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To the Graduate Council:

I am submitting herewith a thesis written by Dharamvir Singh Chaudhary entitled "Adaptation of Chickens to Extremes of Temperatures". 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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ADAPTATION OF CHICKENS TO EXTREMES OF TEMPERATURES

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

Dharamvir Singh Chaudhary

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INTRODUCTION

In poultry production "stress" has become a familiar term. Stress has been defined by Hans Selye (1950) as any deviation from the normal resting state. When an organism has been subjected to a change in its environment which requires it to make an adaptation in order to maintain its homeostasis, then it has been stressed.

The stresses in poultry are many and varied. They may be divided roughly into four groups: genetic, management, disease, and nutrition.

Of the many stress factors affecting poultry, temperature is of major importance. It is known that the environmental temperature influences many characteristics of poultry, such as egg production, fertility and hatchability of eggs, quality of eggs, disease resistance, metabolic rate, efficiency of feed utilization, and growth rate.

The domestication of poultry and the development of the modern poultry industry has resulted in many problems pertaining to temperature. The natural habitats of the ancestors of modern fowl were in restricted areas of the world. It might appear that natural selection might have undoubtedly resulted in populations genetically adapted to their climate. Today poultry production is world wide, and, to a considerable extent, resistance to temperature extremes has been eliminated as a selection factor in the breeding of poultry.

Poultry confined in houses are subjected to the ranges in temperatures of those houses. With the exception of small chicks

it has not been generally considered economically feasible to control the temperature of poultry houses in this area. Temperatures within Tennessee poultry houses may approach 100° F. on certain summer days and below freezing on occasional winter days. A recent trend in poultry production has been to increase the bird density in houses. This means a greater concentration of body heat and greater discomfort to the birds on hot days. In transporting poultry to market the birds are crowded in coops and considerable mortality has been known to occur on hot days.

During periods of extremely high temperatures many deaths of poultry from heat prostration have been reported in all parts of the United States. Thus it is of great economic importance to the poultry industry that it knows the ability of the chicken to withstand the stress of temperature extremes and how resistance might be modified.

OBJECTIVES

Experiments were designed to study in chickens:

- (1) the relationship of rearing temperature to the ability to resist extremes of temperature,
- (2) the relationship of the ability to resist one extreme of temperature to the ability to resist the opposite extreme,
- (3) the relationship of adrenal size and ascorbic acid content to rearing temperatures and the ability to resist temperature extremes, and
- (4) the effect of a tranquilizer upon the development of resistance to extremes of temperature.

LITERATURE REVIEW

The literature on the subject of acclimatization of animals is scattered and information is meager. The ability of a wide variety of animal species to adapt to a given environment has been studied. While it is conceivable that there may be acclimatization to various physical factors of the environment, the subject that has received major attention is acclimatization to temperature.

The heat acclimatization of fishes was studied by Loeb and Wastenoys (1912) and by Hathaway (1927). The latter worker found that, when large-mouthed black bass were exposed to a temperature of 34° C. for one hour, about 50 percent of the fish died; however, if the fish had been kept at 30° C. for four days before exposure to the high temperature, the lethal temperature was 38° C. The lethal temperature dropped to 30° C. if the fish were kept at 10° C. for sixteen days prior to exposure to the elevated temperature.

Sumner and Doudoroff (1938) studied heat acclimatization in a Pacific Coast goby (Gillichthys mirabilis). They acclimatized the gobies by keeping them at a temperature of 30° C. for varying lengths of time. Most of the acclimatization was found to occur within 26 hours in this species.

Ogle and Mills (1933) found that rabbits raised at a high temperature (32° C.) were less able to resist chilling than those raised at lower temperatures.

Sellers et al. (1951a) conducted studies on the acclimatization of rats. When adult rats were clipped and exposed to a cold

environment of 1.5°C ., all died within 3 to 23 hours. However, when rats which had been acclimatized by living in the cold environment for 2 or more months were clipped, most survived for 17 days or more. The explanation of this difference was believed to be the ability of the acclimatized animals to maintain a greatly increased production of body heat. The survival times of adrenalectomized and of thyroidectomized rats subjected to cold were lengthened by previous acclimatization and also by injections of cortical extract and thyroxine. Sellers et al. (1951b) in a later study on rats reported that the acclimatization was only temporary and decreased considerably when the acclimatized rats were kept at room temperature for four days.

The importance of physiological acclimatization in improving the heat tolerance of man in hot climates is well known. Bazett et al. (1940) reported changes in the blood volume and plasma protein concentration of men while exposing them to 21.1°C . and 32.5°C . for several weeks. These workers concluded that blood volume and plasma protein increased at the higher temperature and decreased at the lower temperature. It was concluded by Burton et al. (1940) that the process of acclimatization in man involves changes in both total heat exchange and its partition. Horvath et al. (1947) conducted metabolic studies on five men who resided in cold environments and concluded that the data gave some indication that acclimatization to cold may occur.

The basal metabolism of the house sparrow was found by Miller

(1939) to be increased by exposure to cold. Hoffman and Shaffner (1950) found that residence in a warm climate reduced the basal metabolism of growing chickens. Changes in the histology and size of the thyroids were observed after acclimatization treatment.

That the fowl can tolerate heat better after a series of short sharp exposures has been demonstrated by Hutchinson and Sykes (1953). After 24 successive daily exposures of up to four hours to a temperature of 99° F., exposure to a temperature of 102.5° F. resulted in about the same hyperthermia as did the exposure to 99° F. at the beginning of the tests.

