EFFECTS OF FEED INTAKE AND ACID-BASE BALANCE ON EGG QUALITY UNDER HEAT STRESS CONDITIONS

By

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CHAPTER I

INTRODUCTION

Egg producers have long known that high environmental temperatures have a deleterious impact on layer performance. For instance, during heat stress there is a reduced feed consumption, fewer eggs, lower egg weight, thinner shells, and increased mortality. The implications are clear, a lower income.

Despite the eggs shape, which is partly responsible for the inherent strength of the shell, egg breakage is one of the biggest problems facing the poultry industry today. Peterson (1965) reported that 5 to 7% of all eggs produced in the U.S.A. failed to reached the consumer due to breakage. Miles (1982) reported a loss of $250 million a year in the U.S.A. due to shell quality problems. Shrimpton and Hann (1967) found that 9% of all egg are broken before leaving the farm. Leeson and Clunies (1987) said that around 10 to 15% of all eggs never reach the consumer. However, they say most of the breakage is done by the people themselves.

The egg breakage problem is complex. Egg shell is composed of calcium carbonate ($CaCO_3$)in its majority. Hens get most of the calcium from the diet. Shell bicarbonate appears to come from either the diet or from the metabolism of CO_2. In any case, reduction of feed intake and/or changes in the normal well being of the animal will have a detrimental effect on egg production and egg shell quality.

Reduced feed consumption is a major concern during heat stress periods (Leeson, 1986). Additionaly, Mueller (1966) observed that hyperventilation reduces blood carbon dioxide to the point that shell thickness is reduced by 12% when ambient temperature reaches $93^{o}F$. Studies have not been conducted to partition problems associated with heat distress into feed intake reduction or some other problem such as endocrine. If the problem is related to nutrient consumption numerous drugs are available to enhance feed intake. Additionally, studies have not been conducted to partition the carbonated water effect into a CO_2 and pH effect.

In the following studies we used 72 week old layers to investigate: 1) the implications of feed intake on egg shell quality and their response to an increase in their feed intake and 2) the addition of ammonium chloride and sodium bicarbonate to the diets of birds housed in both thermoneutral and heat stressed environments and their response on the hen's egg shell quality.

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CHAPTER II

LITERATURE REVIEW

Effect of heat stress on layers

Heat production can be controlled by the birds, so their body temperature remains the same (Freeman, 1966). This process, called homeothermy, functions most efficiently within a comfort zone (Leeson, 1986) in which the animals have no need for any physiological changes to maintain their optimum body temperature. Homeothermy in birds is controlled by regions of the hypothalamus which is stimulated by peripheral receptors and by the blood temperature (Smith and Oliver, 1972). The thyroid gland as well as the hypothalamus are involved in the mechanisms for controlling hyperthermia (Thorton and Moreng, 1959).

Homeotherm animals (warm blooded) carry out their normal activity under a wide range of external environment. In homeotherms the heat produced by the body is balanced by the heat loss of the body to maintain a constant body temperature. Thus, in homeotherms the thermoregulatory mechanisms that help to establish a normal and steady body temperature consist in a series of different physiological adjustments that struggle to maintain the heat produced and lost in balance (Anderson, 1977). Heat production by the animal's body is highly dependant on the external temperature. If outside factors change to the point in which the animal is not able to maintain a heat balance, then body temperature will either rise or decline accordingly. In general, the zone of thermoneutrality is one in which animal's body temperature is maintain with only slight changes in circulatory adjustments.

Birds body temperature when compared with mammals is higher. King & Farner (1961) concluded that bird temperature is 41.9 C.. Heywang (1938) showed that layer's body temperature varied from 39.8C to 43.6C.. Lincoln (1964) observed a variation of 0.5C (plus or minus) within each individual layers. More recent work agrees that body temperature of an adult fowl ranges from 41C to 42C (Kadono and Besh, 1978; Brake and Thaxton, 1979). Any increase of environmental temperature above normal causes metabolic changes aimed in the regulation of body temperature under such conditions.

The term "heat stress" is used for environmental conditions which will induce physiological changes other than those seen under thermoneutral or within the thermoneutral zone of comfort of the animal. Cutaneous heat losses under normal ambient temperature accounts to approximately 40% of the total heat loss. This is possible due to the changes that take place in the capillaries blood flow (VanKampen, 1971). Bruckner (1936) showed that the ideal ambient temperature is around 25C.. Above these temperatures vasodilation no longer is able to maintain normal body temperature. Therefore, other means for heat loss must be used to dissipate heat. Physical means of thermoregulation are divided in two general categories: 1) Sensible heat loss, in which heat is loss via the feathers, head and appendages by means of conduction and convection. Increase in the hypothalamic temperature will induce a spreading of the feathers (Bugdell, 1971; McFarland and Bugdell, 1970) to facilitate heat loss by conduction. Surface area for the comb and wattles may be up to 7% of total body area (Freeman, 1983). Since these areas are well vasculirized they are important for heat dissipation when ambient temperature is not too high. As temperature increases, heat loss trough the feathers, head and appendages becomes less important.

At this point, birds rely on their respiratory system for thermolysis. Pullets at 32C lost 60% of their body heat by respiratory evaporation (Longhouse et al., 1960). Evaporation occurs as air passes through the airs sacs having a cooling effect. Relative humidity (RH) of the environment has a direct effect on evaporation. Romijn and Lokhorst (1966) showed that hens at 34C and 40% RH lost 80% of their body heat by evaporation as compared with hens at 34C and 90% RH which could only lost 39% of their body heat by evaporation.

Layers can increase respiration (amount of air inhaled) rate by 20 to 25 times normal while respiration effort is only increased 4 times (Hutchinson, 1954). Calder and Schimdt-Nielsen (1966) and Siegel (1968) reported that respiration rates of layers reached 140 to 170 respiration per minute at a body temperature of 44C. This increase in respiration rate is termed polypnea (very rapid frequency of breathing with an open mouth). This rapid breathing is accomplished by the movement of thorax and abdomen. Vibratory movement of the gular in the upper throat and floor of bucal cavity by the hyoid apparatus will result in an increase of gas exchange in birds under severe heat loads. Panting can be observed with or without gular fluter. In any case, it has been observed that panting increases carbon dioxide losses (Robinson, 1975). Increased evaporative cooling by panting resulted in increased gas exchange precipitated respiratory alkalosis (Smith, 1986). Panting is initiated by an increase in temperature of blood flowing to brain of 0.1 to 0.4C above normal(Randall and Heistand, 1939).

An ambient temperature of 26C or above was suffient to initiate panting in birds (Wilson, 1948). However, these data disagrees with El-Hadi and Sykes (1982) in which they found that birds do not start panting before temperature reaches 32C. Panting rate was found to be proportional to body temperature within a narrow body temperature(41.8-43C). Panting was maximized as ambient temperature rise from 23 to 37C.. When body temperature reaches 45.9C the panting mechanisms begin to fail, heat production exceeds heat loss and body temperature may rise uncontrollably. Reports on the upper lethal body temperature varies widely from 40.5C (Wilson, 1948), 44C for one hour (Squibb, 1959), 46.5C (Boone and Hughes, 1971), 47C (Randall and Hiestand, 1939) and 47.2 (Moreng & Shaffner, 1961). Variables such as body weight, plane of nutrition, bird strain and relative humidity would be expected to impact the results and may account for the variability.

