631
c.	28	117.8	117.5	117.3	32.4	1895	.2686	.3164
d.	28	104.9	104.8	108.0	28.6	1802	.2658	.3432
Over-all	115	99.5	99.3	105.0	24.8	1761.5	.2406	.3557

These reductions in egg production are not directly comparable to those reported by Heywang (1940) when he found that 12½ and 25 percent feed restriction resulted in 31 and 54 per cent reduction, because of the differences in the manner in which these tests were conducted.

Body weight, as a major component of feed consumption, also affects efficiency of egg production. Normally hens gain slowly in body weight throughout the production cycle. The average initial weight of the hens in group c, fed ad libitum, was 1818 grams, and the average final weight was 1895 grams. All of the other groups lost weight during the restricted feeding period; the decrease in weight corresponding with the severity of feed restriction. The effect that loss of body weight had upon egg production can only be conjectured. Two alternatives are suggested, either (a) part of the loss in body weight may have been used to support egg production, or (b) the reduced body weight, requiring less maintenance, may have left more nutrients available for egg production.

When the mean gross efficiency coefficients of the four groups of pullets during the restricted and non-restricted feeding periods were compared, Table VII, it was found that all groups declined in efficiency during the restricted feeding period. The mean differences for all groups were highly significant, suggesting the possible effects of a seasonal decline. During the non-restricted feeding period the mean efficiencies of the four groups ranged from .3264 to .3382 with no significant differences among groups. During the restricted feeding period the mean efficiency coefficients ranged from .1706 to .2686, the rank of efficiency corresponding to the rate of feeding. However, only the mean of groups a, restricted 25 percent, differed significantly from the means of the other groups. This suggests that while 25 percent restriction of feed intake significantly reduces efficiency, the hens may be able to adjust to less severe restrictions. The observed gross reduction in efficiency in group a was 29 percent.

Table VII. COMPARISON OF MEAN GROSS EFFICIENCY COEFFICIENTS OF FOUR GROUPS OF PULLETS DURING 121 DAYS RESTRICTED AND 121 DAYS NON-RESTRICTED FEEDING

Group	Restricted mean Gr E	vs.	Non-restricted mean Gr E	Mean difference	r
a. Y-25%	.1706*		.3315	.1609**	.63
b. Y-12½%	.2584		.3264	.0680**	.43
c. ad lib.	.2686		.3382	.0696**	.52
d. Y	.2658		.3284	.0584**	.63

** Significant beyond .01 probability level
* Significant beyond .05 probability level

SUMMARY

Individual records of feed consumption, egg production, egg weight, and body weight were accumulated on 115 Cornell Randombred Strain of White Leghorn pullets. The records covered a total production period of 242 days. During the first 121 days of the production period, the pullets were fed ad libitum; in the remaining period, the pullets were divided into four groups and different rates of feed restriction were applied to each group.

Fifteen multiple regression equations for estimating feed consumption were calculated. Five equations, using different combinations of variables, were based on data taken from an 86 day production period during non-restricted feeding. Five equations were calculated from data taken during a 121 day production period of non-restricted feeding. Five equations were based on data taken from a 121 day production period of restricted feeding. Analysis of these equations indicated that egg production and body weight were the major factors which influenced feed consumption.

Gross efficiency coefficients and adjusted efficiency coefficients were calculated for each pullet in this study. The adjusted efficiency coefficients for each pullet were calculated by adjusting the rate of egg production to 37 grams per day and the body weight to 1720 grams. A comparison of the

gross efficiency coefficients and the adjusted efficiency coefficients indicated that the gross efficiency coefficients were the more satisfactory measures of efficiency in egg production.

Feed restrictions were based on the predicted feed consumption calculated for each pullet. Restricting feed consumption 25 percent significantly reduced efficiency in egg production. The observed reduction was 29 percent. Restricting feed consumption 12½ percent or feeding at the rate of predicted feed consumption did not significantly reduce efficiency in egg production.

