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To the Graduate Council:

I am submitting herewith a thesis written by Hamdi Abdul Aziz Al-Fayadh entitled "The Effect of Water Restriction on the Laying Hen Performance." 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.

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THE EFFECT OF WATER RESTRICTION ON THE LAYING HEN PERFORMANCE

A Thesis
Presented to
the Graduate Council of
The University of Tennessee

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by
Hamdi Abdul Aziz Al-Fayadh
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ABSTRACT

A study was conducted on 480 Single Comb White Leghorn laying hens to determine the effect of restricting the availability of water to 15 minutes of every one, two and three hours on egg production, egg size distribution, average egg weight, body weight, feed consumption, water content of the droppings and mortality rate. ^{Cont.} Restricting the availability of water resulted in a decrease in the rate of egg production on a both hen-days and hen-housed basis. No significant differences were found in the percent hen mortality among the four treatment groups.

A significant difference was found in feed consumption per hen among the groups studied in this experiment, with the group receiving water ad libitum consuming more feed than the water restricted groups. Droppings from hens receiving water restriction were drier than that from hens giving water ad libitum. No significant differences were found in respect to specific gravity, Haugh units, average egg weight and the distribution of egg size. A significant difference was found in respect to body weight gain with the group of hens receiving 15 minutes of water per hour gaining the most. stop

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I. INTRODUCTION

Although water is quite common in nature and easy to provide, many poultrymen fail to appreciate its importance and overlook the need to give a constant supply of this important nutrient.

Water plays an important role in the formation of new tissues during the growing period. It is present in all cells, it is required in egg production and all body functions.

Water makes up about 56 percent of the composition of the hen's body, and many tissues contain 70-90 percent water.

Dukes (1942) reported that the major functions of water in the chicken's body are as a dispersing medium, temperature regulator, transport mechanism and metabolic activator.

It has been observed that laying hens, caged individually, spent more time drinking water than those kept on the floor, perhaps due to the freedom of the latter to engage in other activities, such as moving around. With the cage system the hens are limited as far as their freedom of movement is concerned, consequently they may play at the feeder or in the watering trough, or they may peck at each other. In some cases hens may consume more water than their metabolic requirement; the result may be loose droppings and wet poultry houses, which contribute to the other problems such as odor and fly problems to which many poultrymen object, resulting in sanitation problems and added labor in maintaining desirable environmental conditions.

Swanson (1968) stated that the intensity of the dropping problem appears to have increased in the last several years which can be explained, in part, by the trend to higher cage densities and the switch to wider and more completely enclosed houses with reduced floor ventilation.

The practice of providing laying hens with short periods of water during the day has been practiced in many parts of this country. Different ways of limiting water consumption of the laying hens through restricted water programs has been practiced in different localities throughout the States, with the programs differing according to weather conditions. Encouraging results in favor of restricting water have been reported by several research workers. A better understanding of time of restriction and amount of water restriction together with temperatures, location, and the influence upon the hen should be studied before making any decision regarding restriction of this essential nutrient to laying hens. The physiology of the bird, its actions in a given environment are some of the considerations to be studied before reaching a decision to restrict water to chickens. Age of the caged birds is an important factor in determining the time of restriction. The young birds in high production require more water than old ones or those in low production. Other factors influence the water economy of birds, such as particle size of feed, amount of protein, and salt content of the ration.

II. OBJECTIVES

The objectives of this study were to determine the effect of water restriction upon the performance and well being of the hen when measured in terms of egg production, egg size distribution, average egg weight, body weight, feed consumption, water content of the droppings, and mortality rate.

III. REVIEW OF LITERATURE

Kare and Biely (1948) provided New Hampshire chicks with diets containing 0.9 and 4 percent salt and deprived some lots of water for from four to six hours a day. They found that the water restricted chicks compensated by drinking more when water was before them which resulted in approximately the same intake of water and feed as was consumed by the control group which had water and feed available ad libitum.

In a study conducted by Ross (1960) one-week-old New Hampshire chicks were given water for three thirty minute periods a day for six weeks. Depressed growth and lower feed conversion in the water restricted chicks were reported.

Nair (1961) stated that keeping chicks directly after being hatched in boxes and deprived of water and feed for four days resulted in 4 percent mortality, the report further showed that mortality rate was greatly increased on the fifth and sixth day after hatching reaching 28 and 91 percent, respectively.

Kellerup et al. (1965) reported that restricting water to 10, 20, 30, 40, and 50 percent of that consumed by cross-bred broiler chicks receiving water ad libitum one to eight weeks of age was found to be deleterious to growth, feed consumption and water:feed ratio. Feed conversion was greatly affected with restriction of 20 percent or more. The report also showed that mortality rate was not significantly affected by any level of water restriction.

