ABSTRACT

LEKSRISOMPONG, NIRADA. Effect of temperature during incubation and brooding on broiler chickens. (Under the direction of John T. Brake)

A series of experiments was conducted to study the effects of the interaction between incubation and brooding temperature on chicks and early broiler performance. Braun Thermoscan infrared thermometer methodology was used to measure internal egg temperature. Ross 344 x 308 broiler hatching eggs were used exclusively and 53% relative humidity was maintained during incubation. During the first 13 or 14 d of incubation air temperature was 37.5-37.7^{0}C (99.5-99.8^{0}F) following which eggs were assigned to either a HIGH 39.5-40.6^{0}C (103.1-105.1^{0}F) or a NORMAL 37.7-37.9^{0}C (99.9-100.2^{0}F) temperature incubator (range varied by experiment).

Six experiments, in various manners, measured the effects of incubation temperature, brooding temperature, sex, egg size, and all possible interactions on body weight (BW) on day of hatching (0 d) up to 28 d of age as well as relative weights of tissues and organs from 0 d to 21 d of age. Certain experiments measured feed consumption, BW, adjusted feed conversion ratio (AdjFCR), and deaths at 0, 2, 5, 7, 12, 14, 21, and 28 d of age.

BW, heart, gizzard, proventriculus, and small intestines of chicks were decreased due to increased incubation temperature while the liver and yolk sac were increased. The proventriculus and small intestines were larger in females than in males. Small sized eggs produced chicks with smaller yolk sacs, and larger hearts and gizzards than average and large sized eggs. BW increased while heart and small intestines weights were decreased at 14 and 21 d by hot brooding.

Feed consumption was decreased by increased incubation temperature at all ages but was increased by hotter brooding temperature during the 0-7 d period but decreased during the 7-14 d period. Hot-brooded chicks that had been incubated in the normal incubator consumed the most feed while cool-brooded chicks that had been incubated in the hot incubator consumed the least feed during the 0-2 and 0-7 d periods.

BW was significantly decreased by increased incubation temperature up to 21 d. Cool brooding increased BW more for normal incubated chicks than did hot brooding at 7 d of age. By 14 d the high incubation-hot brooding chicks were smaller than all other groups while the normal incubated-cool brooded chicks were larger than all other groups. Males with a combination of normal incubation temperature and cool brooding temperature exhibited heavier BW than males with a combination of high incubation temperature with cool brooding temperature while brooding had less effect on males from hot incubation and there was little differentiation among the females at 14 d of age.

AdjFCR was decreased (improved) by increased incubation temperature up to 21 d because the chicks did not eat. The AdjFCR was increased (worsened) by increased brooding temperature during 2-5 d and 0-7 d periods. Chicks from the high incubation temperature and brooded in a cool room had lower (better) AdjFCR than the other chicks. Mortality for the 0-7 and 0-14 d periods was significantly increased by increased incubation temperature. There was higher mortality for high incubated-cool brooded chicks during the 0-7 d period. Males at a cool brooding temperature exhibited a greater percentage mortality than females at 0-7 d. Elevated incubation temperature negatively affect embryo development and broiler performance up to 28 d of age. The problem could be reduced by hot brooding temperatures

during the first days of life. However, hot brooding temperature decreased feed consumption and growth if continued for more than a few days.

EFFECT OF TEMPERATURE DURING INCUBATION AND BROODING ON BROILER CHICKENS

by

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A thesis submitted to the Graduate Faculty of
North Carolina State University
in partial fulfillment of the
requirements for the Degree of
Master of Science

POULTRY SCIENCE

Raleigh

2005

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BIOGRAPHY

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ACKNOWLEDGEMENTS

The author would like to express her DEEP appreciation and thanks to Dr. John T. Brake who through his mentorship, constructive criticism, and friendship has contributed substantially to her professional and personal development in a manner that has extended far beyond the scope of the graduate degree program. Appreciation is also expressed to Dr. Jerry Spears and Dr. Vern Christensen for serving on the graduate committee and providing helpful criticism and insight.

The technical assistance and friendship of fellow graduate students Hugo Romero-Sanchez and Peter Plumstead are greatly valued while a very special thanks goes to Susan Creech who has not only helped considerably in all technical aspects of my work but whose support and advice has also contributed substantially to my personal development. Gratitude is also extended to the staff at the Lake Wheeler Road Field Laboratory and, in particular, to Terry Reynolds, Paul Otto and Quinton Jones for their hard work and attention to detail throughout the execution of my research. I would like to thank my beloved father Vinai Leksrisompong and my mother Phatanee Leksrisompong for guidance, encouragement, and financial support. I would like to thank my sisters Chanatip, Phanin, and Pattarin Leksrisompong for their support.

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LIST OF ABBREVIATIONS

AdjFCR	Adjusted feed conversion ratio, corrected for mortality
ATP	Adenosine triphosphate
BW	Body weight
C	Celsius
cm	Centimeter
d	Day
E	Embryonation
F	Fahrenheit
FCR	Feed conversion ratio
g	Gram
h	Hour
IPP	Inositol pentaphosphate
kg	Kilogram
min	Minute
PCO_2	Partial pressure of carbon dioxide
pH	Power of hydrogen
PO_2	Partial pressure of oxygen
RH	Relative humidity
SD	Standard deviation
SDS	Sudden death syndrome

T_3	Triiodothyronine
T_4	Thyroxine
wk	Week
2,3-BPG	2,3-Bisphosphoglycerate

INTRODUCTION

Incubation has been generally accepted as one of the most important aspects of poultry husbandry. Research has shown the optimum incubation temperature to be around 37.0^0C (98.6^0F) to 38.0^0C (100.4^0F) for chicken eggs (Insko, 1949; Romanoff, 1960; Landauer, 1967; Lundy, 1969; Wilson, 1991) and 37.5^0C (99.5^0F) for turkey eggs (Romanoff, 1935; French, 2000). Abnormal incubation temperatures have been shown to affect post-hatch growth (Romanoff, 1935, 1936; Michels *et al.*, 1974; Decuypere, 1979; Geers *et al.*, 1982) and proper organ development of avian embryos (Shafey, 2004). Eggs that were incubated by feral fowl in natural conditions appeared to develop at a relatively constant temperature that must be near optimum for proper embryo development (Romanoff, 1935). However, it has always been difficult to maintain a completely constant machine air temperature during artificial incubation due to the increase in egg temperature that results from increasing metabolic rate of the large mass of growing embryos in the incubator(s). According to French (1997), eggs will absorb heat from the surrounding air during the first half of incubation due to embryo temperature being slightly lower than incubator temperature but embryos must lose heat during the second half of the incubation as their metabolic rate and heat production increase. This may also be related to the developing chicken embryo being a poikilotherm, making it susceptible to fluctuations in body temperature (Tazawa *et al.*, 1988, 1989; Whittow and Tazawa, 1991). However, in spite of all, according to Lundy (1969), incubation conditions that result in the best hatchability generally elicit the best chick quality, which is the ultimate goal of artificial incubation.

Brooding has also been shown to be a critically important aspect of poultry husbandry. According to Osbaldiston and Sainsbury (1963), brooding has been defined as the provision of a warm place for the young chicken. Chick quality and behavior have been shown to be influenced by brooding conditions. Brooding has been shown to be critical to determination of how rapidly the chick would grow. Having a correct brooding temperature from the first day of brooding could result in having fast growing chicks with a decreased mortality rate (Osbaldiston and Sainsbury, 1963).

The objectives of the present experiments were to confirm that high incubation temperatures adversely affect the development of key organs of the modern chick and decrease post-hatch chick feed consumption and growth rate, while hot brooding temperature (litter temperature) during the first weeks of life could decrease chick mortality and improve chick feed consumption and growth rate.

