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To the Graduate Council:

I am submitting herewith a thesis written by Lloyd Henry Littlefield entitled "The Influence of Environment upon the Performance of Laying Hens." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Poultry Management and a minor in Dairying.

O. E. Goff
Major Professor

We have read this thesis
and recommend its acceptance:

W. Patrick
L. P. Kyle

Accepted for the Council:

J. H. Winters
Dean of the Graduate School

THE INFLUENCE OF ENVIRONMENT UPON THE PERFORMANCE
OF THE LAYING HEN

A THESIS

Submitted to
The Graduate Council
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
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by

Lloyd Henry Littlefield

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INTRODUCTION

The total production of eggs in the United States has almost doubled in the past twenty years. Competition has decreased the margin of income between the cost of production and the sale price of eggs to a point where only those poultrymen following desirable management practices may expect satisfactory returns from their investments. This margin has been small during the past year as it has been throughout many previous periods in the history of the poultry industry. Poultrymen have tried to overcome this problem with efficient feeding methods, improved breeding, effective disease control, and better management.

Among the older precepts of poultry husbandry are the facts that the hen will produce more eggs during early spring; the quality of eggs reaching the consumers is considered at a peak in the cooler months of the year, with the best quality and the highest rate of production expected from pullet flocks during this period. Environmental factors common to these seasons have been considered responsible for these relationships.

Temperature, humidity, light, and air movement are some of the controlling environmental factors. An ideal environment embodying optimum effect of these influences has not been conclusively determined.

OBJECTIVE

The objective of this thesis has been to study the effect of temperature, humidity, and selected housing conditions on the laying hen and to study the effect of temperature fluctuations on market eggs.

LITERATURE REVIEW

Yeates, et al. (1941) studied reactions of numerous domestic fowls to various temperatures and humidities, and found that body functions were initially disturbed when the environmental temperatures rose above 80°F., but relative humidities of 55 per cent, or less, protected against the effect of high temperatures. Wilson (1948) subjected hens to temperatures above 90°F. and found that body temperature rose, feed consumption dropped, water consumption increased, the heart rate lowered, and the respiration was increased. (At 95°F. water intake was double that at 70°F.).

Gutteridge, et al. (1944) found no improvement in egg production when temperatures were increased from a mean of 37°F. to 59°F., but there was an annual saving per hen of 2.85 pounds of feed when the temperature was raised from 38°F. to 60°F.

Bruckner (1936) reported that a constant air temperature of 50°F. stabilized winter egg production by preventing slumps. He decided this stabilizing had no effect on annual production because the winter gain was lost later. Hays (1948) presented evidence that declining house temperatures adversely effected egg production. Hays (1949) later stated that the low temperatures of winter seem to stimulate a higher incidence of winter pause, but do not consistently increase the duration of the pause.

Wilson and Edwards (1952) observed that when hens were subjected to water deprivation and thermal stress (90°F. + 1°F.) they

went out of production in 48 hours and some birds went into a molt. Hutchinson and Sykes (1953) found a slight fall in the heart rate associated with decreased egg production under severe heat stress.

Greenwood (1953) found that hens produced more eggs when kept at constant environmental conditions of 65°F., 60 per cent relative humidity, and 12 hours of artificial light per day, than did a similar group exposed to natural conditions normally used for the flock.

Warren and Bennion (1933) and Warren (1939) found that high temperatures tended to reduce egg size. Bruckner (1936) compared production from birds in a near constant temperature of 50°F. with winter eggs from similar layers in an unheated house and found a decrease in egg size from birds held at the constant temperature. Warren, et al. (1950) reported a similar decrease in egg size at a constant temperature of 65°F. They also showed that under constant temperatures egg size gradually increased throughout the first laying year, then decreased when high summer temperatures were met.

Hutchinson (1953) found that short daily periods of extreme heat stress, ranging in length from 107 to 214 minutes, would reduce egg weight more than continuous living in a warm climate. Wilson (1949) stated that egg size and shell thickness began to decrease at 75°F. and that hens would die of heat prostration when temperatures remained at 100°F. for more than 8 hours.

Jull (1924) found that the percentage of shell increased from December through February, decreased through May, then showed an

irregular upward trend for the balance of the year. Warren and Schnepel (1940) and then Heywang (1946) found a close association between thin shell and high environmental temperatures. Conrad (1939) found that the blood calcium lowered in about the same proportion that the shells thinned. Warren, et al. (1950) failed to find a correlation between blood calcium and shell thickness.

Sturkie (1946) observed that hens with induced hypothermia layed soft-shelled eggs if the eggs were in the reproductive tract during the time of hypothermia. Warren and Schnepel (1940) stated that hens and pullets subjected to high temperatures (90°F.) showed a striking reduction in shell thickness, with high humidity tending to accentuate the effect.

Lorenz and Almquist (1936) found the percentage of firm white to be lowered by high external temperatures. Hunter, et al. (1936) stated there was a lower albumen quality during the summer months. Wilhelm and Heiman (1938) showed a downward trend in albumen quality from October to July with an upward trend following immediately. They also showed that this albumen quality decline was not correlated with either temperature, rate of lay, or egg size. Ringrose and Morgan (1939) found a poorer quality of albumen from late winter to the end of spring.

Jeffrey (1941), in a study with hens starting to lay at different seasons, reported the albumen index to be a function of age rather than a consequence of season. Miller and Bearse (1937) stated that low quality albumen was associated with low production. This

could explain why some workers have found low quality in the spring months.

Long and Godfrey (1952) stated there was indication that the receptivity of the females was lower during cold weather than during warmer weather.

Fox (1951), working with hens denied access to water, found that the heavy breeds were more tolerant to heat than light breeds. Nalbandov and Card (1944), Denton (1947), Taylor (1947), and several other workers agreed that there was no effect of temperature, humidity, nor light upon the incidence of blood spots.

Heywang (1946) observed that growth and gross efficiency of feed utilized is increased when feed is available only in the cooler part of the day.

Brody (1948) found that domestic fowls produced over twice as much thyroxine in the Missouri winter as in the summer, and, as might be expected from the widespread metabolic effects of thyroxine, there was a relationship between thyroxine production and egg production. Barrott and Pringle (1941) showed that the minimum metabolism in the hen occurred at an external temperature of 78°F. and the maximum metabolism at 61°F.

Mueller, et al. (1951) found by controlling the light and the temperature that hens layed more eggs, became heavier, and had a lower mortality than did hens maintained under natural atmospheric conditions.

Whetham (1933) reported that increases in the length of daylight acted on the pituitary gland and thereby stimulated egg production. Barrott, et al. (1951) presented conclusive evidence that the

production per hen could be increased between 10 and 19 per cent by the use of ultra violet radiation.

Byerly and Moore (1941) found that a 14 hour day lengthened the size of the clutches by assuring a lighted period of sufficient length to maintain pituitary and ovarian activity shortly after ovulation. Ragab and Assem (1953) showed length of daylight a positive factor in egg laying. They also found that high temperatures have a greater effect. Hays (1948), however, stated that length of day had little effect on egg production. Heywang (1945) also indicated that artificial light did not appreciably affect feed consumption, egg production, or live weight of the pullets.

Riley and Byerly (1943) found that increased light periods were capable of stimulating reproductive activity in hens which had not finished molting without affecting the progress of the molt. Carver (1941) found that there was no advantage to increasing the foot candles above 2 foot candles when frosted Mazda lights were used to provide a 13 hour day for laying hens.