Bierer et al. (1966) reported a marked decrease in feed consumption of broilers when water was withheld, and conversely that water consumption declined rapidly when feed was withheld. The report also showed that the percentage of body weight loss after 5, 10, 15, 20, 24, 48, and 72 hours of feed and water deprivation was approximately three percent after ten hours and dropped in a straight line to approximately 11 percent at 72 hours.

Sunde (1966) reported when chickens were deprived of water they developed minute areas of congestion and erosion in the gizzard. Congestion and spotty petechiation of the mucosa of the large intestine and cloaca also developed. It was reported that both problems were more serious when the chicks were two to four weeks of age before the deprivation began.

Live weight, rate of egg production and air temperature influences water consumption. Increase in any one of these factors will tend to increase water consumption. Likewise, a decrease in any one of these tended to decrease water consumption according to Heywang (1940). He also reported that the actual water consumption per hen per year of his White Leghorns was 18.25 gallons.

✓ Maxwell and Lyle (1957) reported that wet droppings of caged laying hens could be effectively prevented by the restriction of water if the cause of the wet droppings was excessive water consumption. No harmful effect of water

restriction on egg production or feed conversion was reported, on the contrary, a slight improvement was shown in each case when the water was restricted.

Goodman (1961) reported that hens allowed to drink for 5, 10 or 15 minutes every hour drank nearly as much water and laid as well as hens that had water in front of them all day. Even hens that were limited to one 15 minute drinking period every three hours laid as well as birds getting water free choice. He also stated that water restriction actually increased feed efficiency, at the same time no ill effect on shell thickness, albumen score, or egg size were observed.

Sunde (1962) reported that withholding water for periods up to 12 hours had little effect on subsequent growth of chicks. However, restriction of 24 or 36 hours had long term detrimental effects on weight gain and egg production.

In a study conducted on different species of animals, Bierer and associates (1965) reported seven of ten White Leghorn hens receiving feed but deprived of water died in four to five days with symptoms and lesions indistinguishable from those seen in chickens affected with blue comb disease. It was also indicated that egg production of water deprived hens dropped suddenly within 2-3 days. Egg shells were thinner and there was an increase in the number of cracked and soft shelled eggs after 24-28 hours of water starvation. Feed consumption also was reported to be reduced when water was deprived.

In a report summarizing experiments conducted at several experiment stations Sicer (1965) stated that a shortage of water can affect egg size, as well as decrease growth rate. These experiments also showed that when laying hens drink more water than they need, their droppings would be excessively wet. As the water supply was restricted, drier droppings resulted. More specifically, when the laying hens were limited to five 15 minute drinking periods a day, dried droppings resulted and no harm to egg production was indicated.

Bierer et al. (1966) reported that laying hens deprived of water lived an average of eight days, and that non-laying hens survived an average of 23 days. They also stated that death in the producing hens was generally due to toxemia rather than starvation.

Davis (1966) reported that hens drink too much water if given access to all the water they want. Excess consumption resulted in loose droppings, wet poultry houses, lower feed efficiency, and slightly lower egg quality.

When deprived of water young birds lost weight in a rather short time, and death occurred within 10-14 days, while adult hens lived from 30-98 days according to Jones and Huston (1967). The report also showed that regardless of age or breed of the bird, feed consumption decreased to a very low level shortly after water was withdrawn. They concluded that when about 45 percent of the normal body weight had been lost due

to water deprivation, death would occur.

Lifschitz et al. (1967) reported that water ingestion for females was much higher than for the males, which is due mainly to the physiological activity associated with egg production. Differences in the time of water ingestion were also reported. Males tended to reach a peak in water consumption at 10:30 A.M., but decreased consumption gradually during the afternoon. Females showed a slight increase during the morning but reached their peak of water consumption around 3:30 P.M.

Sunde (1967) reported that withholding water from laying hens for 30-36 hours resulted in egg production reaching its lowest level in five days, which did not return to the "normal" level for at least 30-35 days. When this procedure continued for a longer period of time, it took nine weeks for the production to again reach the "normal" level. It was noticed that 10 weeks later hens that had been deprived of water laid at a slightly higher rate than did the controls. Genetic differences in the laying hen's ability to resist water deprivation were also reported. When one week old baby chicks were deprived of water for different intervals, the chicks gained weight for only six hours and then started to lose weight. Feed consumption was also reported to increase for about 12 hours and then decreased. The report further showed that even deprivation of two or more hours resulted in decreased weight

gains for three days. At five days, however, only those groups deprived of water for 24 or 36 hours showed decreased gains.

In a report by Swanson (1968), pullets in the first few months of production often excreted wetter droppings than later in the laying season, as they consumed more water apparently to meet the demand of the higher rate of production. It was also stated that some birds consumed more water than they actually needed probably due to a hormone imbalance, while others probably developed a habit of overdrinking, which finally contributed to the problem of wet dropping. Some genetic factors were also considered. It was shown that Leghorns consume more water per unit of body weight than did heavy breeds. This difference was attributed to a specific recessive gene which influences water intake.

