THE EFFECTS OF HIGH ENVIRONMENTAL TEMPERATURE ON PERCENTAGE PRODUCTION, EGG SIZE, EGG QUALITY, AND FEED EFFICIENCY OF DOMESTIC FOWL

by

ARTHUR RHENIUS SELLAKUMAR

B.V.Sc., University of Madras, Madras, India, 1961

A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Poultry Science

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1964

Approved by:

Paul E. Sanford

Major Professor

TABLE OF CONTENTS

INTRODUCTION

Biologists have long recognized that climatic environments have a profound effect on growth, reproduction and other functions of both plants and animals. Daily and seasonal fluctuations in temperature, light, humidity, air movements, solar radiation and other reactions from outer space are such that it is almost impossible to characterize a "normal development".

Normal hens have a body temperature of 105°F. to 109°F. Since they are covered with feathers, which hold body heat, and since they have no sweat glands to help carry away heat, hens have a hard time adjusting to high temperatures that prevail during summer months. They also suffer when they get too cold, but the suffering is not so great as when the temperature is too high.

It is a well known fact that seasonal changes occur in both the quality and quantity of eggs produced by the hen. There are numerous reports in the literature to support this. The influence of high ambient temperature affects the well being and performance of laying hens. High summer temperatures are known to cause a decrease in egg production. High environmental temperature is the cause for reduction in egg shell quality, which is of considerable economic importance to the poultry industry because of excess breakage and lowered hatchability. Voluminous research has been initiated to ascertain and alleviate the causative factors of inferior shell quality, especially during the critical summer months.

Even though nutritional, genetic, hormonal, disease factors, and management practices have been shown to influence egg shell quality, the high environmental temperature has a definite effect in decreasing the interior quality of the egg, especially the albumen. It has been demonstrated there is a decline in albumen quality when the pullet or hen is held under a controlled air temperature.

When there is a rise of air temperature, the adverse effect of high ambient temperature on feed consumption and body weight of laying hens is clearly illustrated. Both body weight and feed consumption progressively decreased as temperature increased. Unless there is some means of controlling the bird's environment, it is impossible to maintain the quantity and quality of the eggs.

The purpose of this report is to review the literature concerning the high environmental temperature that affects the production, quality of the egg and the feed intake of the bird.

REVIEW OF LITERATURE

Responses of Laying Hens to High Temperature

The body temperature of cold blooded animals (poikilotherms) varies with environmental temperature, but that of warm blooded mammals and birds (homeotherms) is largely dependent of environmental temperature. The activity of poikilothermal animal is influenced greatly by environmental temperature. In cold weather, such animals and birds have well developed temperature regulating mechanisms which enable them to maintain constant body temperature, and to function under varying environmental temperatures.

Galineo (1955) reported many animals, including birds, apparently undergo seasonal modification of their response to environmental temperature change.

There are numerous reports in the literature that deal with the influence of high ambient temperature on the well being and performances of laying hens. Sturkie (1954) reported the average body temperature of birds is higher than that of mammals, ranging from approximately 105°F. to 111°F.; depending on species. Results obtained by Lee et al. (1945) with Leghorns and Australorps showed that most hens were able to withstand a seven hour exposure to air temperature of 105°F., but none were able to withstand 110°F. Wilson (1948) found it impossible to keep Leghorn hens alive for more than six hours under air temperature of 105°F. Heat waves with intensities ranging from 100° to 105°F. have been reported by Fox (1951) to cause heavy losses of laying flocks in the middle Atlantic and New England States. On the other hand, Hutchinson and Sykes (1953) observed that in Izatnagar, India, where maximum temperatures over 110°F. are frequently recorded, and where many fowls of European breeds are kept along with indigenous birds, heat stroke is not a serious loss to poultry raisers. Kheireldrin and Shaffner (1954) reported exposing growing birds to extremely high environmental temperature for short periods of time depressed growth rate. They observed that families which had the highest growth rate were best able to withstand the treatment, and concluded that heat tolerance is genetically influenced.

Hutchinson (1954) found that non-laying hens should withstand heat stress better than layers on the theoretical basis that their metabolism and heat production are lower. Weis and Borbely (1953) reported that White Leghorns maintained in an average environment, which fluctuated with outside temperature, survived exposure to 105°F. and 70 per cent R. H. better in the summer than in the winter. All 8 of a winter series expired in an average of 127 minutes. Whereas, 2 out of 10 in the summer series survived 4 hours. The 8 that died did so at an average of 190 minutes. This seasonal adaptation of the birds during summer was associated with a slow rise of body temperature and higher rates of respiration.

Family differences due to the effect of sires and dams in tolerating high temperature were found to exist. Kheireldrin and Shaffner (1957) noted there is evidence of dam and sire family differences, within the New Hampshire breed, in tolerating high environmental temperature. Mueller (1961) reported that using performances at 55°F. as a basis for comparison a constant temperature of 90°F. increased mortality by 14 per cent.

Influence of High Environmental Temperature on Egg Production

Egg laying is subject to the influence of various internal and external factors. It is, in large measure, controlled by the individual bird's heredity; it also is largely dependent upon her physiological efficiency and metabolic activity. These, in turn--although inherited to a certain extent--may be profoundly affected by many environmental circumstances.

Investigations of the seasonal variations of egg production in different geographic locations have led to the conclusion that high environmental temperature is one of the major causes of the decline in egg production during summer. In most of these studies, it was difficult to separate the effect of age from the effect of seasonally changing environment.

Warren et al. (1950) found little differences in annual egg production between an uncontrolled environment, where the mean daily temperatures ranged from about 30°F. in winter to about 85°F. in summer, and a controlled environment, where a constant temperature of 65°F. was maintained. Goodman (1952) pointed out that in New York State well insulated houses offered sufficient protection so that low outside temperatures in winter did not adversely affect egg production in White Leghorns. Peterson et al. (1957) reported that egg production was not influenced by energy level, but production was improved when the house temperature was controlled. Wilson et al. (1957) observed that within the range of 48° to 85°F., egg production was not reduced by variation in temperature.