PROCEDURE

Mature Single Comb White Leghorn pullets raised under similar conditions were used throughout this experiment. Water and an all-mash ration, considered adequate in all known required nutrients, were available to all hens ad libitum.

Records were kept on body weight, egg production, egg size, shell thickness, interior quality, mortality and cause of death, hen replacement, feed consumed, number of dirty eggs, and the appearance of the hens. Temperature and humidity were recorded in each room daily.

On September 1, 1954, a comparison was initiated between hens maintained in individual cages and hens maintained in complete confinement under conventional floor management.

The 255 floor managed pullets were confined to a 24' x 48' laying house. The caged birds were placed in a 24' x 48' house divided into two rooms, each of which was equipped to care for 108 pullets.

One lot of caged hens was designated as the controls with no attempt made to modify room temperature of the house other than through adjustment of the doors and windows. Heating tape was arranged in the water trough to prevent freezing of water during inclement weather.

The second lot of caged Leghorns was designated as the experimental lot. Extremes in temperature were to be modified in the house through application of heat during the winter months and through the use of water sprayed on the roof and/or on the surrounding yard area.

No attempt was made to modify the house temperature of the floor managed hens except through adjustment of doors and windows. Heating

tape prevented freezing of the drinking water. The comparison between these 3 groups was recorded for 303 days.

On February 18, 1955, 48 Single Comb White Leghorn hens, selected for vigor, health, and production were placed in individual laying cages in two air conditioned rooms maintained at a temperature of $65^{\circ}\text{F.} \pm 5^{\circ}\text{F.}$ Individual production and egg-weight records were kept on these birds for 33 days, at which time all birds were paired according to production and egg weight. One member of each pair was placed in each of two groups, a total of 24 pullets per group. Group I. was then subjected to a constant temperature of $75^{\circ}\text{F.} \pm 5^{\circ}\text{F.}$, referred to as a moderate temperature, while Group II. was exposed to a room temperature of $85^{\circ}\text{F.} \pm 5^{\circ}\text{F.}$, referred to as a high temperature. The females were maintained under these conditions for 84 days, at which time they were replaced by a second lot.

A duplicate experiment in the air conditioned rooms was begun on June 15, 1955, and was continued for 32 days.

Albumen quality of market eggs was determined by subjecting the eggs to various degrees of temperature for different periods of time in three replications. The eggs for this experiment were gathered hourly from Single Comb White Leghorn pullets. Temperature studies were begun immediately to minimize the effect of conditions other than the experimental environments studied.

The broken out interior egg quality was measured by an egg quality slide rule distributed by the Kaw Company of Trenton, New Jersey, and the shell thickness was measured in the area of the air cell with a micrometer.

RESULTS AND DISCUSSION

Comparison of Individually Caged Hens and Floor Managed Hens

The comparison between individually caged hens and conventional floor managed hens indicated a slightly higher per cent egg production in the cages than on the floor (Figure 1). The mean per cent egg production for the entire ten-month period was 61.7 per cent for the cage managed and 59.6 per cent for the floor managed hens. This production was undoubtedly influenced by the system of replacing hens in cages. The severe production drop during December was attributed to a power failure within the lighting system during the first ten days of the month. Many of the hens went into a molt. A drop in production by the floor managed hens during February was due apparently to the cold weather the latter part of January after which many of these hens went into a molt.

This slight advantage in egg production, however, was offset (Figure 1) by the feed required to produce one dozen eggs. The mean pounds of feed per dozen eggs for the ten-month period was 6.1 pounds for the cage managed hens and 4.8 pounds for the floor managed hens. The greater quantity of feed per dozen eggs in cages was due to the larger amount of feed "consumed" per hundred hens as shown at the bottom of Figure 1. This difference in feed per hundred hens may have reflected some difference in consumption but the apparent wastage in the cage house was much greater than in the floor managed system.

The per cent of culls (Table I.) was slightly greater with the caged hens than with the hens maintained on the floor. The per cent of

FIGURE 1. MONTHLY PRODUCTION AND FEED UTILIZATION OF INDIVIDUALLY CAGED HENS AND FLOOR MANAGED HENS.

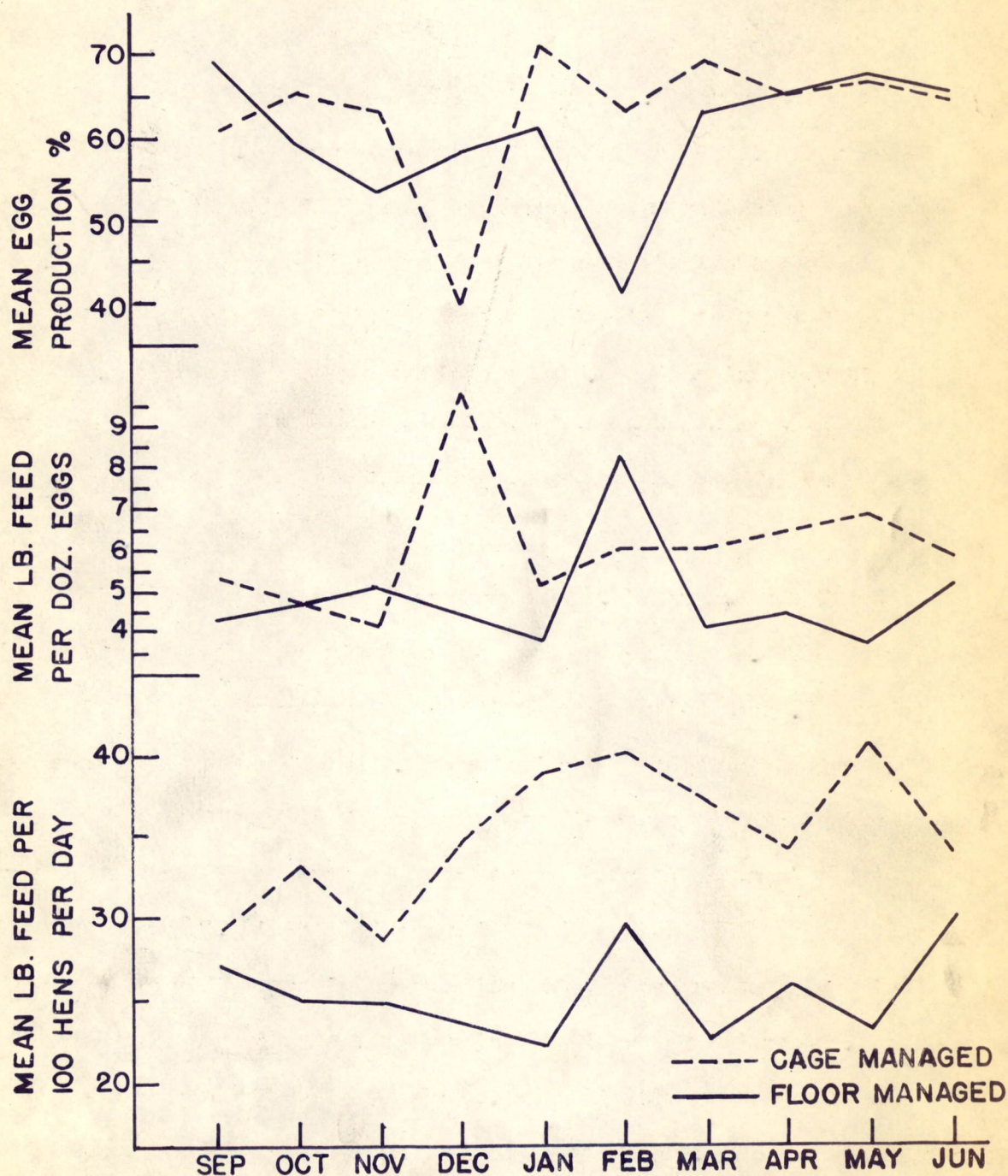


TABLE I

CULLS, MORTALITY, AND REPLACEMENT OF INDIVIDUALLY CAGED HENS
AND FLOOR MANAGED HENS WITH AMBIENT TEMPERATURE
EXTREMES CONTROLLED AND UNCONTROLLED