Wolford and Flegal (1968) stated that loose droppings might result from overconsumption of water and that controlled water intake had been successfully used to reduce the manure water level. The report further stated that humidity and temperature levels are considered to be important when using a restricted water program, a continuous water supply should be provided whenever the temperature goes above 85° F. During hot periods, even slight restriction (below requirement) will result in production decreases. When using the controlled water intake management technique, more attention must be paid to water depth, water space, and water availability to all birds.

Water starvation for 24 hours during hot weather will reduce egg production 20-25 percent.

Crampton and Lloyd (1954) stated that water restriction reduced feed intake of growing rats and consequently inhibited gain in body weight. The suggestion was also made by these authors that the age of the animal (presumably relative physiological age) might affect the extent to which effect of water restriction might have upon food intake.

In a study to determine the influence of withholding water and feed on the rate of growth and mortality of turkey poults, Chilson and Patrick (1946) reported that withholding water and feed for a period of 24, 48, and 72 hours, immediately after hatching, resulted in 4.8, 11.5, and 29.3 percent mortality, respectively, at 12 weeks of age. A decrease in live weight was also reported as the restriction time increased from 24 to 72 hours.

Severe distress and mortality in young turkey poults of 11 and 18 days of age, were reported by Marsden and associates (1965), when deprived of water for 24 hours and followed by free access to cool tap water. Eleven day old poultry showed symptoms of severe distress, including ataxia and convulsion, and suffered mortality of five percent. Eighteen day-old poults suffered a mortality of 18 percent. When the deprivation period was extended to 48 hours, mortality rate for the 11 and 18 day old poultry increased to 83 and 86 percent, respectively.

Haller and Sunde (1966) in a study conducted with turkey poults, 7 and 14 days of age, deprived of water for periods varying from 12 to 60 hours, reported that body temperature drop correspondingly lower as the time of water starvation increased. Feed consumption and weight gain were also reduced as the time of water deprivation increased. Upon making water available ad libitum, both feed consumption and weight gains increased rapidly.

IV. EXPERIMENTAL PROCEDURE

To determine the relationship of time of day to water consumption, the daily consumption per hen, and the associated relationship of water restriction upon water intake and the performance of mature hens a series of short term or preliminary experiments were conducted prior to the design of the long term studies.

Preliminary Experiment I

A total of 12 Single Comb White Leghorn pullets, approximately 52 weeks of age, in 68 percent production, were used in this study to determine the amount of water consumed per hen per hour during a 14 hour day starting at 6:00 A.M. and continuing to 8:00 P.M. The water was measured in grams at hourly intervals. Artificial lights were used during the 14 hour period. During the dark period individual waterers were placed before the hens to determine the amount of water consumed, if any, during the night hours, which lasted from 8:00 P.M. to 6:00 A.M.

Small size cans were used as water containers. The hens were trained for two days to drink from these cans before data were collected. The study extended over two weekends, referred to as Trials I and II. The same diet was used for all hens. The diet was calculated to contain 16.75 percent crude protein and 916 Calories of productive energy per pound. The composition

of the diet used is shown in Table I.

Results and Discussion

Results of this preliminary study are shown in Table II. During the first two hours (6:00 A.M. - 8:00 A.M.) the hens tended to consume water at a low level, then the average consumption per hen increased with some fluctuation until reaching the maximum at 6:00-7:00 P.M. in the first trial and at 5:00-6:00 P.M. in the second trial, then dropping sharply during the final day-light hour. Water consumption during the dark period was small, averaging 10.5 grams for the ten hour period.

Preliminary Experiment II

A total of 96 Single Comb White Leghorn laying hens, approximately 56 weeks of age, in 66.5 percent production, caged individually, was used to determine the effects of a range of restricted watering times on the amount of water consumed by the individual hens.

Sixteen treatments were employed with six hens per treatment. The treatments were as follows:

Five, ten, fifteen, and twenty minutes of drinking time per hour; five, ten, fifteen, and twenty minutes of drinking time per two hours; five, ten, fifteen, and twenty minutes of drinking time per three hours; and five, ten, fifteen, and twenty minutes of drinking time per four hours. Measurements of water consumption were taken at the end of each one, two,

TABLE I

COMPOSITION AND CALCULATED ANALYSIS OF THE LAYING DIET

Feedstuff	Percent of total
Yellow corn	66.975
Alfalfa meal (dehydrated 17% protein)	5.000
Fish meal	2.500
Soybean oil meal (50% protein)	17.000
Ground limestone	6.000
Defluorinated rock phosphate	1.500
Salt	0.500
Manganese sulfate	0.025
Vitamin mix ¹	0.500
Total	100.000
Calculated Analysis:	
Crude protein, %	16.75
Productive energy, Calories per lb.	916.00
C/P ratio	56.70
Methionine, %	0.327
Cystine, %	0.253
Calcium, %	3.026
Phosphorus, %	0.633
Available Phosphorus, %	0.431
Manganese mg./lb.	35.9
Vitamin A, I.U./lb.	7123.
Vitamin D, I.C.U./lb.	1342
Riboflavin, mg./lb.	2.24
Niacin, mg./lb.	20.1
Pantothenic acid, mg./lb.	5.23
Choline, mg./lb.	607.5