Hillerman and Wilson (1955) compared the reaction of hens subjected to sudden changes in temperature with their adapted performance. Hens were acclimatized for three months at 50-60° F. and then exposed to an air temperature of 102° F. for two hours. Body temperatures rose to 110.4° F. and 109.3° F. for males and females, respectively. The hens were then removed to a cooler environment of 90° F. and at this temperature homeostasis was evident on the third day.

Weiss and Borbely (1957) reported that White Leghorn hens, maintained in an environment which fluctuated with outside temperature, survived exposure to 105° F. and 70 per cent relative humidity better in summer than in the winter. All eight hens of a winter series expired in an average of 127 minutes, whereas, two out of ten in a summer series survived beyond four hours. The eight that died did so in an average of 190 minutes. It was suggested that this seasonal

adaptation of the summer birds was associated with a slower rise of body temperature and a higher rate of respiration. Similar results were reported by Weiss (1959a).

An initial effect of temperature extremes is stimulation of the stress-regulating function of the adrenal cortex. Ascorbic acid in the adrenals varies in amount depending upon the activity of the cortex.

It has been reported by Hartman et al. (1931) that cold increases the size of the adrenals. Rats exposed to temperatures ranging from 5 to 20° C. for five or six hours at a time over a period of days or weeks until a total of thirty hours or more had been reached possessed adrenals which averaged 9.7 per cent heavier than those of the control rats which were maintained at 27 to 28° C.

Martini and Torda (1937) showed that the adrenal contains more ascorbic acid in the summer than in the winter and that this may be due to temperature effect as exposure of the animal to high temperatures for several hours greatly reduced the amount of this substance in the adrenal.

Dugals and Therien (1947) reported that ascorbic acid increased markedly in the tissues of the white rat after prolonged exposure and adaptation to cold. These workers fed various levels of ascorbic acid to guinea pigs and found a direct relation between the ability of the animals to adapt to cold and the ascorbic acid level. These experiments indicate that acclimatization to low temperatures requires large quantities of ascorbic acid.

It has been generally considered that under normal conditions the chick does not have a dietary requirement for ascorbic acid. The possibility exists, however, that the power of the chick to synthesize ascorbic acid may be limited during periods of stress such as that produced by temperature extremes.

That the ascorbic acid available to the chick is not always adequate for maximal performance is shown by the work of a number of researchers. Briggs et al. (1944) suggested that chicks fed a highly purified diet were not able to synthesize sufficient ascorbic acid to permit maximum growth. March and Biely (1953) found that the feeding of ascorbic acid increased the growth rate of chicks fed diets containing different levels of folic acid. Dietrich et al. (1949) reported that the effect of vitamin B₁₂ on growth of chicks was enhanced by ascorbic acid. Shell thickness of eggs was reported by Thorton and Moreng (1958) to be increased by the addition of ascorbic acid to the diet of the hens. This effect was more pronounced when environmental temperatures were highest.

The function of ascorbic acid in the animal's body is believed by Hughes et al. (1952) to be that of a coenzyme essential in the production of oxy-type adrenal cortical hormones.

In recent years there has been an increased interest in the use of tranquilizers by the poultry industry. Particularly has there been an interest in the behavior of tranquilized birds under stress. Of the various tranquilizers tested reserpine has produced the most promising results.

Reserpine has been reported by Sturkie (1959) to reduce the heart rate and blood pressure of chickens. Ringer (1959) reported similar results with turkeys. Huston (1959), and Anderson and Smyth (1959) found that when reserpine was fed to chickens the thyroid glands were significantly reduced in size. Huston also reported a reduction in body temperatures of the treated birds.

The effects of reserpine on a number of characteristics of economic importance in chickens have been studied. Burger (1959) observed that the mortality of S. C. White Leghorn chickens subjected to acute heat stress was reduced by the feeding of as little as 5 mg./kg. of feed of reserpine for four days. Treatment for only one day did not give protection but gave a consistently higher death rate at the moderate dosages used. There was found to be no interaction of age of bird and treatment level.

Egg production was lowered by feeding reserpine in experiments conducted by Gilbreath (1959), but Couch (1959), Carlson (1959), and Anderson and Smyth (1959) found no significant difference in egg numbers of the treated birds as compared to the controls.

A number of workers have indicated an improvement in egg characteristics as the result of feeding reserpine to hens. Anderson and Smyth (1959), and Gilbreath (1959) reported an increase in egg size of the reserpine treated hens. Couch (1959) obtained a significant reduction in the percentage of eggs with checks when reserpine was fed.

Weiss (1959b) reported that reserpine fed to laying hens at

the rate of 1.6 mg./kg. of feed for four weeks increased their survival time when exposed to the heat stress of 105° F. in three out of four trials. The one trial with negative results was one on winter acclimatized birds. The birds of the other trials were summer acclimatized. Weiss suggests that the improved heat tolerance of the reserpine treated birds was due to their better ability to eliminate heat through the respiratory mechanism.

MATERIALS AND METHODS

Experimental Animals

A total of 650 chicks was employed in a series of three experiments designed to study the ability of chickens to become adapted, or acclimatized, to various environmental temperatures.

Care of Chicks Prior to Assigning to Treatments

At one day of age the chicks were sexed, vaccinated intra-ocularly with a combination Newcastle-bronchitis vaccine, and placed in electrically heated battery brooders. Temperatures under the heating elements were maintained at 95° F. during the first week and were reduced five degrees per week for the five weeks they remained in the batteries. Feed and water were available to the chicks ad libitum throughout the experiments.

Composition of Diet

The composition of the basal diet used in these experiments is shown in Table I. This broiler diet meets the recommendations of the National Research Council (1954) for all nutrients.

Exposure Tests

The primary criterion of adaptation of the chickens to the environmental temperatures was their ability to maintain a normal body temperature when subjected to extremes of temperature.