Heat Stress, Feed Intake and Egg Shell Quality

Hens exposed to high environmental temperatures showed a decreased in egg weight (Bennion & Warren, 1933). During the summer months shell quality showed a significant decrease (Froning & Funk, 1958; Carmon & Huston, 1965). Several researchers have clearly shown the negative effect that an increase in temperature above 32C has on egg shell thickness, specific gravity and percentage of cracked eggs (Miller and Sunde, 1975; Zimmerman et al., 1972; El-Bousky et al., 1968; Payne, 1966).

During heat stress feed intake is reduced and might partially be responsible for the decrease in egg shell quality (Wilson, 1949; Campos et al., 1960). However, Mueller (1959) stated that the reduction on shell quality can not be entirely attributed to the reduction in feed intake. Pullets reared to 20 weeks of age at 30C weighed less than those at 18C, indicated by the author that protein requirements were increased by the hot environment. High environmental temperatures on pullets at 11 to 20 weeks of age, did not have any effect on the eight months laying period on egg shell thickness.

Age is an important factor in the response of the bird to increase in environmental temperature. In general, egg shell quality does not become a problem until birds are 8 to 10 months old. Evidence suggests that older birds are more susceptible to heat stress (Arima et al., 1976) and the age response to heat stress could be related to feather condition (Richards, 1977).

Laying hens react to heat stress in a very rapid manner. Birds exposed to high environmental temperatures adjust their intake within one hour, even though consumption was not enough to maintain their normal weight (Jones et al., 1976).

Nutritional manipulations have been done to increase amino acid intake (Bray and Gessel, 1961; Payne, 1966; Reid and Weber, 1973) to reduce the deleterious effects of heat stress on egg production and quality. Miller and Sunde (1975) observed a decline on egg shell quality within hours after environmental temperatures have risen; they suggested that the reducion on egg weight was not a direct effect of feed intake, but rather a decrease in FSH output in the pituitary, which could be responsible for a reduced ovum weight. Mueller & Amezcua (1959) showed that thyroxine is secreted at lower rates when environmental temperature is

30C as compared with birds at 18C. Thyroxine has been positively correlated with egg production and yolk weight. When ambient temperature was increase to 38C, thyroid gland was reduced in size (Clark & Das, 1974).

Egg formation processes (Nordstrom, 1971) and oviposition time could be also influenced by environmental temperature. Time intervals between successive eggs is increased probably to a decrease in clutch size. Transit time of the developing egg through the infundibulum, magnum and isthmus appears to be the same, even though less albumin seems to be secreted in the magnum of hens exposed to higher temperatures (Bennion and Warren, 1933). Birds under cyclic temperature tend to oviposition later in the day (Miller and Sunde, 1975) and this could be the cause why birds under cyclic temperature outperform birds under constant temperature.

Feed intake is drastically reduced during heat stress. The percentage of reduction per degree C rise varies from 0.9% (Payne, 1966) when ambient temperature increased from 19C to 30C, to 2.1% when temperature changed from 13C to 32C. Changing ambient temperature in the houses from 16C to 29C reduced egg production, specific gravity and egg weight. However, feed efficiency per dozen egg was increased (Ramson et al., 1974). Energy metabolism is drastically altered under high environmental temperatures. Energetic efficiency was improved when there was increased in ambient temperature (Vhora et al., 1979). Leeson and Summers (1975) found that under short periods of heat stress increasing diet energy content increased metabolizable energy intake but it was less available for egg production. Tannor et al. (1984) also found that manipulation of the diets under short periods of heat stress had very little effect overall. Under conditions of long term stress layers showed response in producution to increases of nutritional density, eventhough, egg shell quality did not have any significant improvement. The question remains as to the direct effect of feed intake on egg production and quality during heat distress.

Shell Formation and Acid-Base Balance

A full size oviduct can be as 0.6mts. long (Gilbert, 1979). It is divided in 6 different parts all of (except the vagina) which are involved in the process of egg formation (Aitken, 1971; Gilbert, 1979). The wall of the oviduct is composed of several layers which increase in thickness toward the vagina. Their major function is in the egg transport throughout the oviduct. The blood supply to the oviduct comes from the cranial artery, the middle oviductal artery, the ventral artery and the caudal ductal artery (Salomon, 1983). The oviduct is innervated by both branches of the autonomic nervous system and their uneven distribution may be a means for controlling time spent in the different parts of the oviduct.

Infundibulum is assumed to be the site of fertilization. Its epithelium secretes an acidic mucus. Egg's albumin formation starts at the magnum, which secretes a turgid mass in which viscocity depends on the content of ovomucin (Salomon, 1983). The isthnus is divided in two parts (Draper et al., 1972). The first part is also called granular, from where secretions are somewhat similar to those from the magnum. Surface epithelial cells linning the tubular shell pouch (TSG), next, are involved in the process of calcium transfer in the formation of the mammillary mantle (Salomon et.al., 1975). These glands cells linning the TSG are distinguished from others by their complement of glycogen which will increase the glucose content of the egg. In the shell gland pouch, the addition of water into the albumin preceding the deposition of calcite is called "plumbing" (Salomon, 1983). This process takes about six hours (Bradfield, 1951), and will decrease the protein content of the egg from 20% to 11%.

Deposition of the shell. Surface epithelial cell of the pouch, function in calcium transfer (Salomon et al., 1975). The calcium concentration in the blood are under control of the antagonistic action of the parathyroid and ultimobranchial body (Anderson and Consuegra, 1970), and it is believed that a carrier is involved in the transport of calcium across the mucosa of the oviduct. Corradino et al.(1968) isolated a calcium binding protein from the shell gland. Ebashi and Lipmann (1962) implicated phosphates to be the carries; and Helbock et al. (1966) said that phosphate ions are the driving force for the movement of calcium.

Shell composition is 95% calcium carbonate and 5% organic matter. The shell gland is supplied by fenestrated types of capillaries which are located in the lamina propia, and are designated to cope with the rapid transfer of metabolites (Salomon, 1983). The egg is innitially coated by the inner layer of keratin fibers. It is followed by the outer membrane where the cores of the mammilary knobs are laid down. Next the mammilary membrane crystal columns of calcium carbonate are assembled to form the spongy or pallisade layer. The pallisade layer is the stronger and thicker part of the egg's shell (Salomon, 1983). Shell deposition requires in the shell gland simultaneous secretions of matrix, calcium and carbonate ions.

Shell is formed almost entirely of calcium carbonate. From this, 60% is carbonate and 40% calcium. Calcium needed for egg shell formation can be obtained directly from intestinal absorption (Hurwitz and Bar, 1969) and from the skeleton. Blood bicarbonate is the direct source of carbonate ions needed for shell formation. This theory was first postulated by Gutowska and Mitchell (1945) as seen in fig. 1.