¹0.5 pounds vitamin mix supplies vitamin D, 134,187 I.C.U.; vitamin A, 111,823 I.U.; riboflavin, 201 mg.; vitamin B₁₂ 0.295 mg.; choline 20,000 mg.; niacin 1,097 mg.; and pantothenic acid, 216 mg.

TABLE II

WATER CONSUMPTION OF HENS DURING DAYLIGHT AND DARK
HOURS, PRELIMINARY EXPERIMENT I

Time	Water consumption per hen ¹		Average water consumption
	Trial I	Trial II	
		gms.	
6:00-7:00 A.M.	9	8	8.5
7:00-8:00	7	7	7.0
8:00-9:00	14	9	11.5
9:00-10:00	14	11	12.5
10:00-11:00	10	14	12.0
11:00-12:00	12	12	12.0
12:00-1:00 P.M.	15	18	16.5
1:00-2:00	12	11	11.5
2:00-3:00	9	18	13.5
3:00-4:00	17	15	16.0
4:00-5:00	14	15	14.5
5:00-6:00	20	24	22.0
6:00-7:00	24	22	23.0
7:00-8:00	8	13	10.5
Dark period			
8:00 P.M.-6:00 A.M.	14	7	10.5
Total consumed	199	204	201.5

¹Twelve hens were used per trial.

Temperature range for the first trial was 50-60° F.
Temperature range for the second trial was 46-52° F.

three, or four hour period for each treatment group on each of two different days.

Metal cans (capacity of 500 grams each) were used as water containers. The hens were trained for two days to drink from these waterers before the experiment started. The water was withheld during the night (7:00 P.M. to 6:30 A.M.) The study was conducted on two days, one week apart. Environmental temperatures were recorded at eight different time intervals during each of the two days. Mean temperature was 67.9° F. for the first day, and 69.1° F. for the second day. The same diet was used as in preliminary experiment I and shown in Table I.

Results and Discussion

Average water consumption per hen during each period for birds receiving the sixteen different degrees of water restriction is presented in Table III. These results indicate that (1) the frequency of drinking influences the amount of water consumed. Hens given the opportunity to drink each hour consumed more water than those receiving water every two hours, and those given the opportunity to drink each three hours consumed more water than hens receiving water every four hours. (2) that, in general, the longer the drinking period, for each of the four frequencies, the greater the consumption of water per hen; and (3) hens generally consume more water in the afternoon as compared to the morning. Peak water consumption appeared to be reached about mid-afternoon in most treatment groups.

TABLE III

WATER CONSUMPTION BY PERIODS AS AFFECTED BY RESTRICTED WATERING TIME,
PRELIMINARY EXPERIMENT II

Period of day	Availability of water													
	Min. per hour				Min. per 2 hrs.				Min. per 3 hrs.				Min. per 4 hrs.	
	5	10	15	20	5	10	15	20	5	10	15	20	5	10
	grams of water consumed per hen*													
6:30 A.M.	36	27	37	54	17	32	39	27	30	30	36	44	34	33
7:30	25	17	18	21										
8:30	21	19	18	18	19	24	24	24						
9:30	22	13	15	14					53	39	39	48		
10:30	21	17	17	20	22	33	34	41					36	56
11:30	22	15	18	15									49	50
12:30 P.M.	22	14	20	19	29	30	35	29	44	50	53	60		
1:30	21	12	17	20										
2:30	20	22	19	16	25	30	36	34					66	66
3:30	22	15	24	26					53	42	56	64	48	49
4:30	19	18	20	18	41	36	38	49						
5:30	17	19	23	20										
6:30	18	15	15	19	31	15	36	40	67	59	52	57	66	58
Total	286	223	261	280	181	200	242	244	247	220	236	273	202	213

*Each value is the average of six hens on each of two days one week apart.

Preliminary Experiment III

A total of 48 Single Comb White Leghorn laying hens, 28 weeks old, individually caged, in 86.5 percent production, was used in a preliminary study to determine the effects of different water restriction times on feed consumption, water consumption, egg production, and the amount of water in the droppings. The experiment was conducted for five consecutive days.