LITERATURE REVIEW

Factors Affecting Embryonic Growth and Development. It has been well documented that chick embryos will develop and hatch in approximately 21 d (Yalcin and Siegel, 2003) and turkey embryos in 28 d (Christensen *et al.*, 1993; French, 2000) when conditions are optimal. Many factors have been shown to affect the metabolism and growth of embryos during the incubation period; such as, turning, vital gas exchange, temperature control, and moisture loss.

Temperature has been indicated to be the most important factor controlling embryo growth and development (Meijerhof, 2000). Embryo body temperature has been shown to be governed by incubation temperature as studies concerning thermogenesis in the chick embryo have indicated that the embryo cannot properly regulate its body temperature until the hatching process has been completed (Romijn and Lokhorst, 1955; Freeman, 1964, 1966, 1967, 1970, 1971; Wekstein and Zolman, 1967, 1968, 1969, 1970; Davidson, 1973).

Eggshell porosity must also be appropriate to accommodate the respiratory needs of the embryo, allowing for adequate gas exchange but also prevention of desiccation (Westmoreland, 2003). For example, the diffusion of vital gases through the eggshell pore system has been shown to be vitally important (Freeman and Vince, 1974). The age of the parent (breeder hen) has been reported to be another factor affecting the embryo such that eggs from early production breeder flocks usually have thicker albumen and eggshells, which can contribute to reduced moisture loss, vital gas exchange (Brake *et al.*, 1997), and nutrient availability (Benton and Brake, 1996). Romanoff (1960) noted that the connection between the albumen sac and the amniotic cavity appeared between E11 and E13 of incubation during the course of normal development. The albumen begins to enter the amniotic cavity at E13,

and almost all of the albumen has been absorbed by E17 or E18 under normal incubating conditions. Romanoff (1960) indicated that high incubation temperatures caused inhibition of embryo growth due to under utilization of albumen due to the interference with albumen transfer from the egg into the amniotic cavity, i.e. due to an induced nutritional (energy) deficiency.

As the growth and development of the embryo progressed to the end of the incubation, the adverse effects of elevated or suboptimal incubation temperatures have been found to diminish over time (Romanoff, 1939). Additionally, once pulmonary respiration commenced, there was no effect on the metabolic rate of the embryo with a change in incubating temperature (Pembrey *et al.,* 1895; Giaja, 1925).

Organ Growth and Development. There have been many studies on the specifics of embryological development since 1900 (Romanoff, 1960). Growth efficiency of the embryo has been reported to be affected by incubation temperature (Penquite, 1938; Michels *et.,* 1974; Kuhn *et al.,* 1982; Geers *et al.,* 1983). Growth appears to be most efficient at the optimum temperature for maximum hatchability (Romanoff, 1936). Studies have been performed to determine the effects of incubation temperature on organ (Romanoff, 1960; Rozemboim *et al.,* 2004) and bone development (Moraes *et al.,* 2002). Yalcin and Seigel (2003) found that variation in temperatures between 36.9^{0}C (98.4^{0}F) and 39.6^{0}C (103.3^{0}F) influenced the growth of the skeleton but a compensatory mechanism ensued to modulate those changes by the time of hatching.

Olivo (1928) stated that the avian heart started its embryonic development at a very early stage and continued up to 10 d post-hatch to provide the basic platform for circulatory system development. The rate of mitotic activity was faster at E2 than at E13 of incubation although

the relatively high mitotic rates at E13 still played a crucial role in increasing the heart wall thickness by E20 of embryological growth (Olivo, 1928). Further studies by Olivo (1931) with three incubation temperatures (34.5^0C (94.1^0F), 36.5^0C (97.7^0F), and 39.5^0C (103.1^0F)) have shown temperature to significantly affect the number of mitotically active myocytes of the heart. It was shown that the weight of the heart of embryos in eggs exposed to a high incubation temperature differed significantly before E7 of incubation; however, the trend changed after E9 to result in a linear weight gain progression at high incubation temperatures, i.e. an increasing negative association between incubation temperature and in cardiac cell division. This allowed the lower temperature embryos to exhibit a greater heart weight.

The liver also develops by mitotic cell division in a manner similar to the heart. Romanoff *et al.* (1938) showed that from E4 (0.3 mg) to E8 (17.4 mg) of incubation the liver grew 58-fold from its initial mass and by E12 liver mass reached between 75-100 mg, by E20 between 580-640 mg and at hatching between 820 to 1500 mg. High incubation temperature also caused a decline in cell division in the liver as it did in the heart.

Recently, a study concerning the effects of photostimulation on embryonic growth and acceleration of organ development (Shafey, 2004) has become of interest.

Effects of Hyperthermic and Hypothermic Incubation Temperatures. Many studies concerning the effects of temperature on hatchability have been reviewed (Barott, 1937; Kosin, 1964; Landauer, 1967; Lundy, 1969). Researchers have shown that the major factors affecting the developing embryo were incubation temperature, thermal conductance of the egg and surrounding air, and metabolic heat production of the embryo (French, 1997). Many factors affecting optimal heat transfer from the incubator air to the egg have been found in

commercial incubators; for example, the manner in which the air rises, the manner in which the fan rotates, and the design of the machine (Owen, 1991). Furthermore, according to the prediction equations of Sotherland *et al* (1987) and Meijerhof and van Beek (1993), air speed was one of the major factors that influenced thermal conductivity. Egg thermal conductivity has been reported to be mainly influenced by air speed (velocity) over the egg, which in turn affects embryo temperature (French, 2000). The uniformity of airflow, and therefore velocity, depends on how easily the air can pass between the trays and the eggs within an incubator (French, 1997). The embryo temperature during incubation has been shown to be a combination of heat production by the embryo resulting from growth and metabolism, the airflow surrounding the eggs, and the ability of the air to transfer heat (French, 1997). It has been suggested that larger eggs have greater difficulty losing metabolic heat produced by the embryos because as egg mass increased, thermal conductance did not increase proportionally (French, 1997).

There have been studies of higher-than-optimum temperatures affecting overall hatchability with turkey eggs (Romanoff, 1935) at different development stages (French, 1994a) and for longer periods of exposure to higher-than-optimum temperatures higher-than-optimum temperatures in chicken eggs (Wilson, 1991). Incubation temperatures above the optimal temperature have been reported to accelerate growth rates of avian embryos (Romanoff, 1960; Christensen *et al*., 1999) and have been reported to negatively impact hatchability, feed conversion, BW, and general post-hatch chick and poult performance (Gladys *et al*., 2000). Evidence has shown that high embryo temperatures during incubation can lead to reduced chick growth rate during the subsequent brooding period due to heat-stressed chicks being less alert and more sensitive to poor post-hatch brooding conditions. These chicks also had

an abnormal appearance (Thompson *et al.,* 1976). Studies with turkey eggs by Romanoff (1935) and French (1994a, b) showed that an increase of 1^0C or more above the generally accepted optimum (37.5^0C (99.5^0F)) reduced hatching success significantly. Overheating turkey eggs caused an increase in embryo mortality during the third and fourth week of incubation and at the pipping stage (French, 2000). Acute heat stress at 40.0^0C (104.0^0F) of E16 embryos caused an increased mortality, especially at E19 of incubation (Romanoff and Faber, 1933). However, Wilson *et al.* (1975) reported no significant decreases in hatchability with exposures of up to 24 h at a similar stage of incubation. Chronic exposure of chicken embryos to 39.0^0C (102.2^0F) or higher temperature caused increased embryo abnormalities and higher chick mortality (Romanoff, 1936; Penquite, 1938; Henderson, 1939). Romanoff *et al.* (1938) found that older embryos were more susceptible to a higher temperature than E0 to E5 chick embryos when exposed to 41.0^0C (105.8^0F) for 24 h. Moreng and Shaffner (1951) found that embryos at E1 or over E7 of age were able to survive 43.3^0C (109.9^0F) when exposed for up to 8 h, but E4 embryos would be killed after 10 min of a similar exposure. Conversely, studies by Ande and Wilson (1981) found that E7 and E19 embryos were the least resistant to high (43.3^0C (109.9^0F)) temperature and E3 embryos were the most resistant to heat stress when exposed to this temperature for 1 to 12 h. Morgan and Tucker (1967) showed that embryo mortality was lower at E7 and E8 compared to E9 and E10 of incubation when embryos were exposed to 41.0^0C (105.8^0F) for 3 h.