From this Mongin and Lacassagne (1966) observed that a metabolic acidosis starts to develop in the general circulation, as soon as the egg enters the uterus. Decrease in pH could be due to the decrease in blood bicarbonate ions which are being used in the shell formation. Increase in ventilatory rate will compensate in part for the acidosis observed but reduces CO_2 for carbonate formation. These same type of observations were reported by Hodges (1966). Thus, the role of acid-base balance in shell formation may be important. Manipulation of the acid-base balance could in fact be a tool to improve shell quality.

Many researchers feel that the carbonate ions used for shell formation does not come from the blood bicarbonate. Frank and Burger (1965) studied the effects of increasing the levels of CO_2 in the environment in order to increase the CO_2 levels in the blood. They observed an increased in egg shell thickness up to 12%. Therefore, contrary from what Gutowski and Mitchell (1945) said, they postulated that the primary source of shell carbonate comes from metabolic carbon dioxide (Fig. 2).

Increasing CO_2 levels in the blood will increase shell thickness regardless of blood pH. However, Helbacka et al.(1963) found that hens exposed to a 5% CO_2 atmosphere led to a marked decrease in shell calcification. Hall and Helbacka (1959) suggested then that deposition of calcium carbonate is dependent upon blood pH and could be depressed by either respiratory alkalosis and or metabolic acidosis (ammonium chloride feeding) in thermoneutral environments. Feeding ammonium chloride and HCl has been found to decrese egg shell thickness. Nesheim et al. (1964) found that excesses of dietary acid could be induced by sodium and potassium deficiency. Acidotic effects of excess Cl^-, low levels of cations or low overall electrolyte balance would have a negative effect on shell quality. Hamilton and Thompson (1980) observed that Na + K/ Cl had a significant effect on acid-base balance but did not have any effect on egg shell quality.

Heat Stress and Acid-Base Balance

Effects from high ambient temperatures rather than nutrition are without a doubt extremely important, since egg breakage usually continues even after corrections in the diet have been made. During heat stress evaporative cooling and panting are the primarily mean for heat dissipation (Jukes, 1971). Mongin (1968) suggested that during hot weather there is weakness in the shell as a consequence of hyperventilation. An increase in the body temperature from 41.4C to 42.6C would increase respiration rate and hence, drastically reduce pCO_2 in the blood (Calder and Schmidt-Nielsen, 1966). Ventilation rate increases CO_2 loss from the lungs which in turn will deplete blood plasma of CO_2, HCO_3^-, and H^+. A change in ambient temperature from 13C to 34C induces respiratory alkalosis and thus, reduces shell thickness by approximately 12%. During heat stress there is very rapid decreases of egg specific gravity which indicates (Harrison and Bellier, 1969) an acid-base inbalance,during which respiratory alkalosis occurs followed by increases in calcium renal excrition. During heat stress, more blood is being delivered to the periphery for cooling with less blood flow sent to the internal organs, including the oviduct.

In an experiment, in which daily temperature fluctuated between 20C and 35C, ElJack et al.(1978) observed an increase in plasma pH and a decrease in levels of plasma pCO_2 and bicarbonate leading to respiratory alkalosis. DeAndrade (1976) obtain the same type of results including some observations of a decrease in plasma Ca concentration. Odom (1982)observed an improved egg production when layers were given carbonated water. Bottje and Harrison (1985) were able to partially correct the blood acid-base imbalance during heat stress. This increases the carbon dioxide and hydrogen ions available for an increase in production.

Figure. 1 Carbonate ions utilization

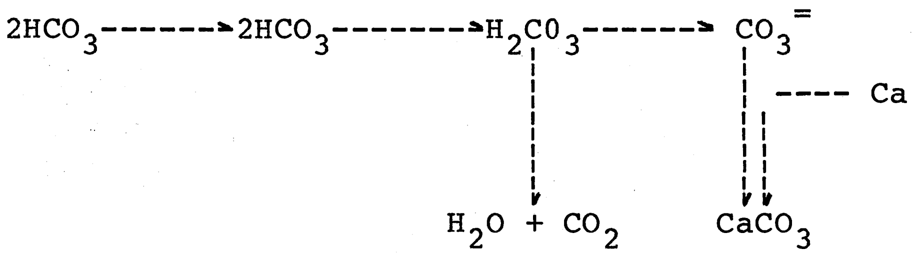
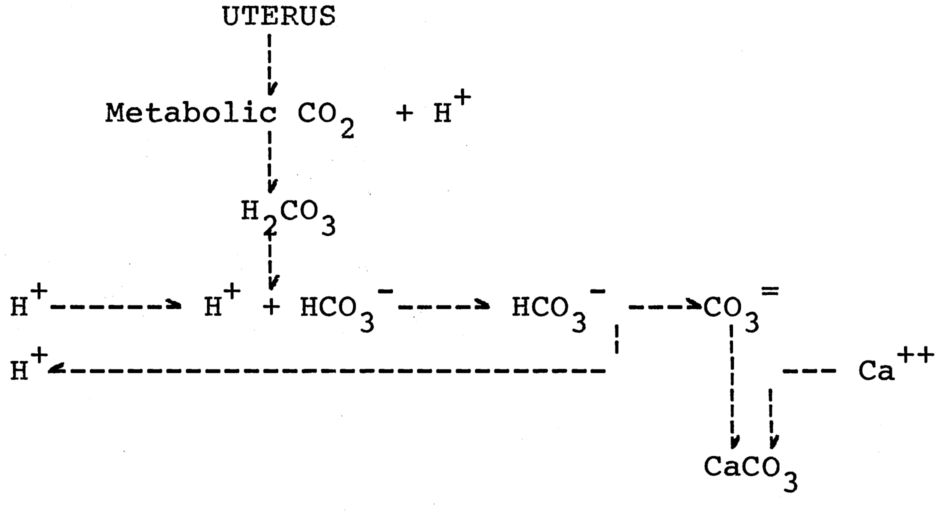


Figure 2. Carbon Dioxide Movement for shell formation



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CHAPTER III

FEED INTAKE EFFECTS ON EGG QUALITY OF NON-STRESS AND HEAT-STRESSED LAYERS

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Abstract

The effects of feed intake and environment on 5 egg quality parameters were estimated by force feeding layers housed under thermoneutral (24C) and heat stressed (35C) environments. Feed intake levels evaluated included 70, 85, 100 and 115% of the level observed for layers housed in the thermoneutral environment. Layers allowed to consume feed ad libitum were observed to consume 7.8% of their body weight daily at 24C and 5.5% at 35C. Heat stress depressed egg weight (3.2%), shell weight (7.4%), shell thickness (9.3%), specific gravity (1%), albumin height (11.2%) and yolk weight (2.1%) in birds fed ad libitum($P<.05$). Increasing feed consumption of heat stressed layers by force feeding increased ($P>.10$) egg weight (2.6%), shell weight (0.4%), shell thickness (0.7%), specific gravity (0.2%) and albumin height (8.7%). However, increasing feed

intake of layers exposed to heat stress also increased mortality. Though increasing feed intake tended to enhance egg quality parameters of the heat stress birds, none of the parameters evaluated returned to levels observed for layers housed in the 24C environment. Layers housed in the thermoneutral environment and force fed at the 70% ad libitum consumption level had reduced egg weight (5.0%) and albumin height (13%) while the others parameters remained nearly constant as compared with the birds fed ad libitum. Increasing feed intake of thermoneutral layers to 115% ad libitum was without effect. Data indicates that increasing nutrient consumption of heat stressed layers enables only partial recovery of egg quality parameters.