Month	Floor Managed Uncontrolled		Cage Managed Uncontrolled		Cage Managed Controlled	
	% Culled	% Mortality	% Culled	% Replaced	% Culled	% Replaced
September	0	1.96	0	0	0	0
October	5.10	1.18	11.11	12.96	12.03	13.88
November	0	0	7.41	9.26	6.48	6.48
December	7.45	0	1.85	3.75	0	0
January	0	0.78	0.93	1.86	0	0
February	0	0.78	0.93	1.86	0.93	2.78
March	9.02	0.78	0.93	1.86	1.85	2.78
April	1.18	0	0	0.93	2.77	5.54
May	0	0	0.93	2.78	1.85	1.85
June	0	0.40	4.63	7.40	7.41	9.26
Total	22.8	5.9	28.7	42.6	31.5	42.6

mortality (Table I.) among the caged hens was more than double that of the floor managed hens. This higher per cent mortality was associated with a condition which outwardly resembled rickets or osteomalacia and referred to as "cage fatigue". Upon autopsy several of these hens showed brittle and broken bones.

There was a 42.6 per cent replacement in the cage house while no hens were replaced in the floor system of management. An estimate of the cost of these replacements was computed at \$1.88 each. This assumed that a pullet consumed 24 pounds of feed valued at 4.5 cents per pound, and that the feed represented 60 per cent of the cost of raising the pullets above a chick cost of 35 cents. The value of the culled hens was found to be 49 cents each at 12 cents per pound as they averaged 4.12 pounds. Subtracting this amount from the cost of replacement left \$1.39 as the cost of replacing each culled hen.

The per cent of dirty eggs gathered from each system was checked (Table II.). A higher per cent of dirty eggs was produced under the caged system than from the floor system. Most of the 49.1 per cent of dirty eggs from the caged system were eggs with stripes made by the dusty wire as the eggs rolled over it. These were harder to clean than the 29.9 per cent of dirty eggs from the floor managed hens.

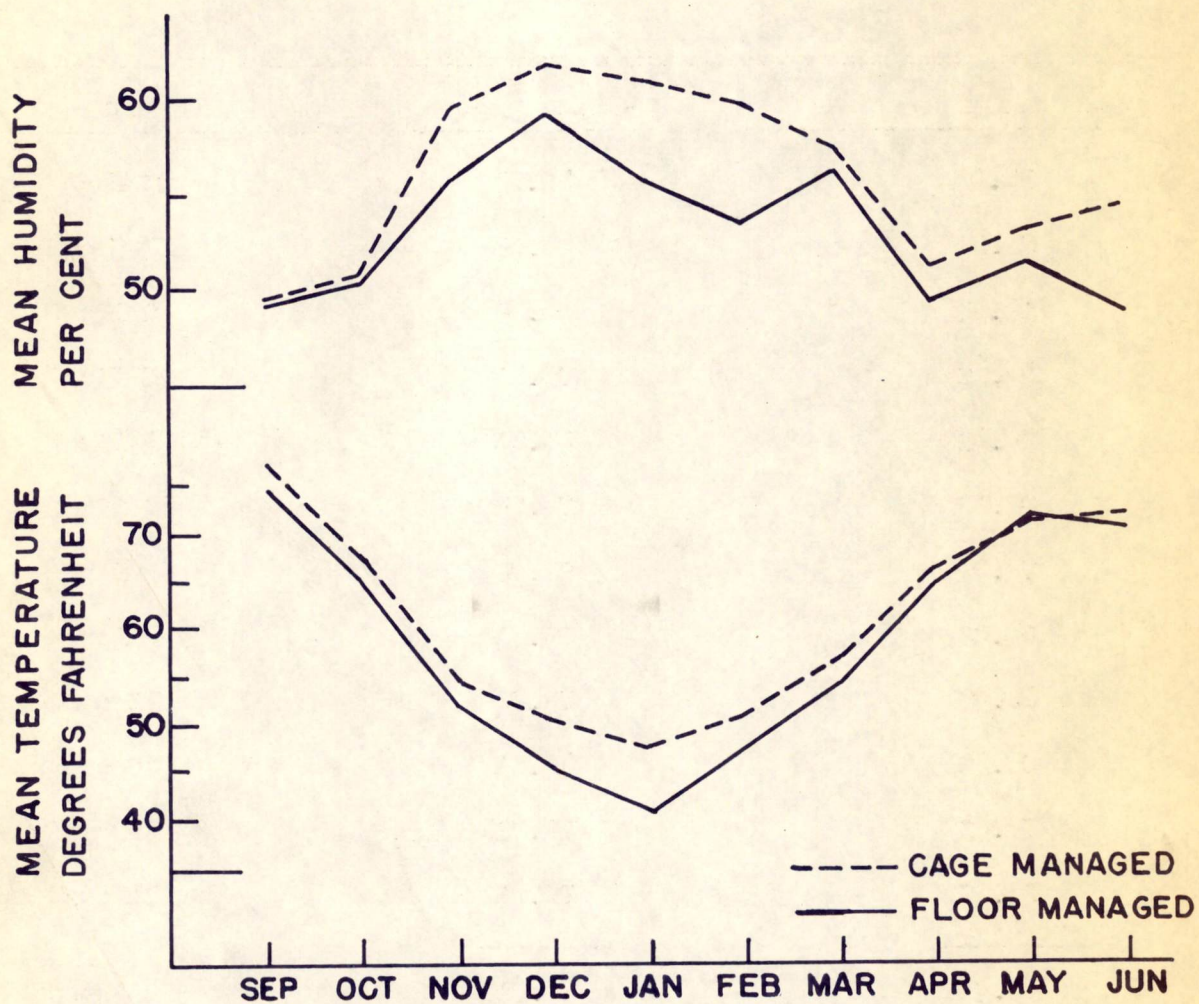
Part of the difference in per cent of dirty eggs may have been an affect of temperature and humidity at bird level as shown in Figure 2. The ten-month average ambient humidity for the caged hens was 55.9 per cent and the average for the floor managed hens was 52.9 per cent. The average ambient temperature for the same period was 61.5°F. and 58.6°F. respectively.

TABLE II

PERCENT DIRTY EGGS FROM INDIVIDUALLY CAGED
HENS AND FLOOR MANAGED HENS

Date	Cage Managed	Floor Managed
March 29	55.08	31.52
March 31	54.38	35.29
April 2	52.00	36.84
April 7	48.07	28.86
April 19	45.45	26.31
April 26	50.87	31.00
May 10	50.72	30.97
May 14	49.31	30.90
June 2	57.57	29.56
June 9	45.16	29.00
June 11	39.39	28.57
June 15	40.67	20.53
MEAN	49.1	29.9

FIGURE 2. MONTHLY AMBIENT TEMPERATURE AND HUMIDITY OF INDIVIDUALLY CAGED HENS AND FLOOR MANAGED HENS.