Chicks that hatched following a severe heat stress were weaker (Thompson *et al.,* 1976), less alert, and had matted, coarse down that resulted in an abnormal and unthrifty appearance (Thompson *et al.,* 1976). Such chicks have been reported to have a high incidence of clubbed, wiry down, and an unsteady gait (Wilson, 1991). On the other hand, embryos

exposed to a lower than optimal incubation temperature for more than 36 h also had improper positioning of the embryo and reduced chick weight (Suarez *et al*., 1996).

High incubation temperatures (between 37.5^{0}C (99.5^{0}F) to 39.0^{0}C (102.2^{0}F)) accelerated embryonic development and hatching time (Romanoff, 1936) but decreased the maximum hatchability. A decrease in incubation temperature by 2 to 3^{0}C towards the end of incubation resulted in an improved embryo growth rate and metabolism while decreasing embryonic mortality and improving chick quality at hatching (Romanoff and Faber, 1933). Incubation of eggs at below optimal temperatures resulted in a delayed hatching time, fewer pipped eggs, and consequently a lower hatching rate (Insko, 1949).

As discussed above, the period of embryo susceptibility to high temperatures varied among the studies and appeared to depend upon the stage of embryo development at the time of exposure and the temperature used during that exposure, i.e. cumulative time and duration effects. The effect of short exposures to high temperatures on embryos incubated at otherwise optimal temperatures was shown to be dependent on length of the exposure, size and age of the embryo, and deviation from the optimal temperature (Lundy, 1969). Studies by French (1997) showed that embryos were more susceptible to high temperature during the second half of incubation and he hypothesized that this was due to a metabolic heat production adaptation by the embryo, but that high incubation temperatures during E6-E18 of incubation could also interfere with the ability of the embryo to position itself correctly within the egg (French, 2000). Studies by Romanoff *et al.* (1938) and Ande and Wilson (1981) demonstrated that embryos were very sensitive to acute high temperature during early stages of incubation. Thus, there remains controversy as to which incubation stage was most

sensitive to acutely high incubation temperatures. Variations might be influenced by genetic differences in metabolism of the embryo and resultant broiler (Ande and Wilson, 1981).

Temperature and Thermoregulatory Effects On Metabolism and Oxygen Dynamics. The shift from poikilothermic to homeothermic metabolism (using elevated V_{O2} (volume of Oxygen) to produce heat to generate body heat) in chicken embryos has been characterized as an important physiological transition that occurs during the last twenty percent of incubation (Black and Burggren, 2004a). This thermoregulatory transition concerning heat production metabolism to support oxygen transport and to regulate body temperature (Black and Burggren, 2004a) and support organ development and maturity (Romanoff, 1960) has been viewed as obligatory and essential. Incubation temperature to modified the onset of the ability of the chicken embryo to trigger endogenous heat production as part of developing thermoregulatory mechanisms (Black and Bruggren, 2004a). Newly hatched chicks have been reported to rely upon non-shivering endogenous heat production as a thermoregulatary mechanism to control body temperature (Whittow and Tazawa, 1991; Roberts, 1996; Tazawa *et al.*, 2001).

Dzialowski *et al.* (2002) stressed the importance of blood oxygen transport efficiency and suggested that total blood oxygen carrying capacity was an important acclimation response that facilitated appropriate vital gas delivery to tissues and organs during embryo development as maturity of both the cardiovascular and respiratory systems was crucial to insure the delivery of oxygen to support metabolic processes, and permit optimum heat production and body temperature regulation.

Oxygen transport rates in the chicken embryo have been reported to be limited by diffusive gas exchange across the shell, especially when oxygen demands were high during the later

development stages of incubation (Tazawa *et al.*, 1992). As reported by Black and Bruggren (2004a), the significantly larger embryo wet mass of 35.0^0C (95.0^0F) incubated embryos contributed to having a low mass-specific V_{O2} and a large amount of variation in V_{O2} during E19-E20 of incubation as compared to 38.0^0C (100.4^0F) incubated embryos. This might be due to failure of the chorioallantoic membrane (CAM) in the 35.0^0C (95.0^0F) embryos to line the entire inner surface of the egg shell causing a smaller surface area for gas exchange as this might have a negative impact on the embryos with the largest metabolic demand, i.e. E19-E20 embryos (Black and Bruggren, 2004a). Studies from Okuda and Tazawa (1988) proved that by covering up to 50% of the shell of chicken eggs with epoxy, effectively reducing the surface area of the CAM able to exchange gases with the environment, that there was a significant reduction in gas conductance that resulted in a reduced V_{O2}. ***Incubation Temperature Effects On Blood Oxygen Carrying Capacity and Hemoglobin-Oxygen Affinity.*** Embryos that were incubated at 38.0^0C (100.4^0F) showed a significant increase in both blood oxygen carrying capacity and hemoglobin-oxygen affinity between E17-E20 of incubation (Tazawa *et al.*, 1971; Black and Burggren, 2004b) but this was not observed in 35.0^0C (95.0^0F) embryos (Black and Burggren, 2004b). According to Black and Burggren (2004b), hypothermic incubation reduced hematocrit (packed cell volume) from 31% in 38.0^0C (100.4^0F) incubation to 27.5% at 35.0^0C (95.0^0F) incubation during later embryonic stages, suggesting a reduction in red blood cell production. On the contrary, hypoxic incubation, which occurred at normal incubation temperatures, increased both hematocrit and hemoglobin (Hb) of embryonic chicken blood (Dusseau and Hutchins, 1988; Dzialowski et al., 2002), and such blood would presumably have a greater potential oxygen carrying capacity than that of typical 35.0^0C (95.0^0F) incubated embryos (Black and

Burggren, 2004b). The 35.0^{0}C (95.0^{0}F) embryos had hemoglobin with a higher oxygen affinity that resulted in more completely saturated blood at the respiratory gas exchange surface (Black and Burggren, 2004b). Black and Burggren (2004b) also suggested that increasing the total oxygen carrying capacity of the blood may be an important acclimation response ensuring adequate oxygen delivery to tissues prior to hatching.

Since an egg incubated at a normal temperature did not have an increased hemoglobin-oxygen binding affinity, as was the case with the lower temperature, oxygen conditions must have become increasingly hypoxic *in ovo* as the restrictions of diffusive gas exchange across the egg shell failed to meet the growing oxygen demands of the rapidly developing embryo (Wagensteen *et al.*, 1970; Rahn *et al.*, 1974; Ar *et al.*, 1980; Tazawa, 1980; Reeves, 1984). Consequently, the partial pressure of oxygen in the air cell (P_{O2}) declined about 5.3 kPa from the early stages of incubation up to prior to pipping (Reeves, 1984; Burggren *et al*., 2000) and venous P_{O2} also declined about 2.5kPa from E12 to E17 of incubation (Tazawa *et al.*, 1971). Following this pattern, the partial pressure of carbon dioxide in blood (P_{CO2}) increased during development, which resulted in a progressive decrease in blood pH (Tazawa, 1973).