Ota (1956) obtained data on Rhode Island Red hens held under various controlled temperatures with constant humidity. These data showed that a house temperature of 45 degrees was satisfactory for egg production, and that egg production was lower when the temperature was either 23 degrees or 37 degrees. From the stand point of economy in production, a house temperature of 45 degrees seemed preferable.

Huston et al. (1957) reported that White Leghorn hens laid as well at a constant temperature of 90°F. as hens kept in an environment where mean daily temperature ranged from 42.6°F. to 62.5°F. Long et al. (1958) reported 55°F. to be the optimum temperature for efficient egg production.

Glick et al. (1959) observed egg production and fertility were highest when the mean high temperature was approximately 70°F. as compared to 80°F. Squibb (1959) reported there were no significant differences in egg production, feed consumption, mortality, body weight and egg size between hens housed in the tropical low lands and hens housed in cooler mountain areas of Gautemala. In a later experiment at New Brunswick, N. J. Squibb *et al*. (1959) found that White Leghorns housed in air environment where maximum temperatures reached 106°F. laid as well as hens housed in an environment where temperatures did not exceed 77°F. They concluded from these two experiments that wide diurnal temperature ranges may produce the stress imposed on hens by extreme maximum temperatures. Hayes (1958) reported that egg production of all stocks declined in December, January and February.

Mueller (1961b) reported that using the performances at 55°F. as a basis for comparison, a constant temperature of 90°F. decreased egg production by 22 per cent, increased mortality 14 per cent and decreased feed consumption, egg weight and shell thickness 32, 15 and 10 per cent, respectively. A 24 hour exposure to 100°F. using a fast rise (4°F./hour) and a slow rise (5°F./day) in air temperature was found to cause a sudden equally severe, temporary drop in egg production of Rhode Island Red and one strain of White Leghorn, but no effect on the egg production of New Hampshire and other strains of Leghorns (Campos *et al*., 1960).

Howes (1961) allocated two rooms at random to each of six constant temperature 50, 60, 70, 80, 90, 100°F. (± 2°F.), and kept the birds in cages. Egg production, body temperature, mortality, egg weight, etc. were recorded together with the outside environment and the environment in the fan ventilated house. The pullets in the 50° and 100°F. chambers laid at 60 per cent during the first month, but the ensuing rate of lay increased in the 50°F. chambers and declined in the 100°F. chambers.

Definition of Egg Quality

Quality may be defined as the inherent properties of a product which determines its degree of excellence. Those conditions and characteristics which consumers want and for which they are willing to pay are in a broad sense factors of quality. The quality of an egg is determined by comparing a number of factors. However, the relative merit of one factor alone may determine the quality score of the egg in as much as the final quality score can be higher than the lowest score given to any of the quality factors.

The quality factors may be divided into two general groups: exterior quality factors apparent from external observation, and interior quality factors which involve the contents of the shell.

As stated in the introduction, the initial quality of an egg can be affected by many factors such as environmental conditions, management, feed, breeds, diseases, the condition of the hen, and others. However, the quality of the egg will be lowered significantly, especially in summer temperatures.

Effect of High Environmental Temperature on Exterior and Interior Quality of Eggs

Size. Egg size is determined by the weight because it measures the quantity received by the buyer. Environmental factors greatly influence production characteristics of chickens. In order to provide a year around uniform supply of eggs for food, hatching and for broiler industry, many of the hatchery egg producers are starting several lots of pullets each year. However, many producers who have tried out of season hatched pullets disliked them because they observed that not only was the average egg weight lower, but the period of laying small eggs was greatly prolonged.

Jeffery and Platt (1941) found that, in the White Leghorn, the date of hatch had a pronounced effect on egg weight. They pointed out that high temperatures tended to reduce egg weight. They found that if most of the out of season hatched birds had not reached large egg size before hot weather began, that birds tended to continue to lay small eggs over a prolonged period. Skoglund et al. (1951) reported that exposing birds to high temperature tended to reduce egg weight. Information on the subject has so far been gained by studies in natural climates or in artificial climates where the temperature has been the same during day and night time. It is uncertain as to how far effects of climate have been due to high average, and as to how far due to high maximum temperature.

Warren et al. (1950) observed that in the hotter summers egg size was depressed by temperature. If the hens were not subjected to high summer temperatures, egg size increased through out the entire first laying year. Rosenberg and Tanoka (1951) have suggested that in tropical climates, where the seasonal variation of temperature is small and where high maximum temperatures are not encountered, the effect of climate on egg size may be small.

Hutchinson (1954b) found that short daily periods of extreme heat stress, ranging in length from 107 to 214 minutes, would reduce weight. The reduction was greater when the birds were kept continuously in a warm climate of 85°F. day and night or 90°F. during day and 80°F. at night.

Using Fayomi and Baladi fowls, Ragal and Assem (1953) showed fluctuations that occurred in egg yield and size in the different months of the year were mainly due to both atmospheric temperature and light. Wilson and Woodward (1957) reported that hens went out of production when they were kept in darkness. However, after 5 weeks of continuous darkness, the egg production rate was about 20 per cent, thus indicating that darkness does not entirely inhibit production.

Huston et al. (1957) observed that egg weight was reduced more significantly in New Hampshire and White Plymouth Rock than in White Leghorn. Froning and Funk (1958) reported that egg size was lowest in July. During November to January, egg weight was increased in caged birds. Glick et al. (1959) observed that temperature control had a favorable effect on egg weight during warm periods.

Cunningham et al. (1960) reported that egg weight varied markedly with season, tending to be larger in the spring and smaller during periods of high temperature. Mueller (1961a) reported that pullets kept in an environment where temperature cycled from 55°F. to 90°F. and back to 55°F. every 24 hours produced eggs with low quality of shell and reduced egg weight, but significantly better than in the constant 90°F. environment. Mueller further observed that using the performances at 55°F. as a basis for comparison; a constant temperature of 90°F. decreased egg size by 15 per cent. Hurtwitz and Griminger (1962) reported that seasonal variations in egg production and egg weight were observed under field conditions, but not in the temperature controlled environment, where egg production decreased and egg weight increased during most of the experimental period.