Introduction

Environmental factors such as the combination of high ambient temperature and relative humidity, have long been known to adversely impact feed intake and egg shell quality (Ota, 1960; Mueller, 1961; Payne, 1966; El-Bousky et al., 1968; Ahmad et al., 1967; Zimmerman et al., 1972; Miller and Sunde, 1975). Nutritional manipulations to increase performance of heat stressed layers has been a subject of controversy. Incresing amino acid intake,(Bray and Gessel, 1961; Payne, 1966; Reid and Weiber, 1973) may reduce the detrimental effects of heat stress on layer production rate. Leeson and Summers (1975) showed that increasing the energy content of the diet had little effect on egg production, while Payne (1967) indicated that high energy diets had beneficial effects. El-Jack and Blum (1978) reported that regardless of environmental temperature, eggs were heavier for birds with a higher energy diet.

The effects of nutrient intake on egg production and shell quality were studied by DeAndrade et al. (1977). The high nutrient density diet used in this experiment improved egg production in the hot environment, even though production was lower than that of the control at the thermoneutral environment. Some improvement was obtained for egg weight with the high nutrient density diet in the 32C environment. Treat et al.(1960) found that addition of fat to layer's diet increased egg weight. Egg weight has also been increased when soybean oil has been added to the laying rations (Kondra et al., 1968). It is generally observed that birds under high environmental temperature have a lower feed consumption than birds in thermoneutral environments. As a result, during short periods of heat stress egg production continues to be reduced long after the ambient temperature and feed intake has returned to normal, (Tannor et al., 1984; Daniel and Balnave, 1981) indicating that factors other than feed intake are affecting production. It has been suggested (Wilson, 1949; Campos et al., 1960; Daniel and Balnave, 1981; Tannor et al., 1984) that the decrease in feed intake is not the main factor responsible for the reduction of egg shell quality under conditions of heat stress. Before appropiate therapy can be developed to counter the deleterious effects of heat stress on layers the precise mode of action (ie. decreased feed consumption vs. undefined factors) must be determined.

Therefore, the objectives of the study describe herein were to investigate the direct effects of four feed intake levels on egg quality parameters for birds housed in thermoneutral and heat stressed environment.

Materials and Methods

One hundred and fifty one, 72 weeks old shaver layers were placed in individual (30 X 80 cms) metabolism cages in one of two environmental chambers. Birds in each chamber were divided into five groups and assigned to treatments at random. All birds were allowed to adapt to surroundings and the basal diet for eight days. During the next 14 days, one chamber was maintained at a constant 24C with 55% relative humidity (RH), while the ambient temperature of the other chamber was increased 2.5C daily to 35C, also at 55% RH. Both chambers were kept under 16 hour per day timed lighting.

Feed intake of birds allowed to consume feed ad libitum was determined daily. Control groups were allowed to consume the basal diet (TABLE 1) ad libitum, while the other groups were force fed at 70, 85, 100 and 115% of the ad libitum feed consumption observed in the thermoneutral environment. Meals were administered in equal quantities 3 times daily. Water was available for ad libitum consumption during the entire experiment. Daily feed consumption of all birds was monitored for three days prior to the initiation of the experiment and the average daily consumption coupled with body weight was used to compute consumption per unit body weight per day for the force fed treatments. The force feeding technique has been previously described (Teeter et al., 1984).

Feed consumption, body weight, egg weight, specific gravity, albumin height, shell weight, shell thickness and mortality data were recorded during the experimental period. Eggs were collected daily and stored at 65F for 12 hours prior to evaluation. They were then weighed and specific gravity determined by obtaining the air weight and water weight. Eggs were then broken and their albumin height measured. Yolks were separated and weighed. Shells were weighed and thickness determined with the Ames egg shell thickness measure model 25-5 dial micrometer with a readout in thousandths of an inch, by averaging two measurements taken at opposite sides of the widest circumference of the top one third part of the egg. Means were analized by the Duncan multiple range test to determine treatment effects. Multiple regresion were use to analize for interactions other than linear if these were significant (SAS, 1982).

Results and Discussion

Layers consuming feed ad libitum in the thermoneutral environment gained ($P<.10$) 2.11% of their body weight as compared with layers under heat stress who lost 2.5% ($P<.05$). If birds reduced feed consumption in accordance to requirements it was not apparent in this study. Equalizing feed intake across the two environmental temperatures resulted in the layers within the heat stress environment gaining ($P<.05$) more body weight (TABLE 2). Such an increase might be due to the reduction of the energy requirements that birds under heat stress tend to have (Leeson, 1986).

The effects of environment on feed intake and the parameters studied for birds fed ad libitum are shown in TABLE 3. Birds allowed to consume feed ad libitum and exposed to heat stress reduced feed intake by approximately 30% ($P<.05$). Payne (1966) suggested that the decrease in feed consumption was due to a decrease in energy requirements and not to an increase in temperature. However, Teeter et al. (1987) observed fasting to reduced body temperature of heat stressed broilers suggesting that voluntary reduction in feed intake may be related to thermoregulation.

In this study, birds fed ad lib and exposed to heat stress had lower ($P<.05$) egg weight (4.3%), which could not be attributed directly to either the high environmental temperature or, to the reduced feed consumption. Miller and Sunde (1975) suggested that the decreased egg weight is a direct response to high environmental temperatures. Izat and coworkers (1985) observed that specific gravity decreased as ambient temperature increases, which agrees with the results found in this experiment, in which specific gravity was reduced by 1% on ad libitum birds housed under heat stress environment. Olson (1934) and Wells (1967) observed that specific gravity is directly related to shell thickness. Shell thickness of eggs of ad libitum fed birds in the heat stressed chamber was also ($P<.05$) reduced by 9.6%. These results agrees with ElBousky et al.(1968) who concluded that shell thickness is significantly reduced by high environmental temperatures. Shell weight and albumin height of ad lib birds were reduced ($P<.05$) by 7.5 and 11.3% respectively as ambient temperature increased, which agrees with results found by Izat and coworkers (1985). Yolk weight was unaffected by the heat stress environment on birds consuming feed ad libitum.

Reducing feed intake to 5.46% of their body weight, resulted in depressed egg weight at both environmental temperatures (TABLE 4). Increasing the heat stress birds feed intake to thermoneutral ad libitum consumption levels (7.80%) enhanced ($P<.05$) egg weight. However, increasing feed consumption at the 115% level of ad libitum consumption for birds under heat stress reduced ($P<.05$) egg weight. Regression lines were determine for the effects of feed intake on egg weight at both environments (FIGURE 1)

Specific gravity (TABLE 5) was elevated ($P<.05$) from 1.066 to 1.089 when birds under heat stress environments were fed at the 115% level. Regression lines are shown in FIGURE 2 for specific gravity and feed intake at both environmental temperatures. Increasing feed intake above thermoneutral ad libitum consumption within both environments did not affect shell thickness (TABLE 6) or shell weight (TABLE 7), although both were ($P<.05$) reduced by the heat stress environment. Albumin height (TABLE 8) was numerically increased ($P>.10$) with feed intake at both environments. In the thermoneutral environment yolk weight (TABLE 9) was not reduced ($P>.10$) with a decreased in feed intake but increased when feed intake was at the 115% level of the ad libitum consumption birds.