In contrast, an incubation temperature of 35.0^{0}C (95.0^{0}F) resulted in a lower oxygen carrying capacity that corresponded to the significantly increased hemoglobin-oxygen affinity required to maximize the loading of oxygen at the respiratory surface to compensate for restriction of total oxygen carrying capacity (Black and Burggren, 2004b). Elevated hemoglobin-oxygen binding affinity has been reported to provide an efficient load of oxygen at the respiratory surface and adequate delivery of oxygen to metabolically active tissues (Reeves, 1984).

Another factor that affected oxygen affinity of embryonic chicken blood was the organic phosphate concentration, as stated by Baumann and Meuer (1992). Chick embryos depend upon adenosine tri-phosphate (ATP) as the primary organic modifier of hemoglobin-oxygen affinity from the beginning to approximately E12 of incubation (Misson and Freeman, 1972; Barlett and Borgese, 1976; Baumann and Meuer, 1992; Hochachka and Somero, 2002). From E8 until E18 of incubation, the hemoglobin-oxygen affinity reached its maximum pre-pipping plateau causing hypoxia to develop within the egg and, at this point, the aerobic production of ATP was more difficult to achieve such that there was a decrease in blood ATP concentration (Barlett and Borgese, 1976; Nikinmaa, 1990). These authors also stated that as ATP concentration declined, the anaerobic production of 2,3-bisphosphoglycerate (2,3-BPG) increased and this organic phosphate then acted as the primary allosteric modifier of hemoglobin until after hatching, when inositol polyphosphate (IPP) became the adult allosteric modifier (Barlett and Borgese, 1976; Nikinmaa, 1990). Thus, it can be concluded that oxygen regulates the concentrations of organic phosphates and the timing of the metabolic shift from ATP to 2,3-BPG while incubation temperature alone did not induce obvious changes in the patterns of organic phosphate concentration in the late-stage chicken embryo (Black and Burggren, 2004b).

Development of Ascites. Over the last twenty years, the broiler industry has reduced the time required to achieve a BW of 2 kg by 1.3 d per year (McKay, 1997). This rapid increase in growth rate within a short period of time may contribute to metabolic problems such as Sudden Death Syndrome (SDS), and ascites (Brake, 1997), which have been related to relative oxygen deficits. There have been several clinical signs associated with the ascites syndrome in broiler chickens: pulmonary hypertension, right ventricular hypertrophy, central

and portal venous congestion, hepatic damage, and transduction of fluid into the abdominal cavity (Riddell, 1991; Yersin *et al.,* 1992; Julian, 1993; Wideman *et al.,* 1995a). These signs were typical of events initiated by hypoxemia (abnormal reduction of oxygen level in the blood) that could results in ascites and death (Julian, 1993, 1998; Wideman and Boittje, 1993; Maxwell *et al*., 1995). SDS and ascites have been characterized by failures of the heart and lungs and enlargement of the liver, which may occur in certain broilers given *ad libitum* access to feed when exposed to low ambient temperatures. There are three categories of ascites according to the most recent reviews of the etiology of ascites: 1) pulmonary hypertension, 2) miscellaneous cardiac pathologies, and 3) cellular damage caused by reactive oxygen species (Currie, 1999). The rapid growth of broilers and cool environmental temperatures have been shown to be two of the primary conditions that trigger ascites (pulmonary hypertension syndrome) in commercial broiler production. Under these two conditions, broilers require more oxygen and thereby force the heart to increase its cardiac output (Vogel and Strukie, 1963; Whittow *et al.,* 1966; Sturkie, 1986; Leeson, 1986; May, 1989; Wideman, 1999). Concurrently, the hematocrit, hemoglobin, and red blood cell count were all increased dramatically in a compensatory manner (Hall and Machicao, 1968; Cueva *et al.,* 1974; Maxwell *et al.,* 1986, 1987; Yersin *et al.,* 1992). However, Kuhn *et al* (1984b); Jones (1994) and Buys *et al* (1999 a,b) stated that ambient temperature and dietary metabolizable energy level were two other important factors related to the rate of metabolic activity and, hence, to the amount of oxygen required by the animal, and should be considered in the etiology of ascites. High metabolic rate has also been associated with the increased secretion of the hormone thyroxine (T_4), which has been shown to be deiodinated to triiodothyronine (T_3) in the periphery, mainly in the liver and kidneys with

triiodothyronine becoming the main metabolic stimulating hormone (McNabb and King, 1993; Gabarrou *et al*., 1997). Triiodothyronine has also been reported to be an important hormone associated with temperature regulation and growth promotion in chickens (McNabb and King, 1993; Carew *et al.*, 1998; Gonzales *et al.*, 1999; Yahav, 2000). Thus, triiodothyronine might also be involved in modification of growth rate in response to environmental temperature.

According to Shigenaga *et al* (1994), a controlling factor in oxygen supply and demand was mitochondria that account for 85 to 90% of cellular oxygen consumption. Also, recent data have indicated that broilers with ascites suffer from increased oxidative stress (Enkvetchakul *et al.*, 1993) and defects in liver (Cawthon *et al.*, 1999) and lung (Iqbal *et al.*, 2001) mitochondrial oxygen consumption. Chance *et al.* (1979) stated that the defect in the electron transport chain may be involved in the development of the mitochondrial dysfunction now associated with ascites since mitochondria were a major contributor to oxidative stress and a primary oxygen consumer.

Metabolic and Physiologic Adjustments at Hatching. The plateau metabolism and pipping stages coincide with hormonal secretions causing maturation of vital tissues, the replacement of diffusive respiration through the shell by pulmonary respiration (Rahn *et al*., 1974), and the onset of homeothermy (McNabb, 1988) influencing both physiologic and metabolic adjustments within the embryo as a whole. Therefore, avian species such as the turkey that spend more time at these stages (Abbot and Craig, 1960) have exhibited increased embryonic mortality due to genetic selection for egg production and accelerated growth (Christensen, 1993). It has been demonstrated that the yolk sac provides nutrients for embryos during the later stages of incubation (Freeman and Vince, 1974) in the form of specific fatty acids that

the embryo may utilize selectively during successive developmental stages (Speake *et al.*, 1998) as a source of energy for growth and organ development. As birds grow, embryonic tissue glycogen levels change concomitantly (Christensen, 1999) allowing for redirection of energy substrates from organ growth to maturation of organ functions (Ricklefs, 1987).

Incubation temperature has already been shown to be the most important factor affecting hatchability and any deviation from the optimal temperature can adversely affect hatchability (Insko, 1949; Landauer, 1967). High incubation temperature (French, 2000; Christensen *et al.*, 1999; Hassan *et al.*, 2004) or low incubation temperature (Black and Burggren, 2004a; Feast *et al.*, 1998; Yalcin and Siegel, 2003) had adverse effects on embryonic growth, as well as metabolic and physiologic adjustments. Incubation temperature has been known to modify the metabolic rate of the developing embryo and affecting nutrient utilization and oxygen consumption. It has been speculated that many of the metabolic problems incurred during the broiler growing period might be initiated by exposure of the embryo to high temperatures during the critical final stages of the incubation period (Brake, 1997).