Shell Quality. Defects in the shells of eggs are a serious problem to the producers and the distributors, and are even of concern to the housewife. Characteristics such as roughness, mottling and non-typical shape are objectionable, but the most serious problem is thinness of the egg shell since the condition results in economic loss because of breakage.

It has been shown that egg quality is influenced by seasons, especially summer temperature. High environmental temperatures reduced the thickness of the chicken's egg shell, thereby reducing its breaking strength. The usual pattern followed is a gradual thinning of the shell, which is initiated during the spring months, and becomes progressively worse as the temperature increases. When the atmosphere cools, there is a return toward normal thickness.

That environmental factors have an effect on shell thickness was first demonstrated by Kansas workers who showed many years ago that temperatures over 70°F. resulted in a decrease of egg shells of birds held under such an environment compared with others held at lower temperatures.

Romanoff (1943) used small segments of shells to determine egg shell permeability and showed that rate of gas transmission through the shell portions was influenced by environmental temperatures and humidity. The hens and pullets held under controlled air temperature showed a striking reduction in thickness of their shells when subjected to 90°F. Their results also suggested that high humidity tends to accentuate the depressing effects of high temperature on shell thickness. Romanoff and Romanoff (1949) reported that shell thickness decreased from March to September.

Warren *et al.* (1950) observed that summer temperature tended to reduce shell thickness. Baker and Curtiss (1957) showed that specific gravity and shell thickness declined from February to July, while egg shell mottling increased during the same period. Froning and Funk (1958) announced that warm temperature had an adverse effect on shell thickness, and that recovery in fall was not sufficient to bring the thickness back to the original level observed in May.

It has been common knowledge for years that eggs laid during the hot summer months generally have thinner more fragile shells than have those laid during cool months. As temperature goes up from 70° to 90°F., blood calcium levels drop and shells become thinner. Since feed consumption drops in hot weather, the calcium intake suffers. Many workers tried to increase the level of vitamin C or D in order to increase the thickness of the shell during the summer months, but their effect on improving the egg shell quality is questionable.

Berg *et al.* (1951) found that increasing the level of calcium in the ration from 2.25 per cent to 2.625 per cent to 3.0 per cent, with the vitamin D content of the ration maintained at 450 A.O.A.C. units per pound of feed, did not prevent the normal seasonal decline in egg production, shell thickness or shell smoothness. Likewise, increasing levels of vitamin D from 450 to 900 A.O.A.C. units, when calcium was maintained at a level of 2.25 per cent of the ration, did not alter the seasonal decline in performance. When both the calcium and vitamin D were simultaneously increased in amounts, no improvement in performances of the birds was recorded. Berg *et al.* (1947) and Couch and Coworkers (1947) found the

National Research Council recommended levels of calcium (2.25 per cent) and vitamin D (450 A.O.A.C. units) supplementation in the ration continuously would promote as satisfactory shell quality as could be obtained by feeding higher levels of these feed components. However, the N.R.C. recommended levels have not been able to prevent the seasonal decline in shell quality.

Huston (1958) observed a decline from a high of 1.086 specific gravity in December to a low of 1.071 in June. Specific gravity declined in both; however, the decline was more rapid at the high temperature. Mueller (1959) concluded that reduction in shell thickness at high air temperature and humidity was not due to the coincident lowering of feed intake and serum calcium levels.

Jenkins and Tyler (1960), in a critical study of the failure of a long term calcium and phosphorus balance experiment with laying hens, found that shell thickness decreased in summer owing to the high temperature and they have shown this effect also occurred in the second and third laying seasons. It has been suggested that when birds come into lay there are inherent metabolic factors which results in ever increasing shell thickness but their effect gradually diminishes as the season progresses.

Fromm (1960) reported that environmental temperature of eggs affected permeability of the shell; however, the opposite of the influence of humidity on permeability were found at high and low temperatures. The influence of season has no effect on shape index, but affects of shell quality were shown by Mueller et al. (1960). Campos et al. (1960) showed a drop in shell thickness which was more pronounced under gradual than under fast rises in air temperature.

Mueller (1961b) reported that high environmental temperature is one of the major causes of declining shell quality. He further showed that pullets kept in an environment where temperature cycles from 55°F. to 90°F. and back to 55°F., showed a significant lower quality of shells than produced by pullets maintained in the constant 55°F. environment. Mueller (1961a) found that using the performances at 55°F. as a basis for comparison, a constant temperature of 90°F. decreased shell thickness by 22 per cent.

Huston and Carmon (1961) found that birds maintained in a variable environmental temperature laid eggs which had a higher specific gravity than eggs laid by birds held at a high constant temperature (90°F.). The decline in specific gravity was related to environmental temperature and age of the hen.

Fromm (1963) reported several factors contributed to variability in permeability of the shell, after the egg is laid, some of which are ambient temperature, humidity, abrasion of the shell and washing the egg.

Mather _et al_. (1961) conducted histological studies to determine the possible structural changes in the egg shell matrix. At the lower environmental temperature, there was a significant negative correlation between egg shell and matrix thickness. When the birds were subjected to the higher temperature this relationship was reduced. The reduction in shell thickness at high temperatures may also be explained on the basis of reduced thyroid activity, for the secretions of this gland are involved in calcium metabolism.

Since the normal body temperature of birds is higher (7-9°F. for the chicken) than that of mammals, and since birds have no sweat glands to aid in heat dissipation, it is of interest to estimate thyroxine secretion rate as an indication of thyroid function of birds under high environmental temperatures. It is generally assumed that rate of thyroid hormone secretion is an important factor in egg production. Such a relationship is indicated by the results of experiments with thyroactive substances (Sturkie, 1954).