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APPENDIX

Table I. Group a. INDIVIDUAL RECORDS OF 29 PULLETS, 86 DAY PRODUCTION PERIOD, NON-RESTRICTED FEEDING

$$\hat{Y} = -4451.40 + .9407X_1 + 2.5025X_2 + 78.69X_3$$

Hen No.	Y	$\hat{Y}$	adj Y	X_1	X_2	X_3	Gr E	adj E
8	115	111	116	31.9	1842	86	.2274	.3190
16	135	140	107	44.5	2401	79	.3296	.3458
17	117	118	111	40.1	1836	103	.3427	.3333
18	116	115	113	37.2	1856	107	.3207	.3274
23	88	90	110	25.2	1423	74	.2864	.3364
40	120	116	116	38.8	1803	99	.3233	.3190
41	111	107	116	38.3	1483	94	.3450	.3190
45	111	112	111	38.5	1676	106	.3468	.3333
55	128	128	112	36.5	2308	87	.2852	.3304
56	108	108	112	36.2	1528	120	.3352	.3304
60	91	90	113	28.6	1336	73	.3143	.3274
62	122	116	118	39.5	1795	86	.3238	.3136
64	116	108	120	37.6	1608	74	.3241	.3083
67	110	115	107	40.4	1721	67	.3673	.3458
70	99	108	103	38.8	1563	77	.3919	.3592
74	117	97	122	36.4	1250	84	.3111	.3033
76	105	104	113	34.5	1547	81	.3286	.3274
81	106	103	115	33.6	1465	112	.3170	.3217
89	96	94	114	21.0	1663	60	.2187	.3246
93	109	109	112	37.8	1568	99	.3468	.3304
94	84	97	99	32.0	1368	87	.3809	.3558
95	103	103	112	35.0	1401	108	.3398	.3304
96	119	111	120	35.0	1758	108	.2941	.3083
97	102	109	105	38.7	1611	70	.3794	.3524
101	112	132	92	33.7	1850	100	.3009	.3814
103	110	119	103	47.6	1635	83	.4327	.3592
115	113	105	120	39.5	1432	79	.3496	.3083
116	136	104	144	37.8	1429	82	.2779	.2569
120	103	99	116	34.0	1414	80	.3301	.3190
Means	110.4	109.2	111.1	36.2	1640	88.4	.3283	.3298
Over-all	112.3	112.0	112.0	36.9	1720	86.8	.3325	.3316

Table II. Group b. INDIVIDUAL RECORDS OF 30 PULLETS, 86 DAY PRODUCTION PERIOD, NON-RESTRICTED FEEDING

$$\hat{Y} = -4451.40 + .9407X_1 + 2.5025X_2 + 78.69X_3$$

Hen No.	Y	$\hat{Y}$	adj Y	X_1	X_2	X_3	Gr E	adj E
2	119	122	109	45.0	1806	80	.3781	.3394
5	111	118	105	40.9	1818	106	.3685	.3524
11	115	118	109	40.7	1818	77	.3539	.3394
13	113	112	113	36.2	1762	87	.3204	.3274
20	103	108	107	39.2	1513	89	.3806	.3458
21	110	106	116	36.2	1556	78	.3291	.3190
24	119	93	138	12.2	1845	72	.1025	.2681
30	108	103	117	32.6	1543	94	.3018	.3162
35	96	104	104	36.5	1459	88	.3802	.3558
36	107	116	103	42.1	1694	109	.3935	.3592
37	153	130	135	42.7	2073	65	.2790	.2741
42	108	96	124	40.0	1307	57	.3740	.2984
46	118	110	120	34.7	1747	79	.2941	.3083
54	124	127	109	45.8	1939	72	.3694	.3394
58	98	105	105	38.2	1394	96	.3898	.3524
65	103	102	113	32.0	1539	95	.3107	.3274
69	114	116	110	38.0	1827	65	.3333	.3363
78	121	120	113	39.3	1925	85	.3248	.3274
79	129	118	123	32.8	2182	115	.2542	.3008
82	129	121	120	44.0	1814	120	.3411	.3083
83	133	110	135	38.4	1599	88	.2887	.2741
84	120	124	108	40.2	2032	85	.3350	.3426
87	100	111	101	37.0	1695	84	.3700	.3663
91	112	112	112	32.3	1897	111	.2884	.3304
92	105	108	109	33.0	1701	103	.3143	.3394
100	119	119	112	41.1	1850	84	.3453	.3304
106	114	119	107	40.8	1838	85	.3579	.3458
113	109	107	114	34.6	1593	101	.3174	.3245
114	123	125	110	50.2	1766	68	.4081	.3363
117	111	111	112	35.3	1725	101	.3180	.3304
Means	114.4	113.0	113.7	37.7	1741	87.9	.3306	.3305
Over-all	112.3	112.0	112.0	36.9	1720	86.8	.3325	.3316