The same diet fed in preliminary Experiment I and shown in Table I, was fed to all groups with feed provided ad libitum. Water was withheld during the dark period which continued from 7:20 P.M. to 7:00 A.M. The cans containing a measured quantity of water was placed before each hen at 7:00 A.M. each day. Hens were trained for two days to drink from these waterers. Hens were given artificial light so as to provide 12 hours and 20 minutes of light per day. Records on egg production were kept for the five days of the experiment and continued for eight days after the termination of the study. Water consumption was measured in grams hourly, or every two or three hours as the time restriction required. Droppings were collected in pans placed underneath the cages. Samples of droppings were taken from every treatment group on the fifth day, and the percent moisture in the droppings determined, according to A O A C methods (1960). Room temperature was recorded daily at four different time intervals.

Results and Discussion

The results of this preliminary experiment are presented

in Tables IV and V.

In this experiment peak water consumption was generally reached during the second period by each of the groups. During the remaining part of the day water intake seemed to be fairly uniform and no afternoon peak was indicated as in the first and second experiments. Table V summarizes the average daily water and feed consumption and moisture content of the droppings of hens subjected to each of the treatments. The hens provided access to water each hourly period consumed more water and produced wetter droppings than those receiving water at two or three hour intervals. Also in the hourly group more water was consumed as the length of the drinking period was increased. This did not appear to be so in the groups receiving water every two or three hours.

Feed consumption showed little or no effects of the water restriction times. Increasing the length of the drinking period showed little or no effect on the percent moisture in the droppings. No relationship between water restriction at the levels studied in this experiment and egg production were found. Data on this factor are not presented here due to the short period of the experiment.

TABLE IV

WATER CONSUMPTION BY PERIODS AS AFFECTED BY RESTRICTED
WATERING TIME

Period of day	Availability of water											
	Min. per hr.				Min./2 hr.				Min./3 hrs.			
	5	10	15	20	5	10	15	20	5	10	15	20
Grams of water consumed per hen*												
7:00 A.M.	8	18	17	32	9	12	11	14	15	13	17	23
8:00	24	23	31	20								
9:00	16	12	14	16	29	32	33	29				
10:00	14	12	14	21					40	32	25	39
11:00	6	9	12	16	20	34	35	24				
12:00	10	11	18	13								
1:30 P.M.	11	14	13	16	25	32	33	22	33	39	27	34
2:00	12	13	15	17								
3:00	16	18	21	28	29	35	21					
4:00	14	12	14	13					41	35	31	27
5:00	17	16	16	16	23	27	26	27				
6:00	18	15	20	19								
7:00	24	27	20	29	29	29	25	34	40	58	44	42
Total	190	200	225	246	163	195	198	171	169	177	144	165

*Each value is the average of three hens on five days.

Average temperature for the five day period was $80.0 \pm 1.4^{\circ}$ F.

Average relative humidity for the five day period was 62.0 ± 9.1 percent.

TABLE V

THE EFFECT OF RESTRICTED WATERING TIME ON THE AMOUNT
OF WATER AND FEED CONSUMED PER HEN AND MOISTURE

Availability of water ¹	Average daily water consumption ¹	Average daily feed consumption	Moisture in the droppings
	grams	grams	percent
5 minutes/hr.	190	77	82.3
10 minutes/hr.	196	94	84.3
15 minutes/hr.	222	98	83.3
20 minutes/hr.	247	93	82.9
5 minutes/2 hrs.	161	78	80.4
10 minutes/2 hrs.	196	81	80.1
15 minutes/2 hrs.	200	81	81.2
20 minutes/2 hrs.	169	78	80.0
5 minutes/3 hrs.	169	75	79.3
10 minutes/3 hrs.	177	86	79.2
15 minutes/3 hrs.	145	75	81.0
20 minutes/3 hrs.	165	83	80.5
<u>ad libitum</u> ²	181	83	82.1

¹Three hens per treatment.

²Twelve hens used.

V. MATERIALS AND METHODS

Experimental Animals

A total of 480 Single Comb White Leghorn type pullets was used in this study to gain further information concerning the effects of water restriction on the performance of laying hens.

Experimental Design

The pullets were housed on June 1, 1967, when twenty-two weeks of age, two per 8 inch by 18 inch laying cage, arranged in stair step style. The duration of the experiment was for eleven twenty-eight day periods, or a total of 308 days.

The hens were divided into four groups of 120 hens each with each group subdivided into four lots of thirty hens each. The hens were vaccinated for Newcastle and bronchitis, debeaked, and legbanded at the time they were housed. Throughout the study all hens were maintained under similar environmental conditions with the exception of the designated treatments. The hens were assigned to treatments as follows:

Group 1 - control - water ad libitum.

Group 2 - Fifteen minutes of water every one hour.

Group 3 - Fifteen minutes of water every two hours.

Group 4 - Fifteen minutes of water every three hours.

Electric time clocks connected to solenoid valves were used to control the watering time procedure automatically.

Lighting Program

The pullets were subjected to artificial light for 14 hours a day for the first six months of production, after which time the amount of light was increased 15 minutes each week for the remainder of the experimental period.