Brooker and Sturkie (1950) reported that pullets laying four egg sequences had higher thyroxine secretion rates than pullets laying two egg sequences. The relationship between thyroid weight and body weight of growing chickens was studied by Schiltze and Turner (1945), who found a positive correlation between two characteristics. Brooker and Sturkie (1950) on the other hand, stated that with mature birds of the same breeds and age there was no close relationship between body and thyroid weight. They reported that thyroids of chickens were larger in winter than in summer. Turner (1948) found that thyroxine secretion rates of two year old White Leghorn hens were lower in May than in January or March. Hoffman and Shaffner (1950) reported that seven week old New Hampshire cockerels, which were kept for three weeks at 45°F., had higher thyroxine secretion rates and higher acinier cells than cockerels kept at 74° to 88°F.

Pipes et al. (1958) described radio iodine methods for the in vivo determination of individual thyroxine secretion rates. Thus it becomes possible to correlate thyroxine secretion rates of individual pullets with their egg production and other individual characteristics.

It has been shown that thyroxine secretion rate (TSR) of fowl increases during the winter months (Stahl and Turner, 1961). Stahl et al. (1961) reported that adjustments of many birds to a low environmental temperature by an increase in TSR is a slow process and the winter environments in

Missouri do not enable fowls to express fully their potential capacity for maximum thyroxine secretion rate. Miller et al. (1962) made an investigation to determine the affect of thyroxine on the laying hen and subsequent egg production. Different levels of thyroxine injections were made into normal and radio thyroid erecticized hens. They observed the cessation of thyroxine injection in radio erecticized caused the bird to go out of production within four weeks. Excessive levels of thyroxine injections caused the pullets to stop laying and develop a rapid molt.

Albumen Quality. Many workers reported that interior quality of the egg decreases when the environmental temperature increases. It is known that shell and albumen quality decreased considerably more than the yolk showing that the oviduct is more sensitive to high environmental temperature than the ovary.

The lowering of interior quality of hen's eggs beginning with March or April and continuing through summer has been noted by many workers. Lorenz and Newlon (1944) in a survey of ranges in California, reported that a significant seasonal trend existed in egg quality and attributed this in part to the advancing age of the flock, and in part to changes in environmental conditions. Warren et al. (1950) also observed a marked decrease in albumen quality as season progressed. They observed a decline in albumen quality of eggs produced by hens both in controlled and non-controlled environments, and concluded the cause was due to factors within the bird, and not to external environmental factors.

Sauter et al. (1954) considered both season and aging of the hen as seasonal variation. They reported a definite seasonal decline in egg quality with winter eggs being superior to summer eggs. King and Hall (1954) reported the seasonal decline in quality was very consistent from year to year and strain to strain. From the 11,870 eggs sampled at the New York random sample test, they observed 65 per cent of the December eggs were graded AA, and only 20 per cent of the June eggs were graded AA. Mueller et al. (1951) reported that albumen quality was highest for pullets under controlled temperature and light conditions. Strain and Johnson (1956) observed that albumen quality differed significantly between strain and hatches in three periods with a strain hatch interaction in October. Specific gravity differed between strains and hatches with a strain hatch interaction early in the season, but only the strain differences were significant in February and June.

Grott (1956) reported a general decline in Haugh units throughout the year of eggs produced both by floor and caged layers. Froning and Funk (1958) also observed no significant differences in egg quality between cage layers and their sisters on the floor.

Seasonal variations in Haugh units were found to be significant at the one per cent level. No seasonal trend was indicated in the per cent of thick albumen throughout the experiment. The per cent of thick albumen was consistently higher in caged layers. Huston (1958) reported that albumen quality was not affected by temperature difference, but there was a decline with age of the birds.

Cunningham et al. (1960b) observed that season had more pronounced effect on the amount of calcium and sodium in egg white than age; however, aging had more effect on the amount of chlorine, phosphorus, and protein than season.

May and Stadelman (1960) reported that season significantly influenced egg contents, weight, albumen height, Haugh units, grams of protein per egg, and in one case per cent moisture and per cent protein of dry egg.

Cunningham et al. (1960a) observed that total volume of albumen and yolk varied with season and age of the bird. As the birds advanced in age the per cent yolk per egg increased. The decline in Haugh units was due entirely to aging of the bird. No seasonal differences were noted. The yield of albumen solids per egg tended to be higher during March and April. It was greater in eggs produced by older birds.

Campos et al. (1961) reported that 24 hour exposure to 100°F., using a fast rise (4°F./hour), and a slow rise (5°F./day) in air temperature, was found to cause an appreciable increase in albumen quality of eggs laid with fast and a lesser extent, with slow rises in temperature. Huston and Carmon (1961) observed that birds kept under individual laying cages in a controlled temperature maintained at 90°F., showed no significant differences in albumen quality.

Blood and Meat Spot Occurrence. Blood spots in chicken eggs represent a serious loss to the poultry industry. The reduction or elimination of blood spots presents a complex problem involving genetic, nutritional and environmental factors. Blood spots and meat spots are one of the most serious obstacles to the marketing of high quality eggs. Loss is due not only to eggs candled out in grading, but also to possible decreased consumer demand because of the effects on the consumer of blood spots overlooked in grading. The importance of blood spots as a factor in consumer demand was brought out by Stadelman (1950). Results of a survey showed that 7 per cent of all consumer complaints about egg quality concerned blood and meat spots. Dawson (1955) reported the blood spots problem is a costly one. Egg producers in Michigan are also penalized over a million dollars per year because of blood spots removed by candling.

Blood spots are caused by rupture of a blood vessel in the follicle at the time of ovulation. Meat spots are caused by bits of tissue being sloughed off the oviduct or may sometimes be the result of blood spots which have lost their bright red color. Brown shelled eggs have more tendency to have colored meat spots than do white shelled eggs. Eggs containing meat spots of any reasonable size should be considered as loss and large blood spots also should be considered as loss.

Seasonal variation in the incidences of blood spots has been reported several times. Lerner and Smith (1942) found significant seasonal differences with a definite increase after April first. Lerner and Taylor (1947) found an increasing incidence of blood spots until June followed by a decrease through September. A similar, though not identical trend was reported by Sharma (1949). Nalbandov and Carol (1944) reported a definite increase in blood spots from December through July.