Effect of Temperature Extremes, Controlled and Uncontrolled

The comparison between individually caged hens with ambient temperature extremes, uncontrolled and controlled as closely as possible between 40°F. and 90°F., indicated with doubtful significance a slightly higher per cent egg production from the uncontrolled room over the temperature controlled room (Figure 3). The ten-month average varied less than one per cent. The feed per hundred hens and the feed per dozen eggs showed little difference between the two groups (Figure 3). Observations showed that temperatures remained above 90°F. for only a relatively short period each day, while the time below 40°F. was often from 8 to 12 hours and occasionally for a full 24 hours. During January, temperatures in the middle and low 20's were frequent in the uncontrolled room of the cage house. These data indicate the adjustment hens can make to temperature extremes and continue to produce at a desirable rate.

The temperature extremes were leveled off, as shown in Figure 4, with the warmer months and cooler months showing nearer the same temperatures in the controlled group than in the uncontrolled group.

It was found that the roof temperature reached as high as 133°F. before noon. This could be reduced 33°F. in 5 minutes by spraying the roof, but the temperature at hen level dropped only from 92°F. to 90°F. After 20 minutes of spraying, the roof cooled to 89°F. and the temperature at hen level was still 90°F. However, this did increase the humidity slightly and the hens appeared to be more contented than the birds in the unsprinkled room.

FIGURE 3. MONTHLY PRODUCTION AND FEED UTILIZATION OF INDIVIDUALLY CAGED HENS WITH AMBIENT TEMPERATURE EXTREMES CONTROLLED AND UNCONTROLLED.

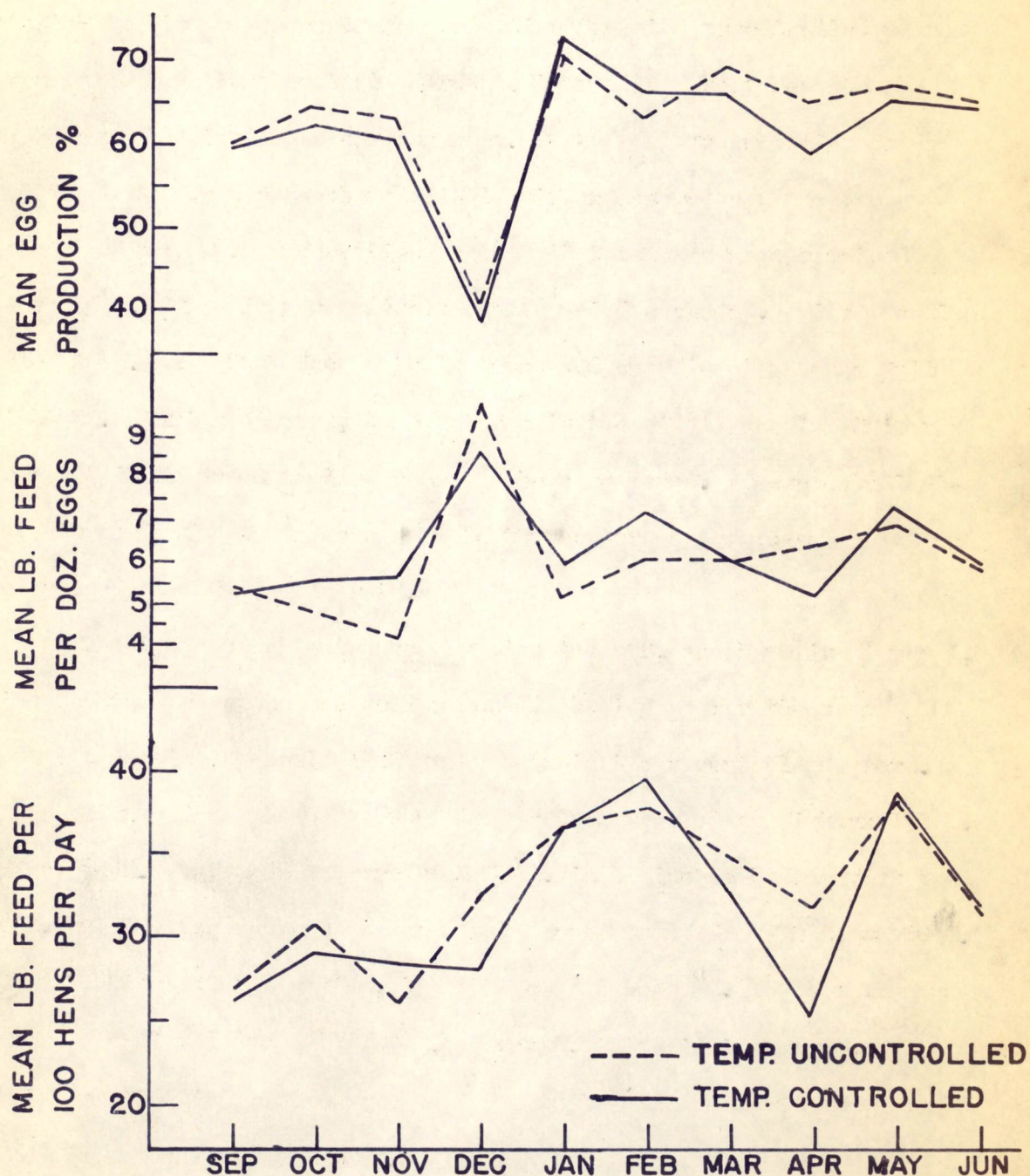
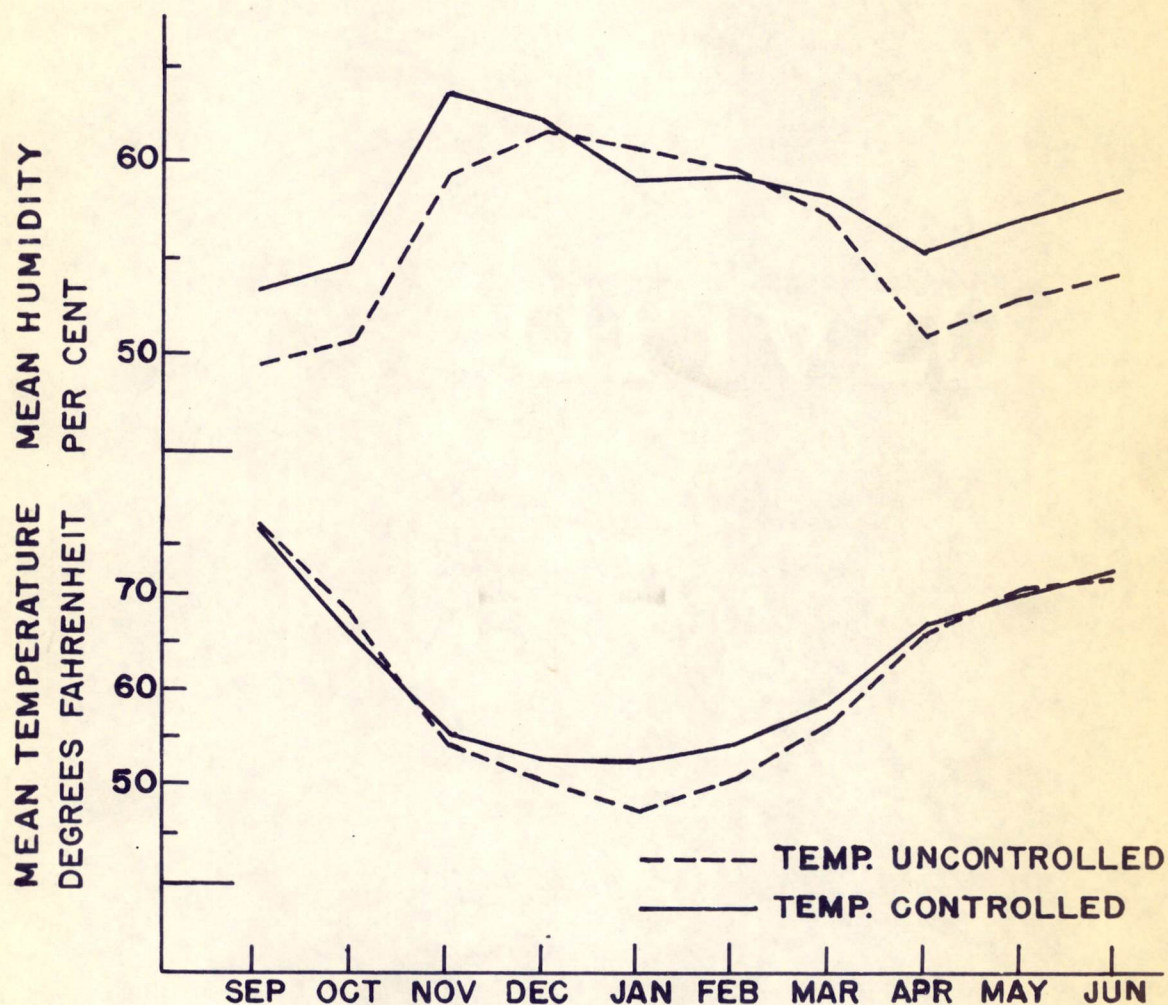