TABLE I

BROILER STARTER DIET

Ingredient	Pounds
Yellow corn	476
Fish meal (menhaden 60% protein)	50
Alfalfa meal (dehydrated, 17% protein)	25
Corn gluten meal	60
Vitamin ¹ , mineral ¹ , and S. Q. mix ²	58
DL-Methionine	1
Dried whey products	20
Hydrolyzed feather meal	20
Soybean oil meal (50% protein)	225
Stabilized animal grease	65
Total	1000

Calculated Analysis

Crude protein	25.49%
Productive energy	1020 Calories per pound
C/P ratio	40:1

¹Calculated to meet minimum requirements of National Research Council.

²Calculated to provide sulfaquinoxaline at the level of 0.0175% of diet.

When the chicks were ten weeks of age, in Experiments I and II, and nine weeks of age in Experiment III, after having been subjected to the various treatments of temperatures and additives in the diet, birds were selected at random from each experimental group. They were then restrained on racks side by side by tying their legs and wings. They were then exposed to one of several extremes of temperatures. Their body temperatures were measured at regular intervals by a thermometer inserted into the cloaca. The time elapsing from the removal from the batteries to start of the exposure was approximately one hour and the length of exposure was from two to two and one-half hours.

The extremes of temperature tested included 50° F. water bath, 60° F. water bath, 120° F. water bath, 0° F. room temperature, and 110° F. room temperature. No bird was exposed to more than one of the above conditions. Generally, a bird was removed from the exposure when its body temperature fell below 95° F. or went higher than 116.5° F.

Ascorbic Acid Determination

The adrenal glands were dissected from the birds and held on ice until the analysis was made during the afternoon of the same day on which they were taken. The procedure employed was that as described in "Methods of Analysis, AOAC", (1945) with the exception that six per cent rather than three per cent metaphosphoric acid was used. The glands of each of the experimental groups were pooled so as to

provide a sufficient quantity of material for each analysis.

Experiment I

Five-week-old broiler type female chicks, grown as previously described, were divided into four groups of fifty each, individually weighed, and placed in growing batteries. The following treatments to ten weeks of age were given:

Group 1. Room temperature of 90° F.

Group 2. Room temperature of 90° F. plus the tranquilizer "Serpasil"¹ in the feed at the level of 1 ppm.

Group 3. Room temperature of 70° F.

Group 4. Room temperature of 50° F.

At ten weeks of age birds from each of the four treatment groups were individually weighed and subjected to temperature treatments. The temperatures to which the chicks were subjected were: 50° F. water bath, 60° F. water bath, 120° F. water bath, 0° F. room temperature and 110° F. room temperature.

Survival times were recorded for the birds placed in the water baths. Body temperatures were measured at 15 minutes intervals in the groups exposed to the extremes of room temperature.

After the birds had been subjected to the water baths their adrenal glands were removed and weighed.

¹Serpasil-Ciba's 0.2 per cent reserpine premix.

Experiment II

Five-week-old broiler-type chicks, of both sexes, grown as previously described, were divided into five groups and placed in growing batteries. They were treated to ten weeks of age as follows:

Group 1. Room temperature of 90° F.

Group 2. Room temperature of 90° F. plus 1 ppm. Serpasil in the feed.

Group 3. Room temperature of 70° F.

Group 4. Room temperature of 50° F.

Group 5. Room temperature of 50° F. plus 1 ppm. Serpasil in the feed.

At ten weeks of age individual body weights and body temperatures of all chicks were recorded. Four males and four females from each group were exposed to 0° F. room temperature and four males and four females from each group were exposed to 110° F. temperature. The body temperature of each chick was recorded at 30 minute intervals.

The adrenal and thyroid glands were dissected out and weighed from an average of five males and five females from each group. These birds had not been exposed to the extremes of temperature. The adrenal glands were analyzed for ascorbic acid content.

Experiment III

Five-week-old Leghorn type cockerel chicks were divided into six groups and placed in growing batteries. They were treated to

nine weeks of age as follows:

Group 1. Room temperature of 90° F.

Group 2. Room temperature of 90° F. plus the addition of one half mg. ascorbic acid per gm. of feed.

Group 3. Room temperature of 90° F. plus the addition of 1 mg. of ascorbic acid per gm. of feed.

Group 4. Room temperature of 70° F.

Group 5. Room temperature of 70° F. plus the addition of one half mg. ascorbic acid per gm. of feed.

Group 6. Room temperature of 70° F. plus the addition of 1 mg. ascorbic acid per gm. of feed.

The diets containing the ascorbic acid supplementation were mixed twice weekly.

At nine weeks of age, after all chicks were weighed and their body temperatures taken, five birds from each group were exposed to 0° F. room temperature and five chicks from each group were exposed to 110° F. room temperature. Body temperatures of each chick were recorded at intervals of 30 minute at these two extremes of temperature.

RESULTS AND DISCUSSION

Experiment I and II

Growth and Feed Conversion. The weight gains of the chickens reared at the various environmental temperatures from five to ten weeks of age are summarized in Tables II and III. In all of the experiments (including Experiment III) the growth rate was best at the 70° F. temperature and poorest at the 90° F. temperature. The growth rate at the 50° F. temperature was less than at 70° F. but better than that at 90° F. temperature. These differences were statistically significant.

In Experiment I (Table II) the diet containing Serpasil resulted in an increased rate of growth of females reared at 90° F. In Experiment II (Table III) the Serpasil resulted in an increased growth rate of females reared at 50° F. Thus in the two cases where a statistically significant increased rate of growth resulted from the use of Serpasil female chicks were involved. At 90° F. and at 50° F. Serpasil retarded the growth of males. This would indicate Serpasil is more effective in promoting growth in females than in males.