Role of Hormones in Late Embryonic Development and Subsequent Brooding. Harvey *et al* (1979), upon examining the ontogeny of growth hormone release in chicken neonates, observed sharp increases in several circulating hormones subsequent to hatching, which they partially attributed to postnatal responsiveness to changes in nutritional and environmental conditions. However, growth hormone levels were decreased on the first day after the initial reduction of the brooding temperature (Harvey *et al.*, 1979; Scott and Washburn, 1985), but subsequently growth hormone levels of their 26.7^0C (80.6^0F) group were significantly elevated above those of their 32.2^0C (90.0^0F) group (Scott and Washburn, 1985). This suggested that lower temperatures stimulated growth hormone secretion**.**

The relatively high circulating levels of corticosterone that have been observed subsequent to hatching by several authors (Kalliecharan and Hall, 1974; Siegel and Gould, 1976; Satterlee *et al*., 1980; Scott *et al*., 1981) have suggested that adaptive mechanisms may be functional in neonates. According to Palokangas and Hisssa (1971), plasma corticosterone was elevated when chickens were exposed to cold (Buckland *et al.,* 1974; El Halawani *et la.,* 1973; Nestor and Bacon, 1982). On the other hand, heat also causes a significant increase in corticosterone concentration in plasma (Nathan *et al.,* 1976; Edens and Siegel, 1976). Corticosterone is the most common glucocorticoid in birds (Remage-Healey *et al.,* 2001) and its role under stress conditions is well known. Glucocorticoids released during stress mobilize lipids from adipose tissue, which supports gluconeogenesis. In this manner, stored triglycerides are broken down into nonesterified fatty acids, which then can be processed by the liver and other tissues for energy supply through synthesis of ATP (Norris, 1985). Also, glucocorticoids inhibit synthesis of triglycerides from nonesterified fatty acids (Bentley, 1998). Corticosterone is essential for bird's life and severe stress depletes its reserves therefore chickens are very susceptible to the extreme temperatures during the brooding.

Freeman (1971) suggested that the thyroid gland was important to neonatal thermoregulation, and that thermoregulation was under the control of thyroid hormones. According to Scott and Washburn (1985), all growth and serum parameters were affected by reduction of brooding temperature and that the responses primarily occurred during the initial 24 to 48 h after placement in the brooding quarters. Therefore, neonatal chickens exposed to a cold environment would have increased levels of thyroxine and triiodothyronine in order to maintain body temperature within a normal range (Freeman, 1970; Davison, 1976; Bobek *et al.,* 1977). Other studies (Nobukuni and Koga, 1975; Nobukuni and Nishiyama, 1975, 1979)

have shown that the survival of chicks exposed to cold was dependent upon the presence of thyroxine. All of the serum proteins, albumin, and globulin concentrations were also higher for neonates brooded at cooler temperature, such as 26.7^0C (80.1^0F) versus 32.2^0C (90.0^0F) (Scott and Washburn, 1985). Several authors (Minne and Decuypere, 1984; Iqbal *et al*., 1990; Yahav and McMurtry, 2001) showed that thermotolerance can be induced by modulation of heat production through changes in circulating triiodothyronine. An improvement in thermotolerance implied the ability to reduce plasma triiodothyronine concentration, especially during a thermal challenge (Iqbal *et al.,* 1990; Yahav, 2000).

Nutrient Availability At Hatching. The yolk sac has been long known to be able to supply nutrients to chicks for a few days after hatching. There were two routes identified whereby yolk may be utilized in the post-hatch chick. One route was by direct transfer to the circulation and the other route was by transport through the yolk stalk into the small intestines (Noy and Sklan, 2002). Nitsan *et al* (1991) showed that the yolk sac content contributes 50% and 40% of total energy and protein at 1 d post-hatch and 2% and 6% at 4 d post-hatch, respectively. Many researchers have confirmed that the yolk sac contained sufficient energy and protein content to maintain the chicks for 3 d after hatching (Sell *et al.,* 1991; Reis *et al.,* 1998; Uni *et al.,* 1998). Fat was considered to be absorbed from yolk sac faster than glucose or methionine in the immediate post-hatch period. Also it has been shown that early nutrition improved the yolk sac absorption (Noy and Sklan, 1995, 1999).

When shifting from embryonic dependence on yolk materials to utilization of exogenous feed, chicks must undergo metabolic adaptations such as increased secretion of digestive enzymes from pancreatic and brush border sources, and adaptation of uptake processes to enable transfer of the required quantities of nutrients (Noy and Sklan, 1999). Marchaim and

Kulka (1967) observed the presence of pancreatic enzymes in the intestine during late embryonic development. The secretion of pancreatic enzymes per gram of feed intake changed little with age after 4 d (Uni *et al.,* 1996), and the digestibility of starch, protein, and fat was 85, 78, and 87%, respectively (Noy and Sklan, 1995).

Factors That Affect Hatching Time and the Effect Of Delayed Removal of Chicks From Hatchers. Research has demonstrated that the longer those chicks remain in the hatchers, the greater the percentage BW loss (Hager and Beane, 1983; Reinhart and Hurnik, 1984). The main factor affecting hatching time was reported to be incubation temperature (Insko, 1949; Reinhart and Hurnik, 1984). High incubation temperatures of between 37.5^0C (99.5^0F) and 39.0^0C (102.2^0F) have been found to accelerate embryonic development and therefore cause chicks to hatch early (Romanoff, 1936) but with decreased hatchability. This suggested that the chicks that hatched in a high incubation temperature environment would remain in the hatchers longer than those chicks that were hatched in a low incubation temperature environment. Insko (1949) reported that eggs that were incubated at a below optimal temperature would result in a delayed hatching time and a low hatchability. On the contrary, studies from Buckland (1970) showed only a slight depression in hatchability of eggs that were exposed to suboptimal incubation temperatures for a short period of time. Another factor affecting hatching time was reported to be the size of the eggs (Landauer, 1961). Larger eggs were found to hatch later than smaller eggs (Landauer, 1961) due to the higher egg temperatures of the larger eggs. Reducing the incubation temperature from 37.5^0C (99.5^0F) to 36.5^0C (97.7^0F) during the second half of incubation has been reported to improve the hatchability of those larger eggs (French, 1994). Chicks that were hatched from young broiler breeder flocks were also reported to have the most problems associated with

the length of time that the chicks remained in the hatcher after completion of the hatching process (Wyatt *et al.,* 1985). Wyatt *et al.,* (1985) reported that the longer that chicks remained in the hatchers the more that subsequent growth was decreased and mortality rate increased. This was associated with dehydration. Reinhart and Hurnik (1984) stated that the main factor causing dehydration after chicks hatched was the relative humidity of the machine and the length of time from completing the hatching process to removal from the hatcher ("pulling"). It was also important to note that the effects of temperature on embryonic development and duration of the incubation period appeared to depend on the temperature (low or high), age of the embryo, duration of exposure, and their interactions, as well as the relative humidity and type of incubator (Wilson, 1991).

Brooding. Osbaldiston and Sainsbury (1963) described brooding as the provision of a warm place for the young chicken. Brooding has long been known to be a critical management stage that may determine how fast the broiler chicken would grow. According to Moraes *et al.* (2002), development during the first week of life of a chick was important to their future performance because physiological processes such as cell hyperplasia and hypertrophy, maturation of the thermoregulatory and immunological systems, growth and differentiation of the gastrointestinal tract will subsequently markedly influence BW and feed conversion until market age. The thermoneutral temperature for broiler chicks during the first week of life should range between 33.0^0C (91.4^0F) and 35.0^0C (95.0^0F), and temperatures higher than this may induce hyperthermia and dehydration that will lead to a lower feed consumption and delayed growth (Mickelberry *et al.,* 1966). In contrast, lower temperatures would induce hypothermia and may lead to ascites in broilers (Moraes *et al.,* 2002).