FIGURE 4. MONTHLY AMBIENT TEMPERATURE AND HUMIDITY OF INDIVIDUALLY CAGED HENS WITH AMBIENT TEMPERATURE EXTREMES CONTROLLED AND UNCONTROLLED.



All rooms had doors and windows open to provide maximum ventilation. Warm or hot air from outside moved through all rooms and undoubtedly influenced the small drop in temperature observed during the hot summer days.

Table I. shows 46.2 per cent replacements each in the temperature controlled and uncontrolled rooms. The mortality was 11.1 per cent in the controlled and 13.9 per cent in the uncontrolled room, thereby increasing the cost in the uncontrolled group. Limited data failed to indicate the influence exerted by temperature on mortality as death from heat prostration was not encountered.

Comparison of Moderate and High Ambient Temperatures of Laying Hens

The results of the duplicate experiments comparing the effect of a moderate temperature of $75^{\circ}\text{F.} \pm 5^{\circ}\text{F.}$ (Group I.) and a high temperature of $85^{\circ}\text{F.} \pm 5^{\circ}\text{F.}$ (Group II.) upon the laying hen are shown in Tables III. - VI. The per cent of egg production was slightly higher at the moderate temperature in both experiments (Table III. and V.). The mean egg production was 52.5 per cent for Group I. and 49.8 per cent for Group II.

The per cent of dirty eggs was higher in Group I in each of the duplicate experiments averaging 20.5 per cent for Group I. and 18.3 per cent for Group II. This increase in dirty eggs at the moderate temperature may have been due to the 15 to 20 per cent higher humidity indicated in Tables III. and V.

Egg size (Tables IV. and VI.) was not consistently different in either group throughout the duplicate experiments, but averaged 26.0

TABLE III

NUMBER OF HENS, PER CENT EGG PRODUCTION, AND
PER CENT OF DIRTY EGGS IN MODERATE AND HIGH
AMBIENT TEMPERATURES IN THE FIRST EXPERIMENT

Wks.	Moderate Temperature ($75^{\circ}\text{F.} \pm 5^{\circ}\text{F.}$) Mean Humidity 56.42%			High Temperature ($85^{\circ}\text{F.} \pm 5^{\circ}\text{F.}$) Mean Humidity 41.56%		
	No. Hens	% Egg Production	% Dirty Eggs	No. Hens	% Egg Production	% Dirty Eggs
1	24	60.70	-	24	58.92	-
2	24	50.00	-	24	48.21	-
3	24	44.70	-	21	45.58	-
4	24	57.73	-	20	68.57	-
5	24	70.83	-	20	62.14	-
6	24	72.58	25.24	20	52.85	18.14
7	24	67.83	20.50	18	65.73	15.25
8	24	60.08	22.00	18	57.13	20.62
9	24	50.69	16.26	18	30.15	22.29
10	24	37.50	22.41	18	31.47	19.32
11	24	26.78	21.43	18	45.23	20.62
12	23	39.74	17.18	18	49.07	22.64
Mean	23.92	53.26	20.72	19.75	51.25	19.84

TABLE IV

EGG WEIGHT, INTERIOR EGG QUALITY, AND SHELL
THICKNESS IN MODERATE AND HIGH AMBIENT
TEMPERATURES IN THE FIRST EXPERIMENT

Date	Moderate Temperature (75°F. $\pm$ 5°F.)			High Temperature (85°F. $\pm$ 5°F.)		
	Mean Humidity 56.42%			Mean Humidity 41.56%		
	Egg Wt. oz./doz.	Interior Quality U.S.D.A.	Shell thickness inches	Egg Wt. Oz/doz.	Interior Quality U.S.D.A.	Shell thickness inches
May 29	25.50	2.58	.0122	25.32	2.91	.0134
Mar. 29	25.45	2.73	.0134	26.11	2.33	.0132
Apr. 2	25.37	2.13	.0131	25.80	1.40	.0126
Apr. 7	25.50	2.17	.0135	25.50	2.10	.0122
Apr. 19	26.15	2.15	.0133	25.77	2.23	.0116
Apr. 26	26.00	2.00	.0125	26.15	2.15	.0121
May 10	25.27	2.40	.0125	25.92	2.25	.0110
May 14	25.69	2.38	.0128	25.60	2.00	.0113
Jun. 2	24.61	1.77	.0128	23.82	2.18	.0114
Jun. 9	24.25	1.50	.0126	25.60	1.80	.0111
Jun. 10	26.60	2.00	.0123	26.44	2.11	.0116
Jun. 11	26.43	2.20	.0125	26.16	2.08	.0121
Mean	25.57	2.17	.0128	25.68	2.13	.0120

TABLE V

NUMBER OF HENS, PER CENT EGG PRODUCTION, AND
PER CENT OF DIRTY EGGS IN MODERATE AND HIGH
AMBIENT TEMPERATURES IN THE SECOND EXPERIMENT

Wks.	Moderate Temperature (75°F. $\pm$ 5°F.)			High Temperature (85°F. $\pm$ 5°F.)		
	Mean Humidity 63.03%			Mean Humidity 42.66%		
	No. Hens	% Egg Production	% Dirty Eggs.	No. Hens	% Egg Production	% Dirty Eggs
1	24	51.19	23.25	24	45.83	20.77
2	24	54.17	13.00	24	40.47	17.64
3	24	50.68	20.27	24	48.81	13.41
4	24	57.74	20.61	24	57.14	15.62
5	24	44.97	24.32	24	50.00	16.43
Mean	24	51.65	20.29	24	48.45	16.77