Jensen et al. (1952) reported the per cent of blood spots detected by candling increased with age of the eggs, when stored up to about 10 days at 36°F. Using white eggs, about 40 per cent of total blood spots or about 75 per cent of red and large blood spots could be detected. Warmer storage temperature made it possible to detect the higher per cent in shorter time. Increases were noted through the seventh day of storage at

55°F. and through the fifth at 72°F. Sauter et al. (1952) reported there was definite and statistically significant seasonal variation in the incidence of blood spots. Percentage of total eggs having blood spots were lowest at the start of observation in December.

McClary and Bearse (1954) reported that genetic correlations have been calculated for egg shell thickness and per cent blood spot relationship for families. Results indicated that among S. C. White Leghorn strains studied, a positive genetic correlation of about .44 exists between egg shell thickness and per cent blood spots.

Stiles and Dawson (1959) observed eggs from birds receiving continuous light had a significantly higher blood spots incidences than eggs from birds receiving 14 hours of light per day. Eggs laid by birds given 15 minutes intermittent light and darkness had a slight increase in blood spot incidences, none of the treatments had any noticeable effect on meat spot incidences. Amer (1961) observed the frequency of both meat and blood spots was higher in Fayomi. The percentage of blood and meat spots was smaller than in Fayomi ones. On the other hand, Leghorn eggs contained the smallest per cent of both meat and blood spots.

Benjamin et al. (1960) reported that summer temperature conditions caused the quality defect termed heat spots. In fertile eggs the development of the embryo may have started, but no blood has yet appeared. A reddened spot appears on the yolk when candling. When the egg is opened the affected area of the yolk usually seems transparent, a condition brought about by the movement of water from the white into the yolk.

Effect of High Environmental Temperature on Feed Intake

When the environmental temperature increases, feed intake decreases in layers. Wilson (1948) reported that body temperature was affected when the air temperature ran above 90°F. Feed consumption was reduced at high air temperature, but the results were not consistent. Water consumption at 95°F. was double that at 70°F. The heart rate was lower at a higher environmental temperature. Respiration increased when the air temperature was 80°F. and at 105°F. was very high.

Warren et al. (1950) observed that birds held under a uniform environment consumed about a pound of feed less per bird in 11 months. Wilson et al. (1951) observed the response of laying hens under thermal stress of cold drinking water and lack of water. The S. C. White Leghorn pullets were kept in a climate chamber under thermal stress of an environmental temperature of 90°F. When water was withheld from the birds for 24 hours, only short interuptions of egg production were observed. When water was withheld for 48 hours, some of the pullets molted. Withholding water limited feed consumption drastically.

Heywang et al. (1955) noted the decrease in feed intake resulted in a decrease in nutrients needed for egg production. It was thought that a higher level of protein in the diet was required during hot weather than during cool or moderate weather. He proved in his experiment that no increase in egg production would occur if the protein level in the diet of laying chickens was higher during hot weather than during cool or moderate weather.

Huston *et al.* (1957) reported New Hampshire and White Plymouth Rock hens did not lay as well at high environmental temperatures as similar groups held in a variable environment. Body weight and feed consumption were also reduced. Joiner and Huston (1951) worked on different breeds and they found the White Leghorn breed consumed more water per unit of body weight than either of the other breeds. Rhode Island Red, New Hampshire, White Plymouth Rock and the Plymouth Rock consumed the least. The amount of feed consumption was lowered in all breeds when the environmental temperature was elevated. It was observed in all groups that water consumed per unit of body weight decreased with age.

Ota and Carver (1958) found that feed consumption was not as great at 85°F. as compared to a 65°F. environment. Squibb *et al.* (1959) found high environmental temperature significantly depressed feed intake and growth and increased water consumption. He noted, the loss of growth was due to reduced feed, not directly to the 99°F. temperature. Mueller (1959) concluded that reduction in shell thickness at high air temperature and humidity was not due to coincidental lowering of feed intake and serum calcium levels.

Prince *et al.* (1961) reported chicks exposed to a 45°F. environment from four to eight weeks of age consumed 0.65 pounds more feed than those in a 65°F. environment. While weight gains were not significantly affected, Bray and Gesell (1961) reported temperature extremes of 42°F. and 86°F. altered feed intake, but did not appear to affect rate of lay provided protein intake was above a maximum throughout the assay period.

Prince *et al*. (1961) observed that increasing the environmental temperature from 45°F. to 75°F. resulted in a highly significant decrease in feed consumption for the four week periods (amounting to 0.472 lbs./bird or 8.6 per cent between these two temperature treatments). Lowering the ventilation rate from 2 to 3/4 cfm per bird significantly decreased feed consumption by 0.126 pounds per bird for the four week period. Wood reported that birds kept cooler on sheltered ranges, preferably with good air drainage are likely to consume greater quantities per age than those whose range provides little escape from the heat of full sunlight. Mueller (1961) using the performance at 55°F. as a basis for comparison observed that a constant temperature 90°F. decreased feed consumed by 32 per cent.

Huston *et al*. (1961) observed the body weights were lower at the high environmental temperature than at either of the other environments. Less feed was required per pound of gain at the high temperature. The rations with the higher protein and energy values produced heavier birds in all environments. Huston and Edwards (1961) reported that with one environment, the temperature was held at 88°F., another at 66°F., and the third at ambient temperature. They found the body weights were lower at the high environmental temperature than at either of the other environments.

SUMMARY

A hen's egg is one of the most perfect nutritive foods, containing all the essentials necessary for the growth and development of the human body. The quality of an egg is very unstable and it changes as it proceeds from the finest when first laid, toward an inedible condition, under the

influence of various factors of which temperature and humidity are the most important.

The initial quality of the egg is influenced by many factors. High environmental temperature is one of the major causes of the decline in egg quality during summer. High environmental temperature reduces the percentage of production. Investigations of the seasonal variation of egg production in different geographic locations have led to the conclusion that high environmental temperature has some effect on egg production.