Chickens develop their thermoregulatory ability quite rapidly after hatching (Wekstein and Zolman, 1967), but before 5 d of age, there has been no relationship between thermoregulatory ability and body mass, feed intake, or insulation identified to explain such rapid homeothermic development. However, chick quality problems and behavior were shown to be influenced by brooding conditions at placement. As demonstrated in a previous section, high incubation temperatures have been clearly shown to accelerate embryonic development and cause chicks to hatch earlier than normal (Romanoff, 1936) and potentially remain in the hatchers for an extended period of time. The longer those chicks remained in the hatchers, the greater the mortality, and the slower the growth rate that resulted (Wyatt *et al.,* 1985). According to Ernst *et al.,* (1984) and Henken *et al.,* (1987), chicks that had survived exposure to high incubation temperatures consumed less feed and grew slower than normal and had a greater chance of dying, when compared to those that were exposed to lower incubation temperatures, after arrival at a farm and placement at normal thermal conditions (Ernst *et al.,* 1984; Henken *et al.,* 1987). This was because chilled chicks (19.4^0C (66.9^0F)) were observed to huddle together for warmth and did not eat nor drink normally while warm chicks (29.4^0C (84.9^0F)) were more active and consumed feed normally (USDA, 1955). Therefore, chicks brooded at temperatures cooler than recommended during the first wk of age resulted in depressed 1 to 7 d BW gain (Hutson *et al*., 1960; Harris *et al*., 1975; Renwick and Washburn, 1982; Renwick *et al*., 1985; Scott and Washburn, 1985; Noy and Sklan, 1999), decreased feed efficiency, and increased mortality (Hutson *et al*., 1960; Renwick and Washburn, 1982). As shown by Moraes *et al.* (2002), the total feed consumption for chicks brooded at 20.0^0C (68.0^0F) (82.7 g) was 33.5 g less than that of chicks brooded at 35.0^0C (95.0^0F) (116.2 g) and this might be due to a reduced heat loss.

During the first wk of brooding, the group of chickens that were brooded at 26.7^{0}C (80.1^{0}F) lost 3.8% of their BW while those that were brooded at 32.2^{0}C (90.0^{0}F) gained 13.9%. However, the BW gain of these two groups was similar at 2 d and 3 d although the 26.7^{0}C brooding group did not gain BW quite as well as the 32.2^{0}C group (Scott and Washburn, 1985). One observation of chickens that did not move or drink after exposure to cold brooding temperature during the first 3 d was an increased hematocrit (packed cell volume) (Scott and Washburn, 1985), which would be indicative of dehydration, i.e. lack of water consumption.

Scott and Washburn (1985) suggested that during the first 5 d of the brooding period, the temperature should be around 32.0^{0}C (89.6^{0}F), even though the thermoregulatory mechanism of the chickens developed very rapidly, in order to have competitive broiler production results. The most important management factor was to have the chicks move and eat during the first 2 d of the brooding period. However according to Van der Hel *et al.* (1991), chickens that were exposed to high temperatures during the first 2 d of life suffered a BW loss of about 12% and chickens that were exposed to 37.0^{0}C (98.6^{0}F) to 40.0^{0}C (104.0^{0}F) exhibited a reduction in dry matter and protein of 18.5 and 7.1 g per chick during the first 2 wk of age, respectively. Fat and ash were also decreased by 8.7 and 2.6 g per chick over the initial 2 wk period, respectively (Van der Hel *et al.*, 1992). Van der Hel *et al.* (1991) stated that BW loss of neonatal chicks during a 24-h period was dependent upon temperature as BW loss increased from 3.5 g/d at 30.8^{0}C (87.4^{0}F) to 4.1 g/d at 35.1^{0}C (95.2^{0}F) and up to 5.7 g/d at 38.8^{0}C (101.8^{0}F). These weight losses could be from both the yolk sac and from the remainder of the body (Hoogerbrugge and Ormel, 1982).

An acute exposure to extreme ambient temperatures demands rapid and extensive responses by the chicken, mainly within the circulatory system (Yahav and McMurtry, 2001). Yahav and McMurtry (2001) suggested that thermal conditioning at 3 d of age with a ambient temperature between 36.0^{0}C (96.8^{0}F) and 37.5^{0}C (99.5^{0}F) produced optimal conditions for improving performance and thermotolerance in broiler chickens. Yahav and McMurtry (2001) also stated that thermal conditioning may be a useful tool for the simultaneous improvement of both thermotolerance and performance due to the resulting growth retardation that was followed by an immediate compensatory growth period, which resulted in complete compensation for the loss of BW gain, and higher ultimate BW of the thermally conditioned chickens at 42 d of age. Chickens that were exposed to heat stress at an early post-hatch age, in fact, lead to chickens that were thermotolerant later in life (Arjona *et al.,* 1988; Yahav and Hurwitz, 1996) with an increased capacity to survive an exposure to high ambient temperature (Altan *et al.,* 2000). However, there have also been many studies that have shown high ambient temperature to have a negative effect on broiler production efficiency (Teeter *et al.*, 1985; Sandercock *et al.,* 2001). Throughout heat stress, behavioral, physiological, hormonal and molecular changes occur that have long term effects (Etches *et al.,* 1995).

Effects of Brooding Temperature on Organ Development. Working with turkey poults and Leghorn chicks at normal brooding temperature, Sell *et al.* (1991) observed the relative weight of the gizzard to remain relatively constant up to 8 d and the gastrointestinal tract to increase in mass very rapidly after hatching, while Yang and Siegel (1997) showed that relative heart and lung weights decline with chick age. Nitsan (1995) confirmed that the pancreas and small intestine/body weight ratio increased four fold and the liver/body weight

ratio doubled during the first wk of life. The heart has been reported to be the most sensitive and responsive to temperature (Deaton and Reece, 1968).

Relative organ weights have been reported to be affected by adverse brooding temperatures. Liver, heart, and gizzard were all significantly smaller, on a relative basis, at 7 d of age when chicks were brooded at 35.0^{0}C (95.0^{0}F) incubation temperature when compared to chicks that were brooded at 20.0^{0}C (68.0^{0}F) but not different from chicks brooded at 25.0^{0}C (77.0^{0}F). However, there were no differences in yolk weight (Moraes *et al.,* 2002). During the first wk post-hatching, chicks reared at a 37.2^{0}C (99.0^{0}F) temperature had a significantly higher liver and heart-to-BW ratio than chicks reared at 32.2^{0}C (90.0^{0}F) temperature. This appeared to indicate a major change in the circulatory system (Deaton and Reece, 1968). However, this was different from tibia and femur growth, both of which were significantly larger when chicks were brooded at 25.0^{0}C (77.0^{0}F) and 35.0^{0}C (95.0^{0}F) compared to 20.0^{0}C (68.0^{0}F) (Moraes *et al.,* 2002). That liver weight was significantly smaller possibly due to a decrease in metabolic needs (Plavnik and Yahav, 1998). This effect was confirmed by Moraes *et al* (2002) who reported that chicks that were reared at 20.0^{0}C (68.0^{0}F) exhibited significantly higher relative liver weights at 7 d of age when compared to birds brooded at 25.0^{0}C (77.0^{0}F).

It has been conclusively demonstrated that temperature was the most important factor controlling embryo growth and development and his incubation temperatures may now be common (Meijerhof, 2000). Both, acutely high and low incubation temperatures affect embryogenesis, organ development, mitotic rates, metabolic adaptations, and disrupt metabolic transitions that affect hatchability, livability, disease resistance and post hatch performance (Romanoff, 1960). Chicks exposed to high temperatures during the last stages of incubation may hatch with as much as 12% lower BW (Van der Hel *et al.,* 1992) because they could not develop properly.

According to Osbaldiston and Sainsbury (1963), brooding has been long known to be a critical management stage that may determine how fast the broiler chicken grows and that lower temperatures may induce hypothermia and lead to ascites (Moraes *et al*., 2002). Conversely, higher brooding temperatures appear to promote early development (Scott and Washburn, 1985). Thus, the logic of this research was that a chick that had been compromised metabolically by high incubation temperatures might benefit from elevated brooding temperature that would promote feed intake and the completion of development.