In Experiment I (Table II) the 90° F. temperature resulted in the best feed conversion whereas in Experiment II (Table III) the 70° F. temperature resulted in the best feed conversion. No explanation can be given for this difference in the two experiments. In both experiments, the poorest feed conversion was obtained at

TABLE II

THE EFFECT OF ENVIRONMENTAL TEMPERATURE AND TRANQUILIZER ON THE
WEIGHT GAIN AND FEED CONVERSION OF FEMALES CHICKS FROM FIVE
TO TEN WEEKS OF AGE. EXPERIMENT I.

Treatment (5 to 10 wks.)	Average body weight		Average Gain ²	Feed Conversion ³
	Initial (5 wks.)	Final (10 wks.)		
	gms.	gms.	gms.	
90° F.	553.3	1464.5	911.2 ^a	3.16
90° F. + tranq. ¹	557.0	1504.5	947.5 ^b	3.12
70° F.	548.1	1628.4	1080.3 ^c	3.34
50° F.	575.4	1622.0	1046.6 ^d	3.52

¹Serpasil (reserpine Ciba) fed at the rate of 1 lb./ton feed. This supplies 1 ppm. reserpine.

²Means with different superscripts are significantly different at the 1 per cent level of probability as determined by Duncan's Multiple Range Test (1951).

³Pounds feed required per pound gain.

TABLE III

THE EFFECT OF ENVIRONMENTAL TEMPERATURE AND TRANQUILIZER ON
WEIGHT GAIN AND FEED CONVERSION OF CHICKS FROM FIVE
TO TEN WEEKS OF AGE. EXPERIMENT II.

Treatment (5 - 10 wks.)	<u>Average Body Weight Gains</u> ²		Feed Conversion ³
	Males	Females	
	gms.	gms.	
90° F. + tranq. ¹	846.4 ^a	756.6 ^a	3.14
90° F.	989.7 ^b	792.6 ^a	3.02
50° F. + tranq. ¹	1223.3 ^c	1091.5 ^c	3.34
50° F.	1284.4 ^d	1023.8 ^b	3.29
70° F.	1364.9 ^e	1052.2 ^{bc}	2.83

¹Serpasil (reserpine Ciba) fed at the rate of 1 lb./ton feed. This supplies 1 ppm. reserpine.

²Means with different superscripts are significantly different at the 1 per cent level of probability as determined by Duncan's Multiple Range Test (1951).

³Pounds feed required per pound gain.

the 50° F. temperature. The total intake of feed per bird was greatest in the 50° F. group indicating a greater maintenance requirement for the birds kept at this low temperature.

Anomalies. Observations were made on the incidence of perosis in the groups of chicks reared at the various temperatures. (Table IV). Among 180 chicks reared at 90° F. temperature 6 cases of perosis were noted whereas among 220 chicks reared at lower temperatures only one case of perosis was observed. These results suggest that the nutritional requirements of chicks reared at a high temperature may be different from those reared at low temperatures.

Excessive bleeding from minor injuries were observed to be common in chicks reared at the 50° F. temperature indicating an effect of environmental temperature upon the coagulation time of the blood.

Survival Test. The average survival time of the chickens in the 50° F. water bath was 12.8 minutes, 45.1 minutes in the 60° F. water bath, and 12.0 minutes in the 120° F. water bath. The room temperature at which the birds were grown from 5 to 10 weeks of age and supplementation of Serpasil in the feed had no significant effect on the survival time (Table V) at these three water temperatures.

It became apparent that the birds of the different treatment groups were dying after about the same lapse of time following submersion it was felt that possibly this was not the best test of survival as the water coming in direct contact with the skin would

TABLE IV

THE EFFECT OF ENVIRONMENTAL TEMPERATURE AND TRANQUILIZER ON
MORTALITY AND OCCURENCE OF PEROSIS OF CHICKS
FROM FIVE TO TEN WEEKS OF AGE.

Treatment (5 - 10 wks.)	Experiment I		Experiment II	
	Perosis per cent	Mortality per cent	Perosis per cent	Mortality per cent
90° F.	4.0	2.0	2.5	10.0
90° F. + tranq. ¹	2.0	2.0	5.0	5.0
70° F.	0.0	4.0	0.0	0.0
50° F.	2.0	4.0	0.0	5.0
50° F. + tranq. ¹			0.0	2.5

¹Serpasil at the rate of 1 lb./ton of feed.

TABLE V

THE EFFECT OF ENVIRONMENTAL TEMPERATURE AND TRANQUILIZER
ON SURVIVAL TIMES OF CHICKS EXPOSED TO COLD
AND HOT WATER BATHS. EXPERIMENT I

Treatment (5 - 10 wks)	Average Survival Time ²		
	50° F. bath ³	60° F. bath ³	120° F. bath ⁴
	min.	min.	min.
90° F.	14.0 ^a	42.5 ^a	14.1 ^a
90° F. + tranq. ¹	13.5 ^a	46.2 ^a	10.9 ^a
70° F.	12.5 ^a	43.5 ^a	11.4 ^a
50° F.	11.0 ^a	48.2 ^a	11.4 ^a

¹Serpasil fed at the rate of 1 lb./ton of feed.

²Average survival times in each column with similar superscripts are not significant at the 5 per cent level of probability.

³Two birds from each treatment tested.

⁴Four birds from each treatment tested.

tend to eliminate certain possible mechanisms of resistance. It was therefore decided to test survival at high and low room temperatures.