These results indicate that increasing feed intake of heat distress layers above ad libitum consumption level tends to increase both egg weight and egg shell quality. However, feed intake manipulation did not restore layer productivity to the nonstressed level. At thermoneutral environments reducing feed intake by 15% similar to heat distress did not adversely impact egg quality though egg weight declined. Feed intake alone does not limit production of heat distress layers.

TABLE 1. Ration composition.

Ingredients	IFN[a]	% of diet
Ground corn grain	4-02-935	59.50
Soybean meal (44%)	5-04-604	21.00
Calcium carbonate	6-01-069	8.40
Animal, tallow	4-08-127	5.00
Dicalcium phosphate	6-01-080	2.60
Alfalfa	1-00-023	2.50
Salt	-	0.50
Vitamin premix[b]	-	0.35
D-L Methionine	-	0.10
Trace minerals	-	0.05
Total		100.00

[a] International feed number

[b] Roche Chemical Division Hoffman-LaRoche, Inc. Nutley, NJ 07410.

TABLE 2. Effects of feed intake and ambient temperature on body weight changes

INTAKE (% body weight)	Temperature 24 C	35 C
	grams	
AD LIB	38.3^{ab}	-42.10^{b}
5.46	-74.6^{bc}	-26.38^{b}
6.63	1.5^{b}	16.29^{b}
7.80	-16.3^{bc}	122.20^{a}
8.97	90.5a	135.17a

[ab] Means within same column without a common superscript differ (P<.05)

TABLE 3. Effects of ambient temperature on egg shell quality of birds fed ad libitum

Parameters	Ambient temperature 24°C	35°C
Feed intake(% body weight)	7.800^{a}	5.470^{b}
Egg weight (gms)	64.300^{a}	62.304^{b}
Specific gravity	1.079^{a}	1.069^{b}
Shell thickness (mm)	0.0135^{a}	0.0122^{b}
Shell weight (gms)	8.306^{a}	7.680^{b}
Albumin height (mm)	5.401^{a}	4.790^{b}
Yolk weight (gms)	18.621^{a}	19.032^{b}

[ab] Means within each row having different superscripts differ (P<.05)

TABLE 4. Effects of feed intake and ambient temperature on egg weight (gms)

INTAKE (% BODY WEIGHT)	Temperature 24 C	35 C
5.46	62.447^{bc}	61.895^{c}
6.63	64.867^{a}	64.276^{ab}
7.80	63.681^{abc}	63.481^{abc}
8.97	65.085^{a}	59.273^{d}

[abcd] Means without a common superscript differ ($P<.05$).

TABLE 5. Effects of feed intake and ambient temperature on egg specific gravity

INTAKE (% BODY WEIGHT)	Temperature 24 C	35 C
5.46	1.084^{a}	1.066^{b}
6.63	1.077^{ab}	1.064^{b}
7.80	$1,077^{ab}$	1.064^{b}
8.97	1.081^{a}	1.089^{a}

[ab] Means without a common superscript differ ($P<.05$).

FIGURE 1. Effects of feed intake and ambient temperature on egg weight

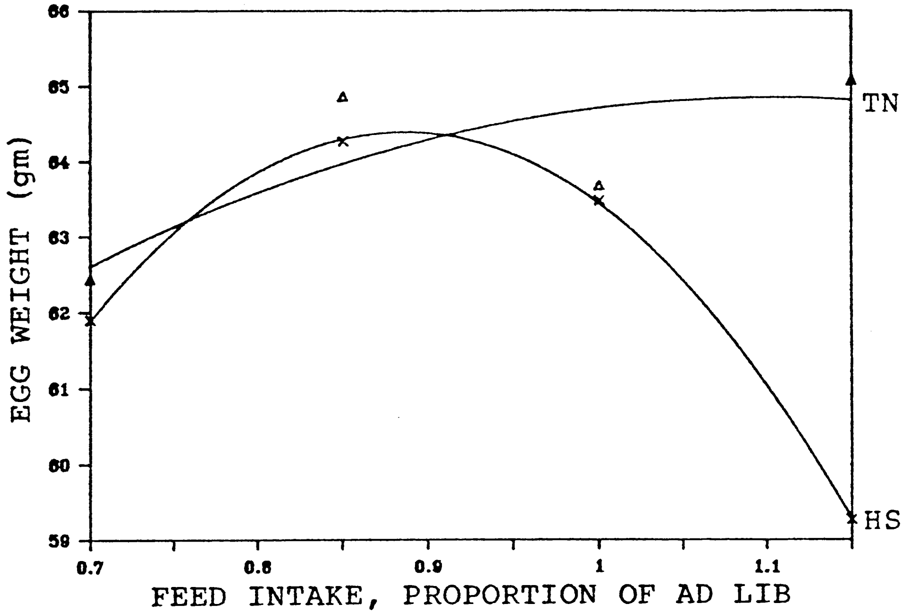

FIGURE 2. Effects of feed intake and ambient temperature on specific gravity

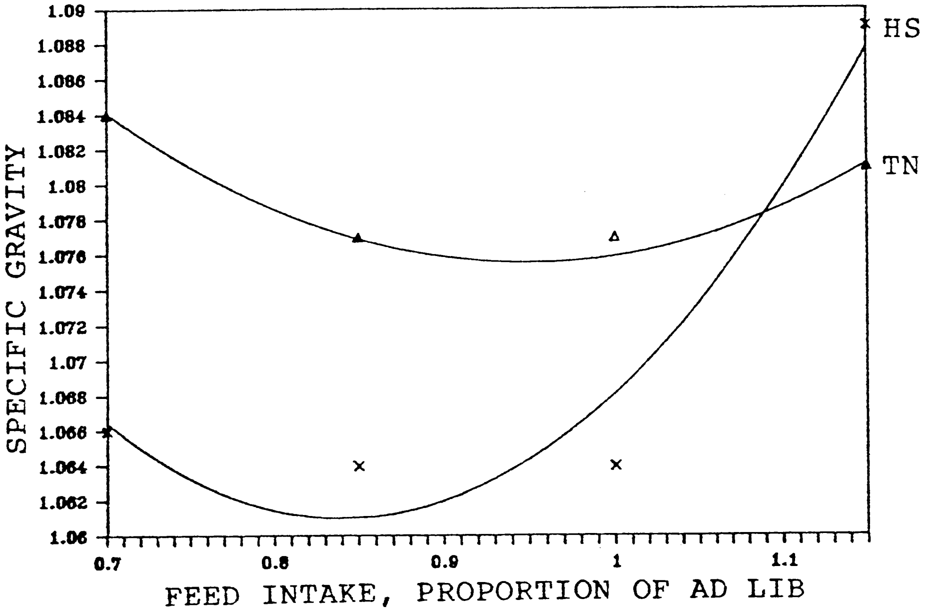

TABLE 6. Effects of feed intake and ambient temperature on egg shell thickness

INTAKE (% BODY WEIGHT)	Temperature 24 C	35 C
	mm	
5.46	.3404^{a}	.3073^{b}
6.63	.3353^{a}	.3124^{b}
7.80	.3429^{a}	.3073^{b}
8.97	.3404^{a}	.3022^{b}

^{ab} Means without a common superscript differ (P<.05).