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MATERIALS AND METHODS

Experiment 1. Before research could begin it was necessary to validate a non-invasive method of measuring internal egg temperature. Two infertile broiler hatching eggs were selected randomly and a circular hole the diameter of a mercury thermometer was cut into the large end of the eggs. A tuberculin syringe was used to withdraw 1 mL of albumen from the egg. The albumen was saved to fill any void after insertion of the mercury thermometer into the egg. The mercury thermometer (Model FS 15142C Thermometer, Fisher Scientific, Hampton, NH 03842) was inserted into the opening until the entire length of the metal tip was in the egg (approximately 3.8 cm) (Figure M-1). Some of the saved albumen was added to the egg until the albumen began to leak out. This insured that the entire length of the metal tip was immersed in liquid and that the proper internal liquid temperature would be measured. The eggs with the mercury thermometer inserted were placed carefully into two Natureform Model NOM-45 incubators (Natureform International, Jacksonville, FL 32218). After placement into the incubators the mercury thermometer was sealed in the circular opening in the shell with a fast drying caulk. Two other infertile eggs were placed on each side of the modified eggs to be used to check uniformity of egg temperature when the infrared thermometer (Braun Ear Thermometer Type 6013, The Gillette Company, Boston, MA 02199) was used.

A plastic tent was constructed around the doors of the two Natureform incubators to keep the internal and external incubator environment equalized during egg temperature measurements (Figure M-2). Electric heaters were used in the plastic tent to stabilize the temperature around the incubator temperatures. The incubator air temperature points monitored ranged from 34.4^0C (94.0^0F) to 41.1^0C (106.0^0F) in an incremental manner. Egg temperatures were measured with both the mercury and infrared thermometers after

Figure M-1. Calibration of infrared with mercury thermometer. The mercury thermometer was inserted into an opening in the egg shell until the entire length of the metal tip was in the egg (approximately 3.8 cm) and then sealed in place. The infrared thermometer was placed onto the equator of the same egg for the comparative temperature measurements.

Figure M-2. Plastic tent with electric heaters used to prevent heat loss from incubators and eggs during egg temperature measurements.

allowing 8-12 h for the infertile eggs and infrared thermometer to equilibrate at each successive machine air temperature set point.

Experiments 2 and 3. A large group of eggs was selected and recorded individually from the Ross 344 male x 308 slow-feathering broiler breeder flock at the Lake Wheeler Road Field Laboratory Chicken Educational Unit. A 65-wk-old flock was sampled for 150 eggs within a 5-gram range for Experiment 2 (66.5-71.5 g) and a 69-wk-old flock was sampled for 150 eggs within 4-gram range for Experiment 3 (67.0-71.0 g). These eggs where then divided randomly into two groups of 75, numbered, and placed in the front rows of two Natureform Model NOM-45 incubators that had been specially modified to hold five trays of 180 chicken eggs each. Five of the eggs, in positions 1, 15, 37, 60, and 75 in each machine, were used to monitor the temperature of eggs in the incubators. On the day before incubation began, both machines were switched on and allowed to reach an air temperature of 37.5^0C (99.5^0F). The machine controls for air temperature were adjusted based on the average temperature trends observed in the five reference eggs in each machine. Egg temperatures were taken daily with a Braun Thermoscan infrared thermometer and machine air temperatures were adjusted to achieve specific internal egg temperatures while maintaining the same relative humidity (RH) of 53% throughout the experiment. The Braun Thermoscan infrared thermometer was placed on the floor of an incubator 15 minutes before use to equilibrate. Egg temperatures were taken at the equator of the egg. In all experiments egg temperatures were taken over a number of days as shown in the respective figures for each experiment. For brevity, the average temperature in the text to represent the high or normal temperature treatments in all experiments.

One group of eggs in each trial was incubated at normal temperature and achieved internal egg temperatures around 38.1^0C (100.6^0F) in Experiments 2 and 3 (Figures M-3, 4) while the high temperature group of eggs was incubated at internal egg temperatures

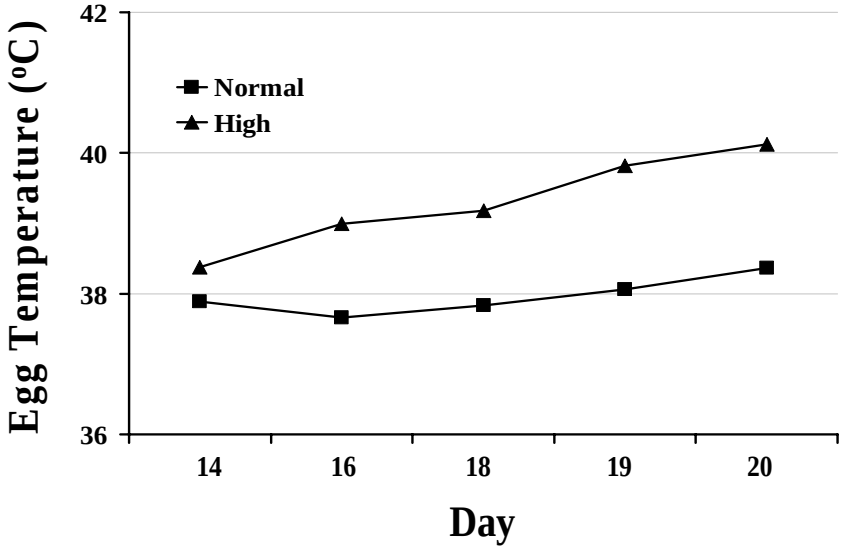

Figure M-3. Internal egg temperatures as a result of high or normal incubation temperature treatments in Experiment 2. The triangle symbols represent the high temperature eggs and the rectangle symbols represent the normal temperature eggs.

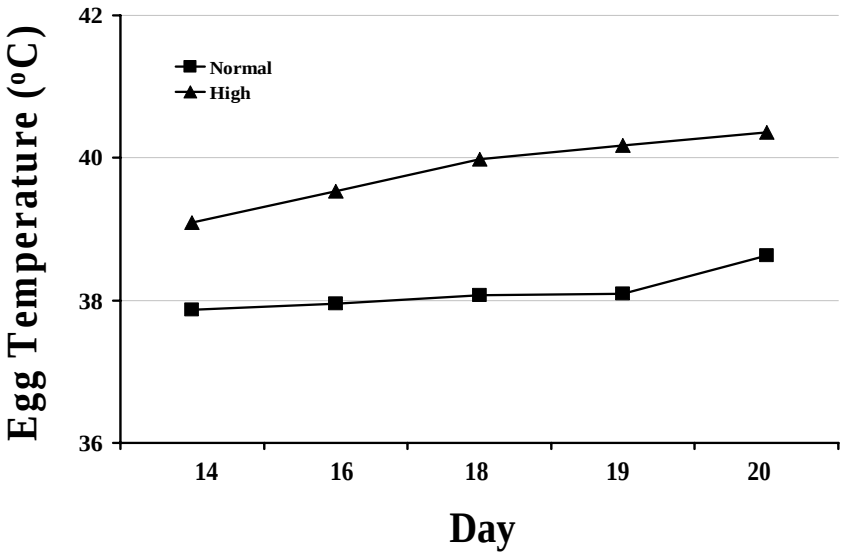

Figure M-4. Internal egg temperatures as result of high or normal temperature incubation in Experiment 3. The triangle symbols represent the high temperature eggs and the rectangle symbols represent the normal temperature eggs.

above 39.8^{0}C (103.6^{0}F) in Experiments 2 (Figure M-3) and 40.2^{0}C (104.4^{0}F) in Experiment 3 (Figure M-4) by E 19 of incubation.

Ventilation and RH in the incubators was similar at all times. To prevent heat loss during egg monitoring, a plastic tent was placed in front of the doors of the incubators and heated with two small forced air electrical resistance heaters in all experiments except Experiment 6. The tent had to be warmed up to 37.8^{0}C (100.0^{0}F) before taking egg temperatures, otherwise egg temperatures would decreased rapidly after the door was opened. Temperatures were monitored at E 14, 16, 18, 19, and 20 d of incubation. At E 18 fertile eggs were transferred into pedigree baskets with individual compartments to prevent the chicks from intermingling during hatching.