Resistance Tests. After exposure to a room temperature of 110° F. for 165 minutes, the birds reared at 90° F. in Experiment I (Table VI) had an average body temperature of 111.2° F. The birds reared at 50° F. in this experiment had an average body temperature at this time of 113.1° F. The group reared at 70° F. was intermediate with an average body temperature of 111.9° F. The same order of resistance occurred in Experiment II (Table VIII). The group reared at 90° F. had an average body temperature of 110.9° F. after exposure to 110° F. for 150 minutes. The 50° F. group averaged 113.1° F. and the 70° F. groups 111.0° F.

On exposure to a room temperature of 0° F. for 120 minutes, the order of resistance of the three groups was reversed as compared to their resistance to 110° F. In Experiment I (Table VII) the 50° F. group averaged 105.2° F. body temperature, the 90° F. group had an average body temperature of 97.7° F. while the 70° F. group averaged 100.0° F. body temperature. In Experiment II (Table IX) the 50° F. group averaged 105.8, the 90° F. group averaged 102.0° F., while the 70° F. group was again intermediate with an average body temperature of 103.4° F.

These results show that chickens can be conditioned to given environmental temperatures. The chickens reared at 90° F. were better able to resist exposure to high temperature. The chickens

TABLE VI

THE EFFECT OF ENVIRONMENTAL TEMPERATURE AND TRANQUILIZER ON
 BODY TEMPERATURE AND CHICKS EXPOSED TO 110° F.
 ROOM TEMPERATURE. EXPERIMENT I

Treatment (5 - 10 wks.)	Average body temperatures ² (°F)					
	Minutes of exposure					
	0	15	45	90	120	165 ³
90° F.	107.1	107.5	107.9	108.1	109.2	111.2 ^a
90° F.+ tranq. ¹	106.8	107.4	107.9	108.5	109.4	112.4 ^a
70° F.	106.9	107.1	107.2	109.0	110.1	111.9 ^a
50° F.	107.3	107.7	109.0	109.6	111.4	113.1 ^a

¹ Serpasil fed at the rate of 1 lb./ton of feed.

² Four female chicks from each treatment were exposed.

³ Averages in this column with same superscript are not significantly different at the 5 per cent level of probability.

TABLE VII

THE EFFECT OF ENVIRONMENTAL TEMPERATURE AND TRANQUILIZER ON
 BODY TEMPERATURE OF CHICKS EXPOSED TO 0° F.
 ROOM TEMPERATURE. EXPERIMENT I

Treatment (5 - 10 wks.)	Average body temperatures ² (°F)				
	Minutes of exposure				
	0	15	45	90	120 ³
90° F.	106.7	105.7	102.9	99.6	97.7 ^a
90° F. + tranq. ¹	107.4	105.9	102.5	99.0	97.5 ^a
70° F.	106.8	106.3	104.6	102.3	100.0 ^a
50° F.	107.1	106.9	106.0	105.6	105.2 ^b

¹Serpasil fed at the rate of 1 lb./ton feed.

²Four female chicks from each treatment were exposed.

³Averages in this column with different superscripts are significantly different at the 5 per cent level as determined by Duncan's Multiple Range Test (1951).

TABLE VIII

THE EFFECT OF ENVIRONMENTAL TEMPERATURE AND TRANQUILIZER ON
 BODY TEMPERATURE OF CHICKS EXPOSED TO 110° F.
 ROOM TEMPERATURE. EXPERIMENT II

Treatment (5 - 10 wks.)	Average body temperatures ² (°F)					
	Minutes of exposure					
	0	30	60	90	120	150 ³
90° F. + t. ¹	107.7	109.4	109.4	109.5	110.0	110.3 ^a
90° F.	108.0	109.3	109.7	110.0	110.5	110.9 ^{ab}
70° F.	107.5	109.5	109.6	109.9	110.5	111.0 ^{ab} (7)*
50° F.	106.9	109.9	111.4	111.6	113.1(7)*	113.1 ^{bc} (5)*
50° F. + t. ¹	106.7	109.9	110.8	111.2	113.5	114.1 ^c (4)

¹Serpasil fed at the rate of 1 lb./ton of feed.

²Four male and four female chicks from each treatment were exposed.

³Averages in this column with different superscripts are significantly different at the 5 per cent level of probability as determined by Duncan's Multiple Range Test (1951).

*The number of chicks, where less than eight, whose body temperatures were recorded at the designated times are enclosed in the parentheses. Chicks were removed from the exposure test upon death or when their body temperature reached 116° F. and their last recorded temperature was used in subsequent averages for their appropriate groups.

TABLE IX

THE EFFECT OF ENVIRONMENTAL TEMPERATURE AND TRANQUILIZER ON
 BODY TEMPERATURE OF CHICKS EXPOSED TO 0° F.
 ROOM TEMPERATURE. EXPERIMENT II

Treatment (5 - 10 wks.)	Average body temperatures ¹ (°F.)				
	Minutes of exposure				
	0 ³	30	60	90	120 ⁴
90° F. + tranq. ²	107.7	104.4	101.8	99.4	97.8 ^a
90° F.	108.0	104.9	104.0	102.5	102.0 ^b
70° F.	107.5	106.3	105.1	104.1	103.4 ^{bc}
50° F. + tranq. ²	106.7	106.4	106.0	105.5	105.1 ^{bcd}
50° F.	106.9	106.7	106.4	106.0	105.8 ^d

¹Four male and four female chicks from each treatment were exposed.

²Serpasil fed at the rate of 1 lb./ton feed.

³Temperatures in this column were recorded prior to removal of the chicks from their respective treatment temperatures.

⁴Averages in this column with different superscripts are significantly different at the 5 per cent level as determined by Duncan's Multiple Range Test (1951).

reared at 50° F. were better able to resist low temperature. It can also be concluded that adaptation to one extreme of temperature results in a decreased resistance to the opposite extremes, for example, while the birds reared at 90° F. were more resistant to 110° F., they were less resistant to exposure of 0° F. Chickens reared at 50° F. were better able to withstand exposure to 0° F., but were less able to withstand the 110° F. temperature. The high temperature exposure had a more deleterious effect than did the low temperature exposure when measured in terms of body temperature.