Composition of Diet

The diet used by these hens and its composition is shown in Table I and has been discussed in Preliminary Experiment I. The all mash diet was provided ad libitum.

Methods of Data Collection

Information on mortality was recorded daily. Daily egg production records were recorded on a lot basis. Egg production was calculated for each individual lot on a hen-day and hen-housed basis.

Feed consumption was determined for each 28 day period for each lot. Feed efficiency was calculated as the number of pounds of feed per dozen of eggs produced during each period.

All eggs produced by each lot on the twenty-eighth day of each period were weighed individually, after cooling overnight.

An estimate of shell thickness as determined by the specific gravity method was made on eggs laid one day of each period. A series of salt solutions ranging from 1.068-1.100 in specific gravity differing by increments of .004 were used

for this purpose. An egg that floated in the solution with a specific gravity of 1.068 was given a score of zero. The score then increased by one as the specific gravity of the solution increased by .004. Eggs that sank in the solution with a specific gravity of 1.10 were given a maximum score of 9.

Interior quality of eggs laid during one day of each 28 day period was determined by breaking the eggs and determining Haugh units. At the time of breakout each egg was examined for the presence of meat or blood spots.

A sample of 20 hens was chosen at random from each group and weighed individually at housing time to secure the initial weights. These same hens were weighed every 56 days until the termination of the experiment.

Ten hens were chosen from each group for the collection of droppings. Special droppings pans, 40 inches by 18 inches with five divisions of 18 inches by 8 inches were used for collection of the droppings. The droppings pans were placed beneath the cages and left for five days during the months of July 1967 - April 1968. At the end of each five day period a sample from each of the five divisions or compartments in each group representing the accumulated droppings of two hens per division was taken, mixed thoroughly and the percent moisture determined.

Analysis of Data

The data were statistically analyzed using analysis of

variance according to Snedecor (1956). The significant treatment mean differences were determined by using Duncan's Multiple Range Test (1955).



VI. RESULTS AND DISCUSSION

Egg Production

Results on egg production are shown in Table VI. Groups with water ad libitum produced at a higher rate on both hen-day and hen-housed basis than any groups receiving water restriction. A significant difference between the water ad libitum group and the restricted groups was found on the hen-day basis ($P < .05$). The group receiving 15 minutes of water every one hour differed significantly from those receiving 15 minutes of water every two, and three hours on a hen-day basis. No significant differences were found among the four groups in egg production on the basis of hen-housed production although the arithmetic average production was in favor of the hens with water ad libitum. No significant differences were found in percent mortality of hens subjected to the several treatments.

The results tended to be in partial agreement with the findings of Wilson and Edward (1955), and Sunde (1962), who reported that water restriction of laying hens resulted in a drastic decrease in egg production. They used different and more severe levels of water restriction, however. At the same time the results obtained in this experiment tended to contradict the report of Goodman (1961) who stated that water could be restricted to caged layers for 15 minutes every one, two, and three hours without affecting their productivity.

TABLE VI

THE EFFECT OF WATER RESTRICTION ON EGG¹ PRODUCTION AND
MORTALITY OF LAYING HENS¹

Availability of water	Percent egg production		Av. eggs per hen		Percent mortality	
	Hen ² day	Hen- housed	Hen ² day	Hen- housed	Entire experiment	Av. per period
<u>Ad libitum</u>	78.4 ^c	66.6 ^a	241 ^c	206 ^a	29.0 ^a	2.64 ^a
15 min./hr.	72.5 ^a	62.4 ^a	223 ^a	192 ^a	23.6 ^a	2.14 ^a
15 min./2 hrs.	74.5 ^b	61.3 ^a	229 ^b	189 ^a	26.6 ^a	2.42 ^a
15 min./3 hrs.	74.0 ^b	63.0 ^a	227 ^b	194 ^a	26.6 ^a	2.42 ^a

¹For 308 days.

²Percentages and averages within each column followed by a different superscript are significantly different from each other ($P < 0.05$).

Total eggs produced per hen on a hen-day basis for the entire experiment of 308 days was significantly higher for hens receiving water ad libitum. On a hen-housed basis no significant differences were found between any of the treatments, although arithmetically the rate of production was greater for hens receiving water ad libitum. On a hen-day basis hens receiving water 15 minutes every hour produced at a significantly lower rate than those receiving 15 minutes of water every two and three hours as shown in Table VII.

Mortality

No significant differences were found in mortality between the treatments as shown in Table VI. The results show that mortality for all groups involved in this experiment ran fairly high, with the group receiving water ad libitum suffering the highest percent mortality on a numerical basis for the 308 days of the experiment. The principle causes of mortality were Marek's disease and fowl leukosis which were probably not associated with treatments.