TABLE 7. Effects of feed intake and ambient temperature on egg shell weight (gm)

INTAKE (% BODY WEIGHT)	Temperature 24 C	35 C
5.46	8.520^{a}	7.611^{c}
6.63	8.274^{ab}	7.778^{c}
7.80	8.176^{ab}	7.605^{c}
8.97	8.222^{a}	7.643^{c}

^{abc} Means without a common superscript differ (P<.05).

TABLE 8. Effects of feed intake and ambient temperature on egg albumin height

INTAKE (% BODY WEIGHT)	Temperature 24 C	Temperature 35 C
	mm	
5.46	4.934^{bc}	4.448^{d}
6.63	5.369^{ab}	4.637^{cd}
7.80	5.207^{b}	5.092^{bc}
8.97	5.846^{a}	5.223^{b}

[abcd] Means without a common superscript differ ($P<.05$).

TABLE 9. Effects of feed intake and ambient temperature on egg yolk weight (gm)

INTAKE (% BODY WEIGHT)	Temperature 24 C	Temperature 35 C
5.46	18.254^{b}	18.583^{ab}
6.63	18.587^{ab}	19.176^{ab}
7.80	18.253^{b}	19.324^{a}
8.97	19.420^{a}	19.583^{a}

[ab] Means without a common superscript differ ($P<.05$).

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CHAPTER IV

AMMONIUM CHLORIDE EFFECTS ON EGG SHELL QUALITY OF LAYERS HOUSED UNDER THERMONEUTRAL AND HIGH ENVIRONMENTAL TEMPERATURES.

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Abstract

The effects of ammonium chloride on six egg quality parameters were estimated in layers housed under thermoneutral (25 C) and heat distressed (35 C) environments. Ammonium chloride levels evaluated were .25, .50, 1.0, 2.0% plus an additional treatment evaluating 1.0% ammonium chloride and .5% sodium bicarbonate. Increasing environmental temperature to 35C reduced egg weight by 8%, albumin height (7%), yolk weight (12%), shell weight (12%) and shell thickness by 8%.

Addition of ammonium chloride or a combination of ammonium chloride and sodium bicarbonate did not impact the parameters evaluated. Ammonium chloride tended (P<.10) to slightly reduced egg weight under the heat stress environment. These results suggest that the respiratory

alkalosis associated with heat distress does not account for deleterious effects of heat distress on egg shell quality.

Introduction

The effects of high environmental temperature on egg shell quality vary widely. During heat distress, evaporative cooling through panting is an important means of heat dissipation. As environmental temperature increases birds rely more on their respiratory system for thermolysis. Randall and Heistand (1939) noted that increasing respiration rate during heat stress increases the birds heat loss. Longhouse et al.(1960) found that pullets at 32C lost 60% of their body heat by evaporation. At 26C respiration rate is four times greater than at 19C (Kerstens, 1964). Siegel (1968) reported that respiration rate reached 140 to 170 respirations/minute when body temperature reached 44C.

Panting is initiated by the increase in temperature of blood flowing to the brain. Wilson (1948) stated that panting begins when ambient temperature reaches 26°C. However, El-Hadi and Sykes, 1982 concluded that birds start panting when ambient temperature reaches 32°C, at 38C is faster and at 41C it is very rapid. Panting is increased until body temperature reaches the upper critical limits and then it begins to fail (Randall and Hiestand, 1939).

Panting increases gas exchange and results in a decreased blood carbonic acid concentration. The increased respiration rate is responsible for changes in plasma $[H^+]$

and plasma [CO_2] (Mongin, 1968) which shift the bird toward respiratory alkalosis (Mueller, 1966). As blood CO_2 levels decrease base excess increases and renal loss of bicarbonate increases to reduce the alkalotic effects of heat stress (Mongin, 1968). Therefore, the birds electrolyte balance is of concern.

Under thermoneutral conditions Hall and Helbacka (1959) showed that feeding ammonium chloride or HCl to layers induced the production of thin shelled eggs. The same results were found by Hunt and Aitken (1962) who suggested that feeding ammonium chloride reduces plasma bicarbonate and carbonate radicals for egg shell formation. However, ammonium chloride inclusion in broiler rations has been observed to reduce the incidence of respiratory alkalosis and enhance broiler growth rate. If heat distressed layers exhibit respiratory alkalosis then ammonium chloride may likewise constitute a therapy.

Though the effects of ammonium chloride consumption by layers under heat distress where blood pH is elevated are not known, Odom reported (1985) that allowing layers to consume carbonated water enhanced egg shell thickness. Teeter (1987) reported that carbonated water increases growth rate of heat distress broilers and that the response is due to increased feed intake. Wether the effect with layers is due to feed consumption or pH is unclear. Increasing atmospheric carbon dioxide levels from .3mm Hg to 19mm Hg maintains egg production levels (Frank and Burger,

1965) while shell thickness was increased by 12% at 19mm Hg. Additional inclusion of sodium bicarbonate did not alter egg weight or shell thickness, blood pH, corbon dioxide or bicarbonate ions in birds housed in a thermoneutral environment. However, feeding sodium bicarbonate under heat stress improves egg shell quality (Howes, 1966; Mongin, 1968; Latif and Quisenberry, 1968). Howes (1966) found that addition of 1% $NaHCO_3$ had beneficial effects at high ambient temperature. Mongin (1968) concludes that addition of sodium bicarbonate during heat stress is beneficial, if sodium chloride levels are restricted. In one study, egg shell quality was reduced (Cox and Ballour, 1968).

Specific gravity of eggs were decreased by sodium bicarbonate supplementation (Hunt and Aitken, 1962). Hamilton and Thompsom (1980) studied the effects by varying the electrolyte balance in the diet observed a positive relationship between the sodium to chloride ratio and blood pH and blood bicarbonate; under normal conditions chlorine has a negative effect on shell quality whereas sodium was without effect. More recent studies, Christmas and Harms (1982) and Odiba (1981) observed no influence of sodium, potassium and chloride balance on egg shell quality under normal conditions.

Therefore the objectives of this experiment were to investigate the effects of 4 dietary levels of ammonium chloride and 1 ammonium chloride and sodium bicarbonate level on egg shell quality of birds housed under thermoneutral and high environmental temperatures.

Materials and Methods

Two hundred and seventy eight-72 week old Shaver layers were placed in individual metabolism cages (30 X 80 cms.) housed within three thermostatically and humidistatically controlled environmental chambers. The chambers were well lighted with both fluorescent and tungsten filament bulbs. Birds were on a 16 hour per day timed lighting schedule. Animals in each chamber were randomly divided into 6 groups and assigned to treatment at random. Both feed and water were provided for ad libitum consumption. All birds were allowed to adapt to the surroundings for a period of eight days. Treatments used in the experiment were composed of .25, .50, 1.0, and 2.0% ammonium chloride and one additional treatment consisting of the combination of 1.0% ammonium chloride and .50% sodium bicarbonate. All additions to the basal diet (TABLE 1) were made at the expense of polyethylene.