TABLE VI

EGG WEIGHT, INTERIOR EGG QUALITY, AND SHELL THICKNESS IN
MODERATE AND HIGH AMBIENT TEMPERATURE IN SECOND EXPERIMENT

Date	Moderate Temperature (75°F. $\pm$ 5°F.)			High Temperature (85°F. $\pm$ 5°F.)		
	Mean Humidity 63.03%			Mean Humidity 42.66%		
	Egg Wt. oz./doz.	Interior Quality U.S.D.A.	Shell thick- ness in inches	Egg wt. oz./doz.	Interior Quality U.S.D.A.	Shell thick- ness in inches
Jun. 16	26.27	3.90	.0116	26.40	3.70	.0118
Jun. 22	26.40	3.00	.0129	25.20	2.50	.0115
Jun. 24	25.55	2.82	.0129	25.44	2.77	.0113
Jun. 28	25.66	2.89	.0125	23.80	2.42	.0117
July 1	26.33	2.50	.0120	24.87	2.00	.0109
July 6	27.20	2.50	.0115	25.20	2.33	.0111
July 8	26.33	2.66	.0118	24.11	2.44	.0120
Mean	26.39	2.90	.0122	25.00	2.59	.0115

ounces per dozen in Group I. and 25.3 ounces per dozen in Group II.

Tables IV. and VI. show that the broken out interior egg quality was only slightly higher in those eggs produced at the moderate temperature throughout the duplicate experiment. The mean U.S.D.A. Scores for the duplicate experiments were Group I., 2.54 and Group II., 2.36.

The shells were slightly thicker in Group I. in each of the experiments (Tables IV. and VI.) averaging in thickness .0125 inches in Group I. and .0118 inches in Group II.

No consistent differences were apparent in the feed per dozen eggs between the two groups. The feed per dozen eggs in Group I. was 7.09 pounds and 8.74 pounds for the first experiment and the duplicate experiment respectively. In Group II. the feed per dozen eggs was 6.57 pounds and 5.76 pounds for the first and second experiment.

Group II. in the first experiment had a higher rate of mortality than did Group I. There was no mortality in the second experiment. During the adjustment period prior to the first experiment at 65°F. $\pm$ 5°F. the hens in one group were without water for 72 hours and had to be replaced. After 36 hours, egg production had dropped from 70 per cent to 6 per cent, and at the end of the 72 hour period, a mortality of 25 per cent was suffered. All but one of the remaining hens went into a molt. These observations unequivocally show the essentiality of a constant supply of drinking water for the laying hen.

Effect of Temperature and Holding Time on Interior Egg Quality

Eggs held at a temperature of 46°F. maintained an interior quality of Grade AA for six days and Grade A for nineteen days. Eggs

held at a temperature of 75°F. were Grade AA at the end of the first day, Grade A from the second to the sixth day and Grade B from the eighth to the nineteenth day (Table VII.). The eggs maintained Grade A quality more than three times as long at 46°F. as they did at 75°F.

Table VIII. shows the broken out interior quality of eggs subjected to fluctuations in temperature for various periods of time similar to the conditions which eggs undergo while being held on the farm and in passing through present day market channels. The period of time of 3, 7, or 24 hours at a temperature of 85°F. or 100°F. was to simulate the temperature conditions eggs might encounter from the time they are layed until they are placed in a cooler under different management conditions. The second period of time of 48 or 96 hours represents the time spent in farm coolers (46°F.) or cellars (75°F.). A one hour period of time was then allowed at 85°F. or 100°F. to simulate the temperature changes to which eggs might be subjected on the way to the wholesaler. The wholesaler might have an egg room as low as 46°F. or an air conditioned room of 75°F. and hold the eggs from 72 to 168 hours as is represented in the next period of time in Table VIII. Another hour at 85°F. or 100°F. was then allowed to simulate the temperature conditions as eggs travel from the wholesaler to the retailer. The last period of time represents the temperature conditions under which the retailer holds eggs. This might range from 72 to 168 hours in a refrigerated room at 46°F. or displayed in an air conditioned store at about 75°F.

The eggs held at 46°F. were Grade A and the eggs held at 75°F.

TABLE VII

BROKEN OUT INTERIOR EGG QUALITY OF EGGS HELD
CONTINUOUSLY AT 46°F. AND 75°F.

Days	Eggs Held at 46°F.		Eggs Held at 75°F.	
	U.S.D.A. Score	U.S.D.A. Quality	U.S.D.A. Score	U.S.D.A. Quality
1	2.8	AA	3.0	AA
2	2.8	AA	4.4	A
3	2.6	AA	4.4	A
4	2.4	AA	4.4	A
5	3.0	AA	6.0	A
6	3.0	AA	3.2	A
8	3.2	A	7.8	B
9	4.2	A	6.4	B
11	3.2	A	6.4	B
12	4.0	A	7.0	B
18	4.6	A	7.6	B
19	4.4	A	7.6	B

TABLE VIII

EFFECT OF FLUCTUATING TEMPERATURE AND HOLDING TIME ON BROKEN OUT
INTERIOR EGG QUALITY

Days from beginning of Experiment	Total Hours at 46°F.	Hours at 85°F.	U.S.D.A. SCORE				U.S.D.A. Quality
			Replication*			Mean	
			1	2	3		
0	0 hrs.	3 hrs.	2.4	3.4	5.0	3.60	A
2	48 hrs.	4 hrs.	3.0	3.4	2.8	3.04	A
5	120 hrs.	5 hrs.	4.2	4.2	4.8	4.40	A
8	192 hrs.	5 hrs.	7.0	3.2	3.0	4.40	A

Days from beginning of Experiment	Total Hours at 75°F.	Hours at 85°F.	U.S.D.A. SCORE				U.S.D.A. Quality
			Replication*			Mean	
			1	2	3		
0	0 hrs.	3 hrs.	2.4	3.4	5.0	3.60	A
2	48 hrs.	4 hrs.	7.2	4.6	5.4	5.73	A
5	120 hrs.	5 hrs.	5.6	5.2	6.8	5.87	A
8	192 hrs.	5 hrs.	7.6	5.4	7.0	6.67	B

Days from beginning of Experiment	Total Hours at 46°F.	Hours at 100°F.	U.S.D.A. SCORE				U.S.D.A. Quality
			Replication*			Mean	
			1	2	3		
0	0 hrs.	3 hrs.	3.4	3.4	2.6	3.13	A
2	48 hrs.	4 hrs.	3.4	2.8	3.0	3.07	A
5	120 hrs.	5 hrs.	3.8	4.6	3.6	4.00	A
8	192 hrs.	5 hrs.	4.0	4.0	4.4	4.13	A

Days from beginning of Experiment	Total Hours at 75°F.	Hours at 100°F.	U.S.D.A. SCORE				U.S.D.A. Quality
			Replication*			Mean	
			1	2	3		
0	0 hrs.	3 hrs.	3.4	3.4	2.6	3.13	A
2	48 hrs.	4 hrs.	4.6	4.2	3.8	4.30	A
5	120 hrs.	5 hrs.	6.2	4.8	6.0	5.67	A
8	192 hrs.	5 hrs.	6.8	7.4	6.6	6.93	B

*Each figure is the mean U.S.D.A. Score of 5 eggs.