High temperature tends to reduce the weight of the egg. If the hens were not subjected to high temperature, egg size increased throughout the entire period of first laying year. The egg weight varied markedly with season, tending to be larger in the spring and smallest during periods of high temperature.

Egg quality is influenced by seasons, especially by summer temperature. The high environmental temperature reduces the thickness of the chickens egg shell thereby lowering its breaking strength. The usual pattern followed is a gradual thinning of the shell, which is initiated during the spring months and becomes progressively worse as the temperature increases. When the temperature cools, there is a return toward normal thickness. Specific gravity and shell thickness declined from February to July, while egg shell mottling increased during the same period.

There is a definite seasonal decline in interior egg quality. The albumen quality is decreased when the temperature is increased. High environmental temperature has more pronounced effect on the amount of calcium and sodium in egg white. The season significantly influenced egg contents, weight, albumen height, Haugh units, and gram of protein per egg.

Increased incidences of blood spots are usually noted until June, followed by a decrease through September. Birds receiving continuous light had significantly higher blood spot incidences than the eggs from birds receiving 14 hours of light per day. Summer temperature conditions caused the quality defect termed heat spots in yolks.

When the environmental temperature increases, the feed intake decreases. The feed consumption is not so great at 85°F., as compared to a 65°F. environment. In high environmental temperatures, birds consumed more water per unit of body weight. The White Leghorn breed consumed more water than any other breed.

ACKNOWLEDGMENTS

The author wishes to express his most grateful thanks to his major instructor, Dr. Paul E. Sanford, Professor of Poultry Science and Poultry Nutritionist for his valuable advice and guidance.

The author whole-heartedly offers his sincere thanks to Professor T. B. Avery, Head of the Department of Poultry Science, for his encouragement and providing facilities that were available in the department. Thanks are extended to Dr. Jack L. Fry, Associate Professor of Poultry Science, University of Florida and to all other faculty members of the department for their support and guidance.

REFERENCES

Amer, M. F. 1961. Incidences of meat and blood spots in eggs of Fayomi and some standard breeds. Poultry Sci., 40:1341-1344.

Baker, R. C. and R. Curtiss. 1957. Strain differences and seasonal changes in egg shell mottling, shell thickness and specific gravity and the interrelationships between these factors. Poultry Sci., 30:1103.

Benjamin, E. W., J. M. Gwin, F. L. Faber, and W. D. Termohlen. 1960. Marketing Poultry Products. 5th ed. John Wiley and Sons, Inc., New York.

Berg, L. R., G. E. Bearse and V. L. Miller. 1947. The effects of prelaying level of calcium on the performance of White Leghorn pullets. Poultry Sci., 26:463-468.

__________. 1951. The effect of water soluble vitamins and energy level of calcium and/or vitamin D on the performance of laying pullets. Poultry Sci., 30:799-804.

Bray, D. J. and J. A. Gesell. 1961. Environmental temperature - A factor affecting performance of pullets fed diets suboptimal in protein. Poultry Sci., 40:1328-1335.

Brooker, E. B. and P. D. Sturkie. 1950. Relationship of rate of thyroxine to rate of egg production in the domestic fowls. Poultry Sci., 29: 240-243.

Campos, A. C., F. H. Wilcox and C. S. Shaffner. 1960. The influence of fast and slow rises in ambient temperature on production traits and mortality of laying pullets. Poultry Sci., 39:119-129.

Couch, J. R., L. E. James and R. M. Sherwood. 1949. The effect of different levels of manganese and different amounts of vitamin D in the diet of hens and of pullets. Poultry Sci., 26:30-37.

Cunningham, F. E., O. J. Cotterill and E. M. Funk. 1959. The effect of season and age of bird on egg composition. Poultry Sci., 38:1196.

__________. 1960a. The effect of season and age of the bird. Poultry Sci., 39:289-299.

__________. 1960b. The effect of season and age of bird. 2. On the chemical composition of egg white. Poultry Sci., 39:300-307.

Dawson, L. E. 1955. Blood spots who should shoulder the responsibility? Poultry Processing and Marketing, 61(6):18-19.

Ewing, W. Ray. 1963. Poultry Nutrition. 5th ed. rev. Ray Ewing Company, Publishers, South Pasadena, California.

Fox, T. W. 1951. Studies of heat tolerance in the domestic fowl. Poultry Sci., 30:477-483.

Fromm, D. 1960. Permeability of the egg shell as influenced by washing, ambient temperature changes, and environmental temperature and humidity. Poultry Sci., 39:1490-1495.

__________. 1962. Permeability of the hen's shell. Poultry Sci., 41:1271.

Froning, G. W. and E. M. Funk. 1958. Seasonal variation in quality of eggs laid by caged layers and their sisters on the floor. Poultry Sci., 37:215-223.

Gelineo, S. 1955. Temperature d'aptalion et production de chalour cherles orseux de petite. Archives Sciences. Phynologiques, 9:225-243.

Glick, Bruce, Jack Griffin, Arivan Tienhoven. 1959. The effect of environment on reproductive characters and endocrine organs of New Hampshire chickens. Poultry Sci., 38:1078-1087.

Goodman, A. M. 1952. Homes for laying hens. Cornell Exp. Bull. 451.

Grotts, R. F. 1956. Seasonal variations in egg quality. M. S. Thesis, University of Missouri, 66p.

Hays, F. A. 1958. Laying house temperature and egg production. Poultry Sci., 37:592-594.

Heywang, B. W., H. R. Bird and W. G. Vavich. 1955. The level of protein in the diet of laying White Leghorns during hot weather. Poultry Sci., 34:148-152.

Howes, J. R., W. Grub, C. A. Rolla. 1961. The effect of high constant environmental temperatures upon caged White Leghorn pullets. Poultry Sci., 40:1416.

Hoffman, E. and C. S. Shaffner. 1960. Thyroid weight and functions as influenced by environmental temperature. Poultry Sci., 29:365-376.

Huston, M. Till. 1958. The influence of high environmental temperature on egg production, size, shell quality and albumen height of domestic fowl. Poultry Sci., 37:1213-1214.