Feed consumption, egg weight, shell weight, shell thickness, specific gravity, yolk weight, albumin height and mortality were recorded during the two weeks of the experimental period. Eggs were collected daily, identified and kept at 65F for up to 24 hours when all egg parameters were determined. Egg weight in air and in water was used to determine specific gravity by the Archimedes principle. Specific gravity is equal to the egg weight in air divided by the egg weight in air minus egg weight in water times the density of the water. Eggs were then broken and albumin height recorded utilizing a ruler in milimeters. Yolks were separated and weighed. Shells were weighed and thickness determined with the Ames egg shell thickness measure model 25-5 dial micrometer. Measurements of egg shell thickness were taken at two different locations on the top one third part of the egg. Means were analized by the Duncan multiple range test to determine treatments effects (SAS, 1982).

Results and Discussion

Feed intake was reduced ($P<.05$) by 8.4% when ambient temperature was increased to 35C (TABLE 2). When .25% and .5% NH4Cl was added to the diet of birds housed under the thermoneutral condition feed intake was increased by 6.9% and 6.7% respectively. However, additions of 1 or 2% NH_4Cl had no effect on the birds feed consumption. Under heat stress addition of .25% NH_4Cl showed an increased of 7.3%. However no other treatment increased feed intake under the high environmental temperature. Exposing hens to the 35C environmental temperature resulted in a significant ($P<.05$) decrease in egg weight (TABLE 3) on birds fed the control diets. Addition of NH_4Cl to the basal diet fed to birds housed in the thermoneutral environment did not impact ($P>10$) egg weight, though, the dietary inclusion of 2% NH_4Cl tended ($P<.10$) to increase egg weight (3.18%). The results obtained in this study are in agreement with Hunt and

Aitken (1962) who observed no statistical differences when NH_4Cl was added to the diet of birds housed under thermoneutral environment. The combination of NH_4Cl and $NaHCO_3$ did not ($P>.10$) impact egg weight. Addition of the different levels of ammonium chloride to the diet fed to the heat stressed birds did not have ($P>.10$) any impact on egg weight. Similarly, the combination of NH_4Cl and $NaHCO_3$ had no effect ($P>.10$) on egg weight under the high environmental temperature.

Shell weight of birds consuming the control feed was decreased ($P<.05$) by the high environmental temperature (TABLE 4). Control birds shells were 12% lighter under the heat stress environment. Addition of different levels of NH_4Cl to the birds diet had no impact ($P>.10$) on shell weight in either the thermoneutral or heat stressed environment. The combination of NH_4Cl and $NaHCO_3$ had no impact ($P>.10$) on shell weight under either thermoneutral or heat stressed environment. However, there was a slight increase ($P>.05$) on egg shell weight when 1% NH_4Cl was fed to the birds under heat stress environment.

Shell thickness as shown in TABLE 5 was reduced by 9.3% ($P<.05$) when control birds were placed in the 35C environmental temperature, as compared with the control birds at 24C environment. Shell thickness on birds housed on the thermoneutral environment decreased ($P<.05$) when .25, .50 and 1% NH_4Cl were given in the diet. However, addition of 2% NH_4Cl to the feed, did not have any impact ($P>.10$) on shell thickness. Under heat stress environment, the inclusion of the various NH_4Cl levels had no effect ($P>.10$) on decreasing the deleterious effects of heat distress on the reduced egg shell quality. Similarly, the combination of NH_4Cl (1%) and $NaHCO_3$ (.50%) did not impact ($P>.10$) shell quality at either thermoneutral or heat stress environments. The .50 and the 1% NH_4Cl levels had a tendency ($P>.05$) to decrease shell thickness.

Egg specific gravity (TABLE 6) was reduced by 2% ($P>.10$) when birds were housed in the high environmental temperature as compared with the birds in the thermoneutral environment. Increasing the dietary NH_4Cl level of birds housed within the thermoneutral environment had no effect ($P>.10$) on specific gravity. Likewise, the combination of $NaHCO_3$ and NH_4Cl did not impact ($P>.10$) egg specific gravity within either the thermoneutral or heat stressed environment. Increasing the NH_4Cl levels to .25% slightly increased ($P>.05$) specific gravity. This specific gravity was maintain or slightly reduced when birds were fed the .50, 1.0, and 2% levels of NH_4Cl.

Increasing the environmental temperature to 35C had a significant effect ($P<.05$) upon yolk weight (TABLE 7). Control birds in the 35C chamber had a 12% decline ($P<.05$) in yolk weight as compared to the controls in the thermoneutral environment. Increasing the levels of NH4CL or the combination of NH_4CL and $NaHCO_3$ did impact ($P>.10$) yolk weight in either heat stressed or thermoneutral environments. However, only the 2% level of NH_4Cl had a tendency (P>.10) to increase yolk weight on birds at the hot environment.

Albumin height has tendency to increase when birds are posed to high environmental temperatures (Campos et al., 1960; Hall and Helbacka, 1959). Alvar et al. (1982) noticed that eggs produced under high environmental temperatures had the relative portion of the albumin higher by 2.9% as compared with birds under thermoneutral environment. In our trial, egg albumin height (TABLE 8) from the control birds was not affected by the high environmental temperature. The addition of NH_4Cl and $NaHCO_3$ to the birds under thermoneutral environment had no effect on albumin height, though 1% NH_4Cl increased (P<.05) albumin height as compared to the control group. Under heat stress, egg albumin height improved by 6.18, 1.9 and 15% (P<.05) when NH_4Cl was added to the diet by .25, .50, and 1.0% respectively. Feeding the birds with 2% NH_4CL showed no effect on albumin as compared to Hall and Helbacka (1959) in which the addition of 3% NH_4Cl to the diet improved albumin height by 11.7% in birds housed at 32C. The inclusion of the combination of NH_4Cl with $NaHCO_3$ did not affect (P>.10) egg albumin height.

Although most of the research done on electrolyte balance has been under thermoneutral environment, and since its implications in egg shell quality have not been conclusive, it is very difficult to conclude or even to predict the affects that addition of NH_4Cl, $NaHCO_3$ or their combination to the diet, would have on the birds egg shell quality under heat stress environment. Our findings indicate that addition of ammonium chloride or the combination with sodium bicarbonate had little if any impact on the egg quality parameters studied. Odom (1982) observed an improved egg production when layers were given carbonated water. Bottje et al. (1983) increased daily gains and feed efficiency in heat stressed cockerels when given carbonated water. According to Bottje and Harrison (1985) carbonated water reduces losses of $pCO2$ during heat stress, thus partially correcting the blood acid-base imbalance, but also would provide a source of carbon dioxide and $H+$ ions for an increase in production. However, long term studies should be conducted to determine if these additives would become beneficial for the poultry industry under condition of high environmental temperatures.

TABLE 1. Ration composition

Ingredients	IFN[a]	% of diet
Ground corn grain	4-02-935	57.50
Soybean meal (44%)	5-04-604	21.00
Calcium carbonate	6-01-069	8.40
Animal, tallow	4-08-127	5.00
Dicalcium phosphate	6-01-080	2.60
Alfalfa	1-00-023	2.50
Salt	-	0.50
Vitamin premix[b]	-	0.35
D-L Methionine	-	0.10
Trace minerals	-	0.05
Polyethylene	-	2.00
Total		100.00

[a] International feed number

[b] Roche Chemical Division Hoffman-LaRoche, Inc. Nutley, NJ 07410.