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TABLE VIII (Continued)

EFFECT OF FLUCTUATING TEMPERATURE AND HOLDING TIME ON BROKEN OUT
INTERIOR EGG QUALITY

Days from beginning of Experiment	Total Hours at 46°F.	Hours at 85°F.	U.S.D.A. SCORE				U.S.D.A. Quality
			Replication*			Mean	
			1	2	3		
0	0 hrs.	7 hrs.	2.4	2.4	2.8	2.53	AA
2	48 hrs.	8 hrs.	4.0	3.4	3.0	3.47	A
5	120 hrs.	9 hrs.	3.4	3.6	3.8	3.60	A
8	192 hrs.	9 hrs.	5.0	3.8	5.0	4.60	A

Days from beginning of Experiment	Total Hours at 75°F.	Hours at 85°F.	U.S.D.A. SCORE				U.S.D.A. Quality
			Replication*			Mean	
			1	2	3		
0	0 hrs.	7 hrs.	2.4	2.4	2.8	2.53	AA
2	48 hrs.	8 hrs.	3.8	4.4	4.4	4.20	A
5	120 hrs.	9 hrs.	5.8	6.0	6.8	6.20	B
8	192 hrs.	9 hrs.	7.2	6.8	6.6	6.87	B

Days from beginning of Experiment	Total Hours at 46°F.	Hours at 100°F.	U.S.D.A. SCORE				U.S.D.A. Quality
			Replication*			Mean	
			1	2	3		
0	0 hrs.	7 hrs.	4.6	3.8	3.6	4.00	A
2	48 hrs.	8 hrs.	4.8	3.0	3.2	3.67	A
5	120 hrs.	9 hrs.	4.0	4.6	4.0	4.20	A
8	192 hrs.	9 hrs.	4.4	4.0	4.8	4.40	A

Days from beginning of Experiment	Total Hours at 75°F.	Hours at 100°F.	U.S.D.A. SCORE				U.S.D.A. Quality
			Replication*			Mean	
			1	2	3		
0	0 hrs.	7 hrs.	4.6	3.8	3.6	4.00	A
2	48 hrs.	8 hrs.	5.6	3.6	3.8	4.33	A
5	120 hrs.	9 hrs.	5.6	5.4	5.6	5.53	A
8	192 hrs.	9 hrs.	6.4	5.8	6.2	6.13	B

*Each figure is the mean U.S.D.A. Score of 5 eggs.

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TABLE VIII (Continued)

EFFECT OF FLUCTUATING TEMPERATURE AND HOLDING TIME ON BROKEN OUT
INTERIOR EGG QUALITY

Days from beginning of Experiment	Total Hours at 46°F.	Hours at 85°F.	U.S.D.A. SCORE				U.S.D.A. Quality
			Replication*			Mean	
			1	2	3		
1	0 hrs.	24 hrs.	4.6	2.4	3.8	3.60	A
3	48 hrs.	25 hrs.	4.6	3.2	5.2	4.33	A
6	120 hrs.	26 hrs.	4.2	3.6	3.4	3.73	A
9	192 hrs.	26 hrs.	2.4	4.0	3.6	3.33	A

Days from beginning of Experiment	Total Hours at 75°F.	Hours at 85°F.	U.S.D.A. SCORE				U.S.D.A. Quality
			Replication*			Mean	
			1	2	3		
1	0 hrs.	24 hrs.	4.6	2.4	3.8	3.60	A
3	48 hrs.	25 hrs.	5.4	5.0	3.6	5.87	A
6	120 hrs.	26 hrs.	6.0	5.2	5.4	5.53	A
9	192 hrs.	26 hrs.	6.2	6.0	6.4	6.20	B

Days from beginning of Experiment	Total Hours at 46°F.	Hours at 100°F.	U.S.D.A. SCORE				U.S.D.A. Quality
			Replication*			Mean	
			1	2	3		
1	0 hrs.	24 hrs.	5.0	3.4	4.2	4.20	A
3	48 hrs.	25 hrs.	4.2	6.2	4.0	4.80	A
6	120 hrs.	26 hrs.	4.4	4.0	4.6	4.33	A
9	192 hrs.	26 hrs.	5.2	3.4	5.2	4.60	A

Days from beginning of Experiment	Total Hours at 75°F.	Hours at 100°F.	U.S.D.A. SCORE				U.S.D.A. Quality
			Replication*			Mean	
			1	2	3		
1	0 hrs.	24 hrs.	5.0	3.4	4.2	4.20	A
3	48 hrs.	25 hrs.	5.4	5.8	4.8	5.33	A
6	120 hrs.	26 hrs.	5.2	6.4	5.4	5.67	A
9	192 hrs.	26 hrs.	5.4	6.4	6.4	6.06	B

*Each figure is the mean U.S.D.A. Score of 5 eggs.

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TABLE VIII (Continued)

EFFECT OF FLUCTUATING TEMPERATURE AND HOLDING TIME ON BROKEN OUT
INTERIOR EGG QUALITY

Days from beginning of Experiment	Total Hours at 46°F.	Hours at 85°F.	U.S.D.A. SCORE				U.S.D.A. Quality
			Replication*			Mean	
			1	2	3		
0	0 hrs.	3 hrs.	2.4	3.4	5.0	3.60	A
4	96 hrs.	4 hrs.	4.2	3.2	4.0	3.80	A
11	264 hrs.	5 hrs.	3.4	3.6	4.6	3.86	A
18	432 hrs.	5 hrs.	4.0	3.8	3.8	3.86	A

Days from beginning of Experiment	Total Hours at 75°F.	Hours at 85°F.	U.S.D.A. SCORE				U.S.D.A. Quality
			Replication*			Mean	
			1	2	3		
0	0 hrs.	3 hrs.	2.4	3.4	5.0	3.60	A
4	96 hrs.	4 hrs.	5.2	5.0	5.2	5.13	A
11	264 hrs.	5 hrs.	7.2	6.0	5.4	6.20	B
18	432 hrs.	5 hrs.	8.2	6.8	10.0	8.33	B

Days from beginning of Experiment	Total Hours at 46°F.	Hours at 100°F.	U.S.D.A. SCORE				U.S.D.A. Quality
			Replication*			Mean	
			1	2	3		
0	0 hrs.	3 hrs.	3.4	3.4	2.6	3.13	A
4	96 hrs.	4 hrs.	3.2	4.8	4.2	4.07	A
11	264 hrs.	5 hrs.	4.0	5.2	4.0	4.40	A
18	432 hrs.	5 hrs.	4.6	4.0	3.8	4.13	A

Days from beginning of Experiment	Total Hours at 75°F.	Hours at 100°F.	U.S.D.A. SCORE				U.S.D.A. Quality
			Replication*			Mean	
			1	2	3		
0	0 hrs.	3 hrs.	3.4	3.4	2.6	3.27	A
4	96 hrs.	4 hrs.	5.8	5.0	5.2	5.33	A
11	264 hrs.	5 hrs.	6.4	6.2	5.0	5.87	A
18	432 hrs.	5 hrs.	8.0	6.6	9.4	8.33	B

*Each figure is the mean U.S.D.A. Score of 5 eggs.