Table III. Group c. INDIVIDUAL RECORDS OF 28 PULLETS, 86 DAY PRODUCTION PERIOD, NON-RESTRICTED FEEDING

$$\hat{Y} = -4451.40 + .9407X_1 + 2.5025X_2 + 78.69X_3$$

Hen No.	Y	$\hat{Y}$	adj Y	X_1	X_2	X_3	Gr E	adj E
1	135	126	121	41.1	2067	80	.3044	.3062
3	120	120	112	42.5	1833	81	.3542	.3304
4	110	114	108	35.6	1819	71	.3236	.3426
6	106	110	108	40.4	1543	86	.3811	.3426
10	110	112	110	37.8	1723	83	.3436	.3364
14	123	126	109	40.6	2061	80	.3301	.3394
22	95	92	115	30.0	1346	75	.3158	.3217
25	107	116	103	37.0	1844	71	.3458	.3592
27	128	123	117	45.8	1813	79	.3578	.3162
29	110	109	113	28.7	1931	100	.2609	.3274
31	115	116	111	46.3	1587	83	.4026	.3333
32	128	116	124	42.0	1706	88	.3281	.2984
38	116	116	112	41.0	1753	76	.3534	.3304
43	117	110	119	36.1	1685	79	.3085	.3109
48	128	117	123	39.0	1855	99	.3047	.3008
49	111	115	108	41.4	1695	69	.3730	.3426
51	94	96	110	34.9	1376	66	.3713	.3364
59	123	137	98	43.8	2168	58	.3561	.3775
61	110	111	111	40.7	1585	83	.3700	.3333
63	126	124	114	48.1	1778	75	.3817	.3245
86	106	114	104	34.2	1930	111	.3226	.3558
88	102	110	104	40.0	1524	99	.3922	.3558
90	110	114	108	36.7	1808	110	.3336	.3426
98	103	108	107	31.9	1741	110	.3097	.3458
111	121	117	116	41.0	1787	108	.3388	.3190
112	108	111	109	35.6	1716	95	.3296	.3394
118	120	111	121	38.9	1598	99	.3242	.3062
119	130	122	120	35.3	2026	63	.2715	.3083
Means	114.4	114.7	111.6	38.8	1761	84.8	.3389	.3315
Over-all	112.3	112.0	112.0	39.6	1720	86.8	.3325	.3316