__________ and J. L. Carmon. 1961. The influence of high environmental temperature on specific gravity and albumen quality of hen's egg. Poultry Sci., 40:1060-1062.

__________ and Hardy M. Edwards, Jr. 1961. The effects of environmental temperature upon growth and feed efficiency of domestic fowl. Poultry Sci., 40:1417.

__________, W. Perry Joiner and James L. Carmon. 1957. Breed differences in egg production of domestic fowl held at high environmental temperatures. Poultry Sci., 36:1247-1254.

Hutchinson, J. C. D. 1954a. Heat regulation in birds. Progress in the physiology of farm animals. Ed. J. Hammand, Butterworth Scientific Publ. London. Vol. I:299-362.

__________. 1954b. The effects of hot climates on egg weight. Poultry Sci., 33:692-696.

__________ and A. H. Sykes. 1963. Physiological acclimatization of fowls to a hot humid environment. J. of Agricultural Science, 43:294-323.

Jeffery, F. P. and C. S. Platt. 1941. A year study out of season hatching. New Jersey Agr. Exp. Sta. Bull. 687.

Jenkins, N. K. and C. Tyler. 1960. The critical study of the failure of long term calcium and phosphorus balance experiment with laying hens. J. Agr. Sci., 54:131.

Jenson, Leo S., E. A. Sauter and W. J. Stadelman. 1952. The detection and disintegration of blood spots as related to age of eggs. Poultry Sci., 31:381-387.

Joiner, P. W. and Till M. Huston. 1951. The influence of high environmental temperature on immature domestic fowl. Poultry Sci., 36:973-977.

King, S. G. and G. O. Hall. 1955. Egg quality studies at the New York Random Sample Test. Poultry Sci., 34:799-809.

Kheireldrin, A. M. and C. S. Shaffner. 1954. Familial difference in resistance to high environmental temperature in chicks. Poultry Sci., 33:1064.

__________. 1957. Familial differences in resistance to high environmental temperatures in chicks. Poultry Sci., 36:1334-1339.

Lee, D. H. K., K. W. Robinson, H. T. Yates and M. I. R. Scott. 1945. Poultry husbandry in hot climates. Poultry Sci., 24:125-128.

Lerner, I. M. and N. R. Smith. 1942. Effect of season and heredity on the incidence of blood spots. Poultry Sci., 21:473.

__________ and L. W. Taylor. 1947. Season and daily fluctuations in the incidence of blood spots. Poultry Sci., 26:662-667.

Long, Jack, A. C. Dale and John G. Taylor. 1958. The effects of different environmental temperatures on chicken hens. Poultry Sci., 32:1221.

Lorenz, E. W. and W. E. Newlon. 1944. A field survey of range egg quality. Poultry Sci., 23:418-430.

Mather, F. B., P. A. Thornton and C. S. Epling. 1961. The effect of heat stress on the microscopic structure of the egg shell matrix. Poultry Sci., 40:1428-1429.

May, K. N. and W. J. Stadelman. 1960. Some factors affecting components of eggs from adult hens. Poultry Sci., 39:560-565.

McClary, C. F. and G. E. Bearse. 1954. An apparent genetic correlation between egg shell thickness and blood spot incidences in chicken eggs. Poultry Sci., 33:1070-1071.

Miller, B. F., P. E. Sanford and R. E. Clegg. 1962. The effect of thyroxine on egg production and egg quality of normal and radio thyroid ecrecticized hens. Poultry Sci., 41:989-994.

Mueller, W. J. 1959. The effects of environmental temperature and humidity on the calcium balance and serum calcium of laying pullets. Poultry Sci., 38:1296-1301.

__________. 1961a. The effects of constant and fluctuating environmental temperature on the biological performance of laying pullets. Poultry Sci., 40:1434.

__________. 1961b. The effects of constant and fluctuating environmental temperature on the biological performance of laying pullets. Poultry Sci., 40:1562.

Nalbandov, A. V. and L. E. Card. 1944. The problems of blood clots and meat spots in chicken eggs. Poultry Sci., 23:171-180.

Ota, H. 1956. Houses and equipments for laying hens. Misc. Publ. 728. U. S. Department of Agriculture.

__________. 1958. Personal communications as quoted by Prince, R. P. Poultry Sci., 40:102-103.

Parnell, E. D. 1957. Profitable Poultry Production. John Wiley and Sons, Inc., New York.

Peterson, C. F., E. A. Sauter, A. C. Wiese and D. H. Conrad. 1951. Effects of energy level and laying house temperature on performances of White Leghorn pullets. Poultry Sci., 36:1149.

Pipes, C. W., N. Premchandra and C. W. Turner. 1958. Measurement of the thyroid hormone secretion rate of individual fowls. Poultry Sci., 37:36-41.

__________ and C. W. Turner. 1946. Factors affecting the thiouracil content of the blood and tissues of fowls. Poultry Sci., 25:410.

Prince, R. P., L. M. Potter and W. W. Irish. 1961. Response of chickens to temperature and ventilation environments. Poultry Sci., 40:102-108.

__________, W. C. Wheeler, W. A. Jummla, L. M. Potter and E. P. Singsen. 1961. Effects of temperature on feed consumption and weight gain in broiler production. Storrs (Connecticut) Agr. Exp. Sta. Progress Report 33.

Ragbab, M. T. and M. A. Assem. 1953. Effect of atmospheric temperature and day light on egg yield in Fayomi and Baladi fowls. Poultry Sci., 32: 1021-1028.

Romanoff, A. L. 1940. Physiochemical changes in unfertilized egg incubated eggs of gallus domesticus. Food Research 5:291-306.

__________ and A. J. Romanoff. 1949. The Avian Egg. John Wiley and Sons, Inc., New York.

Rosenburg, M. M. and T. Tanaka. 1951. Effect of temperature on egg weight in Hawaii. Poultry Sci., 30:745-747.

Sauter, E. A., J. V. Harns, W. J. Stadelman. 1954. Seasonal variations in quality of eggs as measured by physical and functional properties. Poultry Sci., 33:519-524.