Tranquilizer and Resistance. The feeding of a tranquilizer for the 5 weeks period preceeding the exposure test resulted in a decreased resistance to the 110° F. temperature as measured by the rise in the body temperature in two out of three experimental groups.

In Experiment I (Table VI), the average body temperature of the group reared at 90° F. without receiving the tranquilizer was 111.2° F. after exposure to 110° F. for 165 minutes while that of the 90° F. group receiving the tranquilizer was 112.4° F. In Experiment II (Table VIII) the average body temperature after exposure to 110° F. for 150 minutes was 113.1° F. in the group reared at 50° F. as compared to 114.1° F. for the group reared at 50° F. with tranquilizer. In the groups in Experiment II reared at 90° F. with and without tranquilizer the body temperatures were the reversal of those of the first experiment. The 90° F. group with tranquilizer had an average body temperature of 110.3° F. as compared to 110.9° F. for the group reared at 90° F. without tranquilizer.

In Experiment I (Table VII) the group of birds reared at 90° F. when exposed to 0° F. for 120 minutes were able to maintain an average body temperature of 97.7° F. while the group reared at the same temperature receiving tranquilizer had an average body temperature 97.5° F. In Experiment II (Table IX) the difference was considerably greater between these compared groups. The group reared at 90° F. without tranquilizer had an average body temperature of 102° F. while the group reared at this temperature and receiving tranquilizer had a body temperature of only 97.8° F.

In Experiment II (Table IX), the group reared at 50° F. without tranquilizer had an average body temperature of 105.8° F. as compared to 105.1° F. for the group reared at 50° F. and receiving tranquilizer.

Adrenal Glands. While the results are not statistically significant, the data in Table X might be interpreted to indicate that the weights of the adrenal glands of the birds reared at the higher temperature were reduced less by exposure of the birds to the 120° F. water bath than by exposure to the 60° F. water bath. In contrast, the weights of the adrenal glands of the birds reared at the lower environmental temperatures were reduced more by exposure of the birds to a water bath of 120° F. than by exposure to a water bath of 60° F.

The temperatures at which the birds were reared resulted in different, though not statistically significant, average adrenal weights (Table XI). The data indicate that as the environmental temperature either increased above 70° F. or decreased below 70° F.

TABLE X

THE EFFECT OF EXPOSURE OF CHICKS TO HOT AND COLD WATER BATHS
ON THE WEIGHT OF THEIR ADRENAL GLANDS. EXPERIMENT I

Treatment (5 - 10 wks.)	Adrenal weights ¹	
	per bird	per 100 gm. body wt.
120° F. water bath		
	gm.	gm.
90° F.	.0958	.0066 ^a
90° F. + tranq. ²	.0874	.0060 ^a
70° F.	.1016	.0064 ^a
50° F.	.0902	.0053 ^a
60° F. water bath		
90° F.	.0627	.0043 ^b
90° F. + tranq. ²	.0704	.0045 ^b
70° F.	.0976	.0060 ^b
50° F.	.0908	.0058 ^b

¹The average of the combined weights of two glands from each of four chicks.

²Serpasil fed at the rate of 1 lb./ton of feed.

³Averages in this column with different superscripts are significantly different at the 5 per cent level of probability as determined by Duncan's Multiple Range Test (1951).

TABLE XI

THE EFFECT OF ENVIRONMENTAL TEMPERATURE AND TRANQUILIZER ON
THE WEIGHT OF THE ADRENAL AND THYROID GLANDS
OF CHICKS. EXPERIMENT II

Treatment (5 - 10 wks.)	Av. adrenal wt. ¹		Av. thyroid wt. ¹	
	per bird	per 100 gm. of body wt.	per bird	per 100 gm. of body wt.
	gm.	gm. ³	gm.	gm. ³
90° F.	.2122	.0112 ^a	.1563	.0082 ^a
90° F. + tranq. ²	.1651	.0111 ^a	.1557	.0104 ^a
70° F.	.1996	.0106 ^a	.2333	.0125 ^a
50° F.	.2396	.0124 ^a	.2127	.0110 ^a
50° F. + tranq. ²	.2266	.0124 ^a	.2681	.0145 ^a

¹Two adrenal and two thyroid glands were weighed from an average of 10 chicks per treatment group.

²Serpasil fed at the rate of 1 lb./ton of feed.

³Averages in these columns with the same superscript are not significantly different at the 5 per cent level of probability.

an increase in adrenal weight per 100 gm. body weight occurred. It would thus appear that temperature stress results in an enlargement of the adrenal gland.

The determination of ascorbic acid content of the adrenal glands of the birds subjected to various rearing temperatures shows that the extremes of temperature resulted in adrenals which were not only possibly larger in average size but had a greater concentration of ascorbic acid per unit of material (Table XII). This indicates that the larger size of the adrenal glands of the birds subjected to temperature stress can be partially attributed to a larger content of ascorbic acid.

Experiment III

Ascorbic Acid Supplementation. The average body weights of the chickens fed diets containing three levels of ascorbic acid supplementation (Table XIII) were not statistically significant, however, the average weight of chicks receiving the larger amounts of ascorbic acid in the feed was smallest. The weights of the birds reared at 70° F. were significantly heavier than those reared at 90° F.