Feed Consumption

Pounds of feed consumed per hen for the entire experiment, and the amount of feed required to produce a dozen eggs is presented in Table VII. Significant differences in feed consumption per hen were found between those hens with water given ad libitum and those with the water restricted at all levels. A significant

TABLE VII

FEED CONSUMPTION AND EFFICIENCY AND PERCENTAGE MOISTURE
IN DROPPINGS AS AFFECTED BY DIFFERENT WATER
RESTRICTION LEVELS

Availability of water	Pounds of feed		Percent moisture in droppings ²
	Per hen ¹	Per dozen eggs	
<u>Ad libitum</u>	76.6 ^c	3.97 ^a	79.6 ^b
15 minutes/hr.	73.4 ^b	4.03 ^a	78.9 ^b
15 minutes/2 hrs.	72.6 ^b	3.83 ^a	77.4 ^a
15 minutes/3 hrs.	71.5 ^a	3.89 ^a	76.9 ^a

¹Amount of feed consumed per hen for 11 periods, 28 days each period.

²Percentage moisture was determined on the droppings of ten hens for five days each 28 day period for a total of ten periods.

Averages within each column followed by the same superscripts are not significantly different from each other ($P < 0.05$) as determined by Duncan's Multiple Range Test (1955).

difference was also found between the group given water 15 minutes every three hours and the groups receiving water 15 minutes each one or two hours. No significant differences were found between the four groups in the amount of feed consumed per dozen of eggs produced. The results further show that as the time restriction increased from one to three hours, the amount of feed consumed per hen tended to decrease. Most of the work reported in literature dealing with the effect of water restriction on feed consumption agree that water deprivation tends to decrease feed consumption. The data reported in this experiment, on feed consumption, tend to agree with the findings of Bierer et al. (1966) and Haller and Sunde (1966).

No significant differences were found in feed consumed per dozen eggs produced and degree of water availability.

Moisture in the Droppings

Results on the percentage moisture in the droppings are summarized in Table VII. There was no significant difference between the group with water ad libitum and the one receiving water 15 minutes per hour but these two groups produced significantly wetter droppings than the two groups receiving water 15 minutes per two and three hours. The data showed that as the length of time off water increased, the percentage moisture in the dropping decreased. It was observed during the collection of the data throughout the experimental time that the trays containing the droppings of the water restricted hen were easier

to clean and that the excrement appeared to be drier at all times than did the droppings from the birds given water ad libitum. It was observed however, that young hens in their first month of production often voided much wetter droppings than later in the production year.

During this early period they also tend to consume larger quantities of water to meet the demands of a high rate of lay or perhaps due to nervousness associated with being confined.

These results tended to be in agreement with the findings of Tyler (1957) which stated that as the water intake increased, there was an increased loss of moisture through the droppings. It is also in agreement with the findings of Maxwell and Lyle (1961), Goodman (1961) and Wilson et al. (1965) all of whom indicated that wet droppings can be effectively prevented by the restriction of water.

Egg Quality

The results on egg quality characteristics, including egg weight, specific gravity, Haugh units, and incidence of meat and blood spots are summarized in Table VIII. There were no significant differences found between treatments for average egg weight, specific gravity score, nor Haugh unit score. The results secured in this experiment regarding egg quality characteristics agree with the findings of Wilson et al. (1965) who stated that no differences were found in egg weight,

TABLE VIII
EGG WEIGHT, EGG SIZE DISTRIBUTION AND EGG QUALITY SCORES AS AFFECTED BY DIFFERENT
LEVELS OF WATER RESTRICTION

Availability of water	Average egg ¹ weight ¹ gms.	Egg size ²			Meat and blood spots ³		Average specific gravity	Average Haugh ¹ units
		Small	Medium	Large	Extra large	Small		
Ad libitum	59.2 ^a	1.15 ^a	16.50 ^a	45.15 ^a	37.2 ^a	9.7	3.5 ^a	75.0 ^a
15 min./hr.	58.6 ^a	0.40 ^a	21.10 ^a	42.10 ^a	36.4 ^a	12.2	3.5 ^a	75.1 ^a
15 min./2 hrs.	58.7 ^a	1.50 ^a	17.80 ^a	39.20 ^a	41.5 ^a	1.9	3.4 ^a	75.0 ^a
15 min./3 hrs.	58.8 ^a	0.70 ^a	20.0 ^a	46.50 ^a	32.8 ^a	5.6	3.5 ^a	73.5 ^a

¹ Averages within each column followed by the same superscript are not significantly different from each other ($P < 0.05$).

² Percentage within each column followed by the same superscript are not significantly different from each other ($P < 0.05$).

³ Total percentage for 308 days.

specific gravity or Haugh units between the control group with water ad libitum and the water restricted groups. Average egg weight and average specific gravity tended to maintain a rather uniform value for all groups throughout the entire experimental period. The results suggest that water restriction for laying hens at the restriction levels studied in this experiment has little or no effect on egg quality and egg weight.