Schiltze, A. B. and C. W. Turner. 1956. The determination of rate of thyroxine secretion of certain domestic animals. Missouri Agr. Exp. Sta. Res. Bull. 392.

Sharma, G. P. 1949. Note on an abnormal intrafollicular ovum. Poultry Sci., 28:310-312.

Skoglund, W. C., A. C. Tomhave and C. W. Mumford. 1951. Egg weight in New Hampshire hatched each month of the year. Poultry Sci., 30:452-454.

Squibb, R. L. 1959. Relation of diurinal temperature and humidity ranges to egg production and feed efficiency of New Hampshire hens. Poultry Sci., 52:217-222.

__________, M. A. Gurman and Nevin S. Scrimshaw. 1959. Growth and blood constituents of immature New Hampshire fowl exposed to a constant temperature of 99°F. for 7 days. Poultry Sci., 38:220-221.

Stahles, Perry and C. W. Turner. 1961. Seasonal variation in thyroxine secretion rates in two strains of New Hampshire chicks. Poultry Sci., 39:239-241.

Stiles, P. G. and L. E. Dawson. 1961. The effect of physical disturbance, sound and light on the incidences of blood spots and other egg quality factors. Poultry Sci., 40:189-195.

Strain, J. H. and A. S. Johnson. 1956. Seasonal hatch and strain effects of egg quality. Poultry Sci., 35:1174.

Sturkie, Paul. 1954. Avian Physiology. Comstock Publishing Associated, Ithaca, New York.

Thornton, Paul. 1961. Environmental temperature influences of the body temperature of the chicken. Poultry Sci., 40:1464-1465.

Turner, C. W. 1948. Effect of age and season on the thyroxine secretion rate of White Leghorn hens. Poultry Sci., 27:146-154.

Wallace, H. B. 1961. What to do for egg shell problems. Hy-Line Service Bull.

Warren, D. C. 1948. The laying hen's response to seasonal fluctuations in her environment. Kansas Agr. Expt. Sta. Bull. No. 172.

__________, Ralph Conrad, A. E. Schumacher and T. B. Avery. 1950. Effects of fluctuating environment on laying hens. Kansas Agr. Expt. Sta. Bull. No. 68.

__________ and R. L. Schnepel. 1940. The effects of air temperature on egg shell thickness in the fowl. Poultry Sci., 19:67-72.

Weiss, H. S. and Eugene Borbely. 1953. Seasonal changes in the resistance of the hen to thermal stress. Poultry Sci., 36:1383-1385.

Wilson, W. O. 1948. Some effects of increasing environmental temperatures on pullets. Poultry Sci., 27:813-817.

__________. 1951. Response of laying hens under thermal stress to cold drinking water and lack of water. Poultry Sci., 30:933.

__________ and A. E. Woodward. 1957. Egg production of chickens kept in darkness. Poultry Sci., 36:1169.

THE EFFECTS OF HIGH ENVIRONMENTAL TEMPERATURE
ON PERCENTAGE PRODUCTION, EGG SIZE, EGG QUALITY,
AND FEED EFFICIENCY OF DOMESTIC FOWL

by

ARTHUR RHENIUS SELLAKUMAR

B.V.Sc., University of Madras, Madras, India, 1961

AN ABSTRACT OF A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Poultry Science

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1964

Biologists have long recognized that climatic environments have a profound effect on growth, reproduction and other functions of both plants and animals. Daily and seasonal fluctuations in temperature, light, humidity, air movements, solar radiation and other reactions from outer space are such that it is almost impossible to characterize a "normal development".

The purpose of this report is to review the literature concerning the high environmental temperature that affects the production, quality of the egg and the feed intake of the bird.

The seasonal changes occur in both the quality and quantity of the egg. Eggs are among the most delicate and perishable food products. They are subject to rapid deterioration, and are easily affected by unfavorable surroundings. Investigations of seasonal variation of egg production in different geographic locations have led to the conclusion that high environmental temperature is one of the major causes of the decline in egg production during summer. Winter did not affect the egg production much. Birds lay better at 55°F. than 90°F.

High temperature tends to reduce the weight of the egg. Most of the out of season hatched birds which have not reached large egg size before hot weather begins, tend to continue to lay small eggs over a prolonged period. Egg size was depressed by high temperature. If the hens were not subjected to high temperature, egg size increased throughout the entire period of the first laying year. The egg weight varied markedly with season tending to be larger in the spring and smaller during periods of high temperature. Seasonal variations in egg production and egg weight were observed under field conditions but not in the temperature controlled environment.

Egg quality is influenced by seasons, especially by summer temperature. The high environmental temperature reduces the thickness of the chicken's egg shell, thereby lowering its breaking strength. The usual pattern followed is a gradual thinning of the shell, which is initiated during the spring months and becomes progressively worse as the temperature increases, when the atmosphere cools, there is a return toward normal thickness. Specific gravity and shell thickness declined from February to July while egg shell mottling increased during the same period. The warm temperature had an adverse effect on shell thickness, recovery in fall was not sufficient to bring the thickness back to the original level observed in May.

The lowering of interior quality of the hen's eggs begins with March or April and continues through summer. There is a definite seasonal decline in egg quality. The albumen quality decreased when the temperature increased. High environmental temperature has more pronounced effect on the amount of calcium and sodium in egg white. The season significantly influenced egg contents, weight, albumen height, Haugh units, and gram of protein per egg. Birds kept in individual laying cages in a controlled temperature maintained at 90°F. showed no significant differences in albumen quality.

Increasing incidences of blood spots are usually noted until June, followed by decrease through September. Birds receiving continuous light had a significantly less blood spot incidence than eggs from birds receiving 14 hours of light per day. Summer temperature conditions caused the quality defect termed heat spots in yolks.

When environmental temperature is increased, feed intake is lowered. The feed consumption is not so great at 85°F. as compared to a 65°F. environment. In high environmental temperature birds consumed more water per unit of body weight. The White Leghorn breed consumed more water than any of the other breeds.