While the average body temperatures of the birds fed different levels of ascorbic acid were not statistically different after exposure to 110° F. room temperature or to 0° F. room temperature, there was an indication that ascorbic acid may be an important factor in the ability of the bird to resist exposure to cold. Especially

TABLE XII

THE EFFECT OF ENVIRONMENTAL TEMPERATURE AND TRANQUILIZER ON
THE ASCORBIC CONTENT OF THE ADRENAL GLANDS OF CHICKS.
EXPERIMENT II

Treatment (5 - 10 wks.)	Ascorbic Acid		
	per bird	per 100 gm. body wt.	per 100 gm. of adrenal tissue
	mgm.	mgm.	mgm.
90° F.	.19	.0118	100.1
90° F. + tranq. ¹	.13	.0085	84.0
70° F.	.14	.0071	77.9
50° F.	.23	.0199	103.3
50° F. + tranq. ¹	.21	.0182	97.4

¹Serpasil fed at the rate of 1 lb./ton of feed.

TABLE XIII

THE EFFECT OF ASCORBIC ACID SUPPLEMENTATION ON THE BODY
WEIGHT GAINS OF CHICKS AT TWO REARING TEMPERATURES
FROM FIVE TO TEN WEEKS AGE. EXPERIMENT III

Rearing temp. (5 - 10 wks.)	Average gains in body weights ¹ (gms.)			
	<u>Mgm. ascorbic acid/gm. feed</u>			
	0	1/2	1	Av.
90° F.	513.8	474.0	449.0	478.9 ^a
70° F.	577.4	587.7	556.9	574.0 ^b
Av.	545.6 ^a	530.8 ^a	502.9 ^a	

¹Averages within each row or column with different superscripts are significantly different at the 5 per cent level of probability as determined by the analysis of variance and the F test.

it might be true that ascorbic acid supplementation may be of value in increasing resistance of a non-adapted bird upon exposure to cold (Tables XIV and XV). The body temperatures of the birds reared at 90° F. temperature were significantly lower than those reared at 70° F. temperature after exposure to 0° F. room temperature for 120 minutes (Table XIV). The body temperature of the birds reared at 70° F. were significantly higher than those reared at 90° F. temperature after exposure to 110° F. for 120 minutes (Table XV).

TABLE XIV

THE EFFECT OF ASCORBIC ACID ON THE BODY TEMPERATURE OF
CHICKS EXPOSED TO 0° F. ROOM TEMPERATURE
EXPERIMENT III

Treatment (5 - 10 wks.)		Average body temperature ¹ (°F.)				
Rearing temp.	Mgm. ascorbic acid/gm.	Minutes of exposure				
		0	30	60	90	120 ²
90° F.	0	108.0	104.0	101.3	97.3	93.3 ^a
	$\frac{1}{2}$	107.6	103.6	101.5	98.6	95.2 ^a
	1	107.7	103.2	100.7	96.6	94.2 ^a
70° F.	0	107.4	103.6	100.7	99.0	97.3 ^b
	$\frac{1}{2}$	107.4	104.4	102.3	100.2	99.0 ^b
	1	107.0	105.1	103.0	101.4	100.5 ^b

¹ Average of five birds per group.

² Averages in column with different superscripts are significantly different at the 5 per cent level of probability as determined by Duncan's Multiple Range Test (1951).

TABLE XV

THE EFFECT OF ASCORBIC ACID ON THE BODY TEMPERATURE OF
CHICKS EXPOSED TO 110° F. ROOM TEMPERATURE
EXPERIMENT III

Treatment (5 - 10 wks.)		Average body temperature ¹ (°F.)				
Rearing temp.	Mgm. ascorbic acid/gm.	Minutes of exposure				
		0	30	60	90	120 ²
90° F.	0	108.0	109.2	110.9	112.0	112.9
	$\frac{1}{2}$	107.6	108.3	110.2	111.7	112.3
	1	107.7	108.8	111.6	113.6	114.2
70° F.	0	107.4	109.0	111.6	114.2	114.9
	$\frac{1}{2}$	107.4	109.4	111.5	114.0	115.0
	1	107.0	109.3	111.3	114.0	115.0

Rearing temp.	Body temp. (°F)	Mgm. ascorbic acid/gm. feed	Body temp. (°F.)
90° F.	113.1 ^a	0	113.9 ^a
70° F.	115.0 ^b	$\frac{1}{2}$	113.7 ^a
		1	114.6 ^a

¹ Average of five birds per group.

² Averages in each column with different superscripts are significant at the 5 per cent level of probability as determined by the analysis of variance and the F test.

SUMMARY

A total of 650 chickens was involved in a series of three experiments designed to study the relationships of rearing temperatures and of certain feed additives to the development of resistance to extremes of environmental temperatures.

When exposed to a room temperature of 110° F., chickens reared five to ten weeks of age at 90° F. were able to maintain the lowest body temperature while chickens reared at 70° F. were intermediate in this respect and those reared at 50° F. had the highest body temperature.

When exposed to a room temperature of 0° F. chickens reared at 90° F. were least able of the three groups to maintain a normal body temperature; chickens reared at 70° F. were intermediate and chickens reared at 50° F. were best able to maintain a body temperature near normal.

Serpasil increased the growth rate of female chickens. Evidence was obtained that the tranquilizer interfered with the adaptation of chickens to extremes of temperatures when fed over a prolonged period of time.

The growth rate of chickens from 5 to 10 weeks of age was best at a room temperature of 70° F., slightly less at 50° F. and poorest at 90° F.

The relationships of adrenal size, ascorbic acid content of the adrenals, and the level of ascorbic acid in the feed to the ability of chickens to resist temperature extremes were studied.

The results indicate that temperature extremes tend to cause adrenal enlargement and this enlargement is partially due to a greater content of ascorbic acid. Ascorbic acid feed supplementation appears to be more effective in increasing resistance of the chicken to a cold temperature than to a hot temperature.