Table IV. Group d. INDIVIDUAL RECORDS OF 28 PULLETS, 86 DAY PRODUCTION PERIOD, NON-RESTRICTED FEEDING

$$\hat{Y} = -4451.40 + .9407X_1 + 2.5025X_2 + 78.69X_3$$

Hen No.	Y	$\hat{Y}$	adj Y	X_1	X_2	X_3	Gr E	adj E
7	113	113	112	42.8	1622	66	.3788	.3304
9	112	117	107	40.8	1779	85	.3643	.3457
12	117	107	122	37.7	1571	76	.3222	.3033
15	114	119	107	44.0	1728	90	.3860	.3457
19	112	114	110	42.5	1604	84	.3794	.3364
26	108	113	107	41.0	1600	111	.3796	.3457
28	108	107	113	34.6	1603	85	.3204	.3274
33	111	111	112	42.0	1516	94	.3784	.3304
34	105	112	105	41.2	1631	66	.3924	.3524
44	120	120	112	44.5	1759	79	.3708	.3304
47	121	120	113	41.4	1863	87	.3421	.3274
50	96	100	108	36.1	1370	79	.3760	.3426
52	107	112	107	30.3	2016	115	.2832	.3457
53	95	98	109	25.6	1626	81	.2695	.3394
57	112	118	106	38.0	1904	97	.3393	.3490
66	96	94	114	36.1	1266	69	.3760	.3246
71	119	116	115	38.3	1832	84	.3218	.3217
72	108	95	125	16.8	1788	89	.1555	.2960
73	125	131	106	40.4	2271	87	.3232	.3490
77	66	71	107	13.8	1207	69	.2090	.3457
80	84	95	101	34.6	1257	81	.4119	.3663
85	131	128	115	40.7	2162	85	.3107	.3217
104	125	115	122	34.7	1882	82	.2776	.3033
105	116	112	116	37.7	1712	74	.3250	.3190
107	99	109	102	35.5	1668	84	.3586	.3627
108	128	124	116	35.4	2260	100	.2766	.3190
109	111	118	105	34.5	2016	86	.3108	.3524
110	123	125	110	45.2	1894	83	.3675	.3364
Means	110.0	111.2	110.8	36.6	1729	84.5	.3323	.3346
Over-all	112.3	112.0	112.0	36.9	1720	86.8	.3325	.3316

Table V. Group a. INDIVIDUAL RECORDS OF 29 PULLETS, 121 DAY PRODUCTION PERIOD, NON-RESTRICTED FEEDING

$$\hat{Y} = 38.9816 + .9216X_1 + .0229X_2$$

Hen No.	Y	$\hat{Y}$	adj Y	X_1	X_2	Gr E	adj E
8	115	110	118	30.4	1904	.2643	.3136
16	135	136	112	45.6	2404	.3377	.3304
17	121	121	113	42.1	1887	.3479	.3274
18	118	120	111	39.0	1968	.3305	.3333
23	92	99	106	28.0	1521	.3043	.3491
40	124	120	117	40.1	1934	.3233	.3162
41	114	110	117	39.0	1523	.3421	.3162
45	116	117	112	40.0	1826	.3448	.3304
55	121	118	116	29.0	2306	.2396	.3190
56	113	112	114	39.1	1605	.3460	.3246
60	88	98	103	29.1	1405	.3306	.3592
62	124	120	117	41.1	1886	.3314	.3162
64	118	113	118	39.4	1655	.3338	.3136
67	113	111	115	42.0	1792	.3716	.3217
70	101	113	101	39.1	1662	.3871	.3663
74	115	105	123	38.1	1356	.3313	.3008
76	109	110	112	37.0	1605	.3394	.3304
81	110	105	118	34.1	1534	.3100	.3136
89	110	106	117	29.5	1767	.2681	.3162
93	113	114	112	40.1	1672	.3548	.3304
94	89	96	106	33.0	1428	.3707	.3491
95	108	106	115	36.3	1492	.3361	.3217
96	122	116	119	36.0	1910	.2950	.3109
97	106	113	106	40.0	1649	.3773	.3491
101	113	113	113	35.1	1843	.3106	.3274
103	110	119	104	48.0	1588	.4363	.3558
115	114	110	117	41.0	1460	.3596	.3162
116	129	107	135	39.0	1420	.3023	.2741
120	101	98	116	29.0	1430	.2871	.3190
Means	112.5	111.6	113.9	37.2	1704	.3315	.3259
Over-all	114.7	114.4	112.2	37.8	1728	.3300	.3308