TABLE 2. Effects of environmental temperature ammonium choride and sodium bicarbonate on feed intake (gm)

Treatments	Environmental Temperature	
	24C	35C
CONTROL	94.64^{a}	86.81^{b}
0.25 % NH_4Cl	101.64^{a}	93.66^{a}
0.50 % NH_4Cl	101.49^{a}	85.59^{b}
1.00 % NH_4Cl	93.63^{a}	86.96^{b}
2.00 % NH_4Cl	99.23^{a}	86.64^{b}
1.0% NH_4Cl and 0.5% $NaHCO_3$	95.98^{a}	88.05^{b}

^{ab} Means without common superscripts differ ($P<.05$)

TABLE 3. Effects of environmental temperature, ammonium chloride and sodium bicarbonate on egg weight (gms)

Treatments	Environmental Temperature	
	24 C	35 C
CONTROL	64.11^{abc}	60.59^{cde}
0.25 % NH_4Cl	62.40^{abcd}	60.13^{de}
0.50 % NH_4Cl	64.32^{ab}	57.40^{e}
1.00 % NH_4Cl	63.38^{abcd}	58.54^{e}
2.00 % NH_4Cl	66.21^{a}	59.26^{e}
1.0% NH_4Cl and 0.5% $NaHCO_3$	64.36^{ab}	57.94^{e}

^{abcde} Means without common superscripts differ ($P<.05$)

TABLE 4. Effects of environmental temperature ammonium chloride and sodium bicarbonate on shell weight (gms)

Treatments	Environmental Temperature	
	24—C	35—C
CONTROL	8.05^{ab}	7.08^{de}
0.25 % NH_4Cl	7.89^{abc}	7.11^{de}
0.50 % NH_4Cl	7.93^{abc}	6.80^{d}
1.00 % NH_4Cl	7.47^{bcd}	7.32^{cde}
2.00 % NH_4Cl	8.34^{a}	7.09^{de}
1.0% NH_4Cl and 0.5% $NaHCO_3$	8.04^{ab}	6.65^{e}

^{abcde} Means without common superscripts differ ($P<.05$)

TABLE 5. Effects of environmental temperature ammonium chloride and sodium bicarbonate on shell thickness (mm)

Treatments	Environmental Temperature	
	24 C	35 C
CONTROL	$.3261^{a}$	$.2955^{def}$
0.25 % NH_4Cl	$.3146^{bcd}$	$.3021^{cde}$
0.50 % NH_4Cl	$.3090^{bcde}$	$.2796^{f}$
1.00 % NH_4Cl	$.2975^{cdef}$	$.2796^{f}$
2.00 % NH_4Cl	$.3349^{a}$	$.2949^{def}$
1.0% NH_4Cl and 0.5% $NaHCO_3$	$.3168^{abc}$	$.2895^{ef}$

^{abcdef} Means without common superscripts differ ($P<.05$)

TABLE 6. Effects of environmental temperature ammonium chloride and sodium bicarbonate on specific gravity

Treatments	Environmental Temperature	
	24 C	35 C
CONTROL	1.0736^{ab}	1.0690^{bcd}
0.25 % NH_4Cl	1.0719^{ab}	1.0713^{abc}
0.50 % NH_4Cl	1.0688^{bcd}	1.0660^{cd}
1.00 % NH_4Cl	1.0690^{bcd}	1.0655^{d}
2.00 % NH_4Cl	1.0758^{a}	1.0689^{bcd}
1.0% NH_4Cl and 0.5% $NaHCO_3$	1.0720^{ab}	1.0663^{cd}

[abcd] Means without common superscripts differ ($P<.05$)

TABLE 7. Effects of environmental temperature ammonium chloride and sodium bicarbonate on yolk weight (gms)

Treatments	Environmental Temperature	
	24 C	35 C
CONTROL	18.30^{a}	16.46^{b}
0.25 % NH_4Cl	18.31^{a}	16.21^{b}
0.50 % NH_4Cl	18.67^{a}	15.75^{b}
1.00 % NH_4Cl	17.94^{a}	16.01^{b}
2.00 % NH_4Cl	18.69^{a}	16.53^{b}
1.0% NH_4Cl and 0.5% $NaHCO_3$	17.94^{a}	16.17^{b}

[ab] Means without common superscripts differ ($P<.05$)

TABLE 8. Effects of environmental temperature ammonium chloride and sodium bicarbonate on albumin height (mm)

Treatments	Environmental Temperature	
	24 C	35 C
CONTROL	5.56^{c}	5.53^{c}
0.25 % NH_4Cl	5.93^{bc}	6.35^{abc}
0.50 % NH_4Cl	5.67^{bc}	6.42^{abc}
1.00 % NH_4Cl	6.54^{ab}	6.88^{a}
2.00 % NH_4Cl	5.93^{bc}	5.82^{b}
1.0% NH_4Cl and 0.5% $NaHCO_3$	5.81^{bc}	6.05^{abc}

^{abc} Means without common superscripts differ ($P<.05$)

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CHAPTER V

SUMMARY AND CONCLUSIONS

The key to success for the egg producer under tropical climate or during the summer months is a proper management. Factors that are influenced by high ambient temperatures such as: feed intake and acid-base balance are of upmost importance in the formulation of poultry diets and in the birds handling during such periods.

In this study, research was conducted to evaluate the effects that different levels of feed intake have on the egg's shell quality and the impact that different levels of ammonium chloride and sodium bicarbonate have on the shell quality. Two trials utilizing 152 and 278, 72 weeks old birds were used at two environmental temperatures to investigate the egg's shell quality as affected by the above treatments.

In the first trial, five different levels of feed intake were forced to hens in two different environmental temperatures. Feed intake levels were 70, 85, 100 and 115% of the levels observed for layers housed in the thermoneutral environment. They were housed at $24^{O}C$ and $35^{O}C$. All parameters studied were measured and recorded daily during the 10 days experimental period. Egg weight, shell weight, shell thickness, specific gravity, albumin height and yolk weight were all decreased (P<.05) when birds were placed in the high ambient temperature. Increasing feed intake above heat stress ad libitum slightly increased egg's shell quality. However, feed intake manipulation did not restored layer's egg shell quality to the nonstressed levels.

In the second trial, different levels of ammonium chloride and sodium bicarbonate were mixed to a regular diet and feed to hens housed at two environmental temperatures (24C and 35C). Increasing environmental temperatures reduced egg weight, shell weight, shell thickness, albumin height, yolk weight and specific gravity, although only shell weight, shell thickness and yolk weight differences were significant (P<.05). Increasing levels of ammonium chloride and the combination with sodium bicarbonate had little, if any, impact on egg shell quality of birds housed under heat stress conditions.

This data indicate that during heat stress conditions, it is possible to reduce the negative impact it has on shell quality by increasing the birds feed intake. On the other hand, trying to correct the blood's pH balance of the birds under heat stress had no effect on reducing the undesired effect of heat stress conditions.

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