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APPENDIX

ANALYSIS OF VARIANCE¹ OF BODY WEIGHT GAINS IN TABLE II

Source	Degrees of freedom	Sum of squares	Mean square	F
Total	187	3426649.1		
Treatment	3	903220.0	301073.3	22.0**
Error	184	2523429.1	13714.3	

**Significant at the 1 per cent level of probability.

¹Snedecor (1956).

ANALYSIS OF VARIANCE¹ OF BODY WEIGHT GAINS IN TABLE III

Source	Degrees of freedom	Sum of squares	Mean square	F
Total	154	11030592.6		
Treatment	4	4389349.0	1097337.3	32.44**
Sex	1	1486963.5	1486963.5	43.96**
Sex X treatment	4	249951.9	62488.0	1.85
Error	145	4904329.6	33823.0	

**Significant at the 1 per cent level of probability.

¹Snedecor (1956).

ANALYSIS OF VARIANCE¹ OF SURVIVAL TIMES, IN TABLE V,
OF CHICKS EXPOSED TO WATER BATHS

50° F. water bath

Source	Degrees of freedom	Sum of squares	Mean square	F
Total	7	17.5		
Treatment	3	10.5	3.5	2.0
Error	4	7.0	1.8	

60° F. water bath

Source	Degrees of freedom	Sum of squares	Mean square	F
Total	7	473.2		
Treatment	3	72.4	24.1	0.23
Error	4	420.9	105.2	

120° F. water bath

Source	Degrees of freedom	Sum of squares	Mean square	F
Total	15	596343.8		
Treatment	3	94513.3	31504.4	.75
Error	12	501830.5	41819.2	

ANALYSIS OF VARIANCE¹ OF BODY TEMPERATURES IN TABLE VI

Source	Degrees of freedom	Sum of squares	Mean square	F
Total	15	81.3		
Treatment	3	8.3	2.8	0.4
Error	12	73.0	6.1	

¹Snedecor (1956).

ANALYSIS OF VARIANCE¹ OF BODY TEMPERATURES IN TABLE VII

Source	Degrees of freedom	Sum of squares	Mean square	F
Total	15	246.2		
Treatment	3	155.7	51.9	6.87**
Error	12	90.6	7.6	

**Significant at the 1 per cent level of probability.

¹Snedecor (1956).

ANALYSIS OF VARIANCE OF BODY TEMPERATURES IN TABLE VIII

Source	Degrees of freedom	Sum of squares	Mean square	F
Total	39	283.1		
Treatment	4	82.5	20.6	3.82*
Sex	1	13.2	13.2	2.45
Sex X treatment	4	25.6	6.4	1.19
Error	30	161.8	5.4	

*Significant at the 5 per cent level of probability.

ANALYSIS OF VARIANCE¹ OF BODY TEMPERATURES IN TABLE IX

Source	Degrees of freedom	Sum of squares	Mean square	F
Total	39	504.9		
Treatment	4	326.8	81.7	31.7**
Sex	1	33.7	33.7	13.1**
Treatment X sex	4	66.9	16.7	6.5**
Error	30	77.5	2.6	

**Significant at the 1 per cent level of probability.

¹Snedecor (1956).

ANALYSIS OF VARIANCE¹ OF WEIGHTS OF ADRENAL GLANDS IN TABLE X

Source	Degrees of freedom	Sum of squares	Mean square	F
Total	31	59.4		
Env. temp.	3	4.2	1.4	0.88
Bath temp.	1	7.1	7.1	4.44*
E. temp. X bath temp.	3	9.2	3.1	1.94
Error	24	38.9	1.6	

*Significant at the 5 per cent level of probability.

¹Snedecor (1956).

ANALYSIS OF VARIANCE¹ OF WEIGHTS OF ADRENAL AND THYROID
GLANDS IN TABLE XI

Adrenal glands

Source	Degrees of freedom	Sum of squares	Mean square	F
Total	24	91.6		
Treatment	4	10.6	2.6	0.6
Error	20	81.0	4.1	

Thyroid glands

Source	Degrees of freedom	Sum of squares	Mean square	F
Total	24	345.8		
Treatment	4	102.4	25.6	2.10
Error	20	243.4	12.2	

¹Snedecor (1956).

ANALYSIS OF VARIANCE¹ OF BODY WEIGHT GAINS IN TABLE XIII

Source	Degrees of freedom	Sum of squares	Mean square	F
Total	59	431826.9		
Ascorbic acid	2	18766.6	9383.3	1.88
Temperature	1	135565.0	135565.0	27.11**
Temperature x acid	2	7510.3	3755.1	.75
Error	54	269985.0	4999.7	

**Significant at the 1 per cent level of probability.

¹Snedecor (1956).

ANALYSIS OF VARIANCE¹ OF BODY TEMPERATURES IN TABLE XIV

Source	Degrees of freedom	Sum of squares	Mean square	F
Total	29	406.4		
Ascorbic acid	2	24.2	12.1	1.42
Temperature	1	167.57	167.6	19.62**
Ascorbic acid x temp.	2	9.57	4.8	0.56
Error	24	205.1	8.5	

**Significant at the 1 per cent level of probability.

¹Snedecor (1956).

ANALYSIS OF VARIANCE¹ OF BODY TEMPERATURES IN TABLE XV

Source	Degrees of freedom	Sum of squares	Mean square	F
Total	29	109.8		
Ascorbic acid	2	4.7	2.4	0.75
Temperature	1	25.4	25.4	8.11**
Temp. x ascorbic acid	2	4.5	2.3	0.72
Error	24	75.2	3.1	

**Significant at the 1 per cent level of probability.

¹Snedecor (1956).