The percentage of meat and blood spots was highest in the group receiving 15 minutes of water per hour while the group with water ad libitum had the second highest percentage. It was noticed while collecting the data on blood and meat spots that certain pens within these treatments showed a higher incidence than did other pens within the same treatment throughout the entire experiment. This suggests that individual variation and not the treatments was responsible for this tendency. The hens receiving 15 minutes of water per two hours had a low incidence of spots relative to the other groups shown in Table VIII. These data were not statistically analyzed due of the relatively small numbers of eggs involved.

Egg Size Distribution

Egg size distribution is summarized in Table VIII. No significant differences were found between the group receiving the various treatments. The hens involved in this study produced no peewee eggs. Few small eggs and a low percentage of medium eggs were produced. It is concluded from the results presented

that water restriction at the levels studied in this experiment had little effect on egg size distribution.

Body Weight

The results pertaining to body weights are presented in Table IX. The group of hens receiving the 15 minutes of water per hour treatment gained a greater amount of weight during the 308 day experiment than did the other three groups. When the average final body weights are considered, however, the group receiving water ad libitum had the highest average final body weight, followed by the group receiving 15 minutes of water per hour, per two hours, and per three hours, in that order. As restricting water intake did result in a decrease in feed intake, it is to be expected that body weights would be affected in the above manner. Considerable variation was found in the initial body weights and this may help to explain the differences in rate of gain in body weight.

The results secured by this study on body weight is not in full agreement with the popular opinion that water restriction causes a loss in body weight as indicated by Wilson and Edward (1955), Sunde (1962 and 1966), and Haller and Sunde (1966).

TABLE IX

AVERAGE WEIGHT GAIN AS AFFECTED BY DIFFERENT LEVELS OF
WATER RESTRICTION

Availability of water	Average ¹ initial body weight	Average ² final body weight	Average gain	Percent gain
	gms.			
<u>Ad libitum</u>	1651	2036	385 ^a	23.3
15 min./hr.	1519	1948	429 ^b	28.0
15 min./2 hrs.	1645	1890	245 ^a	14.8
15 min./3 hrs.	1479	1832	353 ^a	23.1

¹Taken at housing time when hens were 22 weeks old.

²Taken after 308 days in laying house.

Averages within column with superscripts followed by the same letter are not significantly different from each other ($P < 0.05$) as determined by Duncan's Multiple Range Test (1955).

VII. SUMMARY AND CONCLUSIONS

A total of 480 Single Comb White Leghorn type hens, housed two per cage at 22 weeks of age, was used in a study to gain information concerning the effects of different water restriction levels on egg production, egg weight and size distribution, egg quality, feed consumption, mortality and the percentage of moisture in the droppings. ^{stop} Results of three preliminary experiments involving 156 hens showed that increasing the frequencies of the periods tended to result in increased water consumption.

In the principle experiment ^{Continue} four levels of water restriction were compared: (1) water ad libitum, (2) 15 minutes of water per hour, (3) 15 minutes of water per two hours, (4) 15 minutes of water every three hours. The experiment was continued for a period of 308 days. ⁴⁵

Restricting the availability of water resulted in a decrease in the rate of egg production on both hen-day and hen-housed basis. Hens receiving water ad libitum laid at a significantly higher rate than the other three groups when measured on a hen-day basis. Significant differences in rate of production on a hen-day basis were found among the water restricted groups with the group receiving 15 minutes of water every hour producing at a significantly lower rate than those receiving 15 minutes of water every two and three hours. Production differences on a hen-housed basis, while not

statistically different, followed a similar pattern.

No significant differences were found in the percent mortality among the four treatment groups.

A significant difference was found in feed consumption per hen among the groups, with the group receiving water ad libitum consuming more feed than the water restricted groups. The results further show that as the degree of restriction increased, the amount of feed consumed per hen decreased, with the group given fifteen minutes of water every three hours consuming the least amount of the feed. The differences in the number of pounds of feed required per dozen eggs were not significant.

Excrement from hens receiving water restriction was drier than that from the hens giving water ad libitum. No significant difference was found between the water ad libitum group and the fifteen minutes of water per hour group, but restricting watering time to fifteen minutes every two and three hours resulted in significantly drier droppings. It is concluded that water restriction of hens results in drier droppings.

No significant differences were found in respect to specific gravity and Haugh unit scores.

There were no significant differences found among the treatment groups in respect to average egg weight nor the

distribution of egg sizes.

Hens receiving 15 minutes of water every hour gained on significantly higher rate than other treatment groups including the group with water ad libitum, however, the group receiving water ad libitum had the highest average final body weight.

It can be concluded from this study that the water intake of laying hens can be affected by restricting the amount of time water is available to the birds and that the restriction levels used in this experiment tended to reduce the percent egg production, the amount of feed consumed, final body weight, and the amount of moisture in the droppings. Mortality, egg quality and egg size were not significantly affected.



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VITA

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