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TABLE VIII (Continued)

EFFECT OF FLUCTUATING TEMPERATURE AND HOLDING TIME ON BROKEN OUT
INTERIOR EGG QUALITY

Days from beginning of Experiment	Total Hours at 46°F.	Hours at 85°F.	U.S.D.A. SCORE				U.S.D.A. Quality
			Replication*			Mean	
			1	2	3		
0	0 hrs.	7 hrs.	2.4	2.4	2.8	2.53	AA
4	96 hrs.	8 hrs.	3.8	3.0	4.0	3.60	A
11	264 hrs.	9 hrs.	4.0	3.4	4.8	4.07	A
18	432 hrs.	9 hrs.	4.0	3.6	3.8	3.80	A

Days from beginning of Experiment	Total Hours at 75°F.	Hours at 85°F.	U.S.D.A. SCORE				U.S.D.A. Quality
			Replication*			Mean	
			1	2	3		
0	0 hrs.	7 hrs.	2.4	2.4	2.8	2.53	AA
4	96 hrs.	8 hrs.	4.8	5.4	5.6	5.27	A
11	264 hrs.	9 hrs.	7.2	6.6	5.4	6.40	B
18	432 hrs.	9 hrs.	8.2	9.6	8.2	8.70	B

Days from beginning of Experiment	Total Hours at 46°F.	Hours at 100°F.	U.S.D.A. SCORE				U.S.D.A. Quality
			Replication*			Mean	
			1	2	3		
0	0 hrs.	7 hrs.	4.6	3.8	3.6	4.00	A
4	96 hrs.	8 hrs.	3.6	3.2	3.0	3.27	A
11	264 hrs.	9 hrs.	5.0	3.2	4.4	4.20	A
18	432 hrs.	9 hrs.	4.8	4.0	4.2	4.33	A

Days from beginning of Experiment	Total Hours at 75°F.	Hours at 100°F.	U.S.D.A. SCORE				U.S.D.A. Quality
			Replication*			Mean	
			1	2	3		
0	0 hrs.	7 hrs.	4.6	3.8	3.6	4.00	A
4	96 hrs.	8 hrs.	7.0	5.2	5.4	5.87	A
11	264 hrs.	9 hrs.	5.0	5.6	5.4	5.33	A
18	432 hrs.	9 hrs.	7.6	8.0	8.8	8.13	B

*Each figure is the mean U.S.D.A. Score of 5 eggs.

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TABLE VIII (Continued)

EFFECT OF FLUCTUATING TEMPERATURE AND HOLDING TIME ON BROKEN OUT
INTERIOR EGG QUALITY

Days from beginning of Experiment	Total 46°F.	Hours at 85°F.	U.S.D.A. SCORE				U.S.D.A. Quality
			Replication*			Mean	
			1	2	3		
1	0 hrs.	24 hrs.	4.6	2.4	3.8	3.60	A
5	96 hrs.	25 hrs.	3.2	3.6	4.2	3.67	A
12	264 hrs.	26 hrs.	4.0	3.4	4.6	4.00	A
19	432 hrs.	26 hrs.	4.4	4.4	4.6	4.47	A

Days from beginning of Experiment	Total 75°F.	Hours at 85°F.	U.S.D.A. SCORE				U.S.D.A. Quality
			Replication*			Mean	
			1	2	3		
1	0 hrs.	24 hrs.	4.6	2.4	3.8	3.60	A
5	96 hrs.	25 hrs.	5.2	4.8	6.2	5.40	A
12	264 hrs.	26 hrs.	7.4	5.0	5.6	6.00	A
19	432 hrs.	26 hrs.	8.8	10.0	6.4	8.40	B

Days from beginning of Experiment	Total 46°F.	Hours at 100°F.	U.S.D.A. SCORE				U.S.D.A. Quality
			Replication*			Mean	
			1	2	3		
1	0 hrs.	24 hrs.	5.0	3.4	4.2	4.20	A
5	96 hrs.	25 hrs.	3.0	4.8	5.6	4.47	A
12	264 hrs.	26 hrs.	4.0	4.6	4.0	4.20	A
19	432 hrs.	26 hrs.	4.2	5.0	4.2	4.47	A

Days from beginning of Experiment	Total 75°F.	Hours at 100°F.	U.S.D.A. SCORE				U.S.D.A. Quality
			Replication*			Mean	
			1	2	3		
1	0 hrs.	24 hrs.	5.0	3.4	4.2	4.20	A
5	96 hrs.	25 hrs.	4.8	4.6	8.0	5.80	A
12	264 hrs.	26 hrs.	5.6	5.8	5.8	5.73	A
19	432 hrs.	26 hrs.	8.8	6.4	8.8	8.00	B

*Each figure is the mean U.S.D.A. Score of 5 eggs.

were Grade B at the end of the 8 to 19 day periods in all groups. Whether the eggs were originally held at 3, 7, or 24 hours had little influence on the interior egg quality at the end of this experiment. This indicates that further studies should be undertaken concerning the relationship between frequency of gathering, egg quality, and temperature.

Analysis of variance showed no significant difference in interior egg quality between the original holding periods of 3, 7, or 24 hours. No significant difference was found to exist in interior quality when eggs were held at 85°F., or 100°F. during the original holding time nor during transfer, but a significant difference did exist, at the 5 per cent level, between holding temperatures of 46°F. and 75°F.

SUMMARY

A ten-month study regarding the influence of environment on the performance of the laying hen involved 661 Single Comb White Leghorn pullets. A total of 1962 eggs were broken out to study the relationship between interior quality and selected holding temperatures.

Including 92 replacements, 308 pullets were maintained in individual laying cages, and 255 were housed under conventional floor management methods. Apparent differences in per cent production between caged and floor managed hens, although slightly favorable to the cage system, were insignificant. This scant advantage was largely due to the high percentage of replacements in the cages.

The feed required to produce a dozen eggs was slightly more for individually caged hens than for conventional floor managed hens. The feed required per hundred hens was much greater for caged hens than for floor managed hens, because of the greater wastage in the cages.

The per cent of dirty eggs was higher from the cage system than for the floor system of management.

The per cent mortality of the caged hens was greater than for the floor managed hens. This was due largely to the high incidence of "cage fatigue".

Small differences were apparent in per cent egg production, feed consumed, or feed consumed per dozen eggs when the minimum and maximum room temperature to which caged hens were exposed was held between 40°F. and 90°F. and when temperatures were uncontrolled.

Broken out interior quality was measured in 402 eggs produced by

108 pullets used to determine the effect of moderate temperature ($75^{\circ}\text{F.} \pm 5^{\circ}\text{F.}$) and high temperature ($85^{\circ}\text{F.} \pm 5^{\circ}\text{F.}$) on the performance of the laying hen.

The per cent of dirty eggs and the interior egg quality were higher at moderate temperature with a relatively high humidity than at a high temperature with a relatively low humidity.

Shells produced at the moderate temperature were thicker than those produced at high temperature.

Mortality was induced in hens even maintained at a temperature of $65^{\circ}\text{F.} \pm 5^{\circ}\text{F.}$ when the hens were deprived of water for 72 hours.

In studying the effect of temperature fluctuations and holding time on interior egg quality, 1560 eggs were broken out.

Eggs held at 46°F. maintained Grade A quality three times as long as eggs held at 75°F.

No significant difference was found in the interior egg quality at the end of the 8 to 19 day holding periods when freshly layed eggs were initially held for either 3, 7, or 24 hours at 85°F. or 100°F.

A significant difference existed in interior egg quality of eggs held at 46°F. and those held at 75°F. for 8 to 19 days.



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