All hatched chicks were tagged and weighed. The chicks were then euthanized with carbon dioxide. There were 114 chicks were dissected and the liver, heart, proventriculus, gizzard, small intestines from junction with the gizzard to the ileo-cecal junction and unabsorbed yolk sac excised and weighed. A completely randomized design was utilized taking incubation temperature as the main effect and chicks as the experimental unit. Analyses of variance using Proc GLM were employed to evaluate the data and when the *P*-value was significant ($P \leq 0.05$) for the interaction term, the LS MEANS procedure was used (SAS Institute, 1998).

Experiments 4 and 5. Two experiments were conducted using two incubators as a source of different machine air temperatures. Broiler hatching eggs were collected during a two-day period at 48 wk and 35 wk of age for Experiments 4 and 5, respectively. Eggs were stored at 18.0^{0}C (64.4^{0}F) and 65% RH for 5 d or 2 d, respectively, for Experiments 4 and 5 before setting. There were 1,440 eggs set in a Natureform Model NMC-2000 incubator that held eleven 180-egg trays to E 15 of incubation. There were eight trays of experimental eggs placed in the machine with one tray of "extra" eggs placed above and two trays of "extra" eggs placed below the experimental eggs to insure uniform airflow in

the machine. All trays were labeled with colored tape numbered and 1-8 in order to prevent errors during the transfer process. Each tray contained six 30-egg plastic flats arranged so that there were 15 eggs across the front of each tray that could be easily accessed. These 120 eggs were numbered consecutively with pencil for subsequent temperature determination. The incubator was initially operated at 37.4^{0}C (99.3^{0}F) and 53% RH. This machine was equipped with an electronic humidistat that automatically adjusted the wet bulb temperature relative to changes in dry bulb temperature in order to maintain a consistent RH. Proper operation was assured by insertion of a reference ASTM mercury thermometer (Fisher Scientific, Hampton, NH 03842) and an electronic humidity stick (Testo 605-H1, Testo, Inc., Flanders, NJ 07836) each day. The machine controls were adjusted to maintain the internal egg temperature in the 37.5-37.7^{0}C (99.5-99.9^{0}F) range from setting to E 14 of incubation with egg rotation every 30 minutes.

At E 15 of incubation the eggs were transferred to two Natureform Model NOM-45 incubators that held five 180 egg trays of chicken eggs each. A tray of "extra" eggs were placed in the lower most position in each machine to maintain uniform air flow. Experiments 4 and 5 treatments were rotated between the two machines to account for possible machine effects. Four trays were transferred to the incubator designated to incubate the eggs at a high temperature of greater than 39.4^{0}C (103.0^{0}F) in Experiment 4 (Figure M-5) and 39.9^{0}C (103.8^{0}F) in Experiment 5 (Figure M-6) and the remaining trays were transferred to the incubator designated to incubate the eggs at a normal temperature of 37.6^{0}C (99.7^{0}F) in Experiments 4 and 5 (Figures M-5 and M-6) by E 19 of incubation. The eggs were transferred from the setter trays to plastic hatching baskets at E 20 of incubation while the fifth tray of "extra" eggs was maintained in each machine to insure uniform air flow.

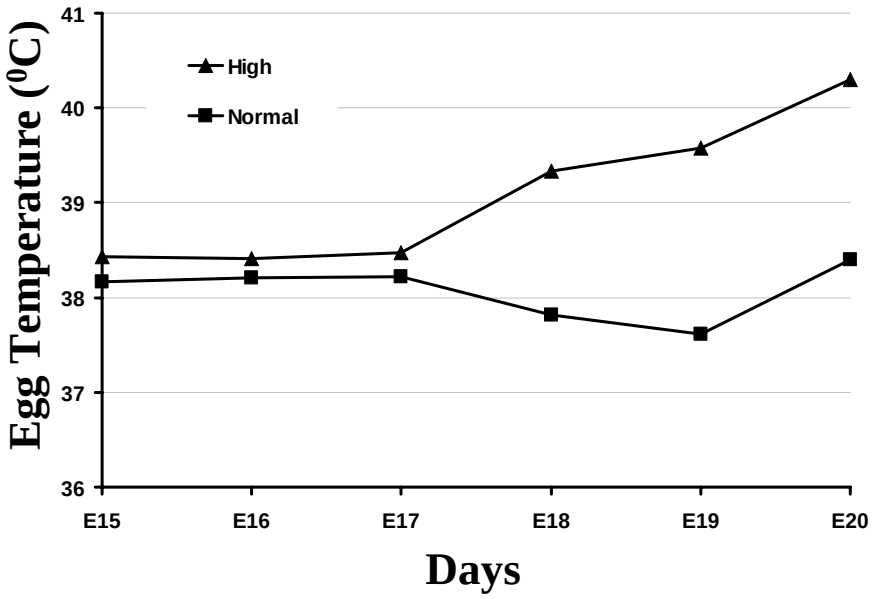

Figure M-5. Internal egg temperatures as a result of high and normal temperature incubation in Experiment 4. The triangle symbols represent the high temperature eggs and the rectangle symbols represent the normal temperature eggs.

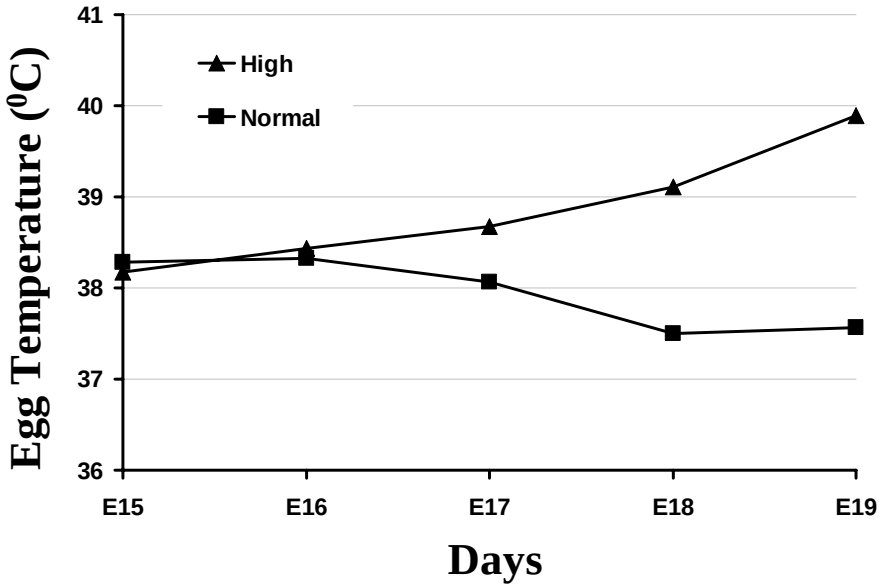

Figure M-6. Internal egg temperatures as a result of high and normal temperature incubation in Experiment 5. The triangle symbols represent the high temperature eggs and the rectangle symbols represent the normal temperature eggs.

The temperatures of the 60 marked eggs on the front rows of the four trays (15 eggs per tray) in each machine were measured and recorded daily with a Braun Thermoscan infrared thermometer, as described previously, and the machine controls adjusted to obtain the desired differences in eggshell temperature while maintaining the same RH throughout the experiment.

At 21.5 d of incubation the chicks that had completed the hatching process were removed from the trays, counted, group weighed, and sexed using the feather-sexing method. Five chicks from each sex and tray in Experiment 4 (80 chicks total) were necropsied to determine BW, and weights of the yolk sac, heart, liver, proventriculus, gizzard, and small intestines.

The remaining chicks were permanently identified with neck tags and placed in floor pens on wood litter shavings. There were four brooding rooms with 16 pens per room. Each 85.1 cm x 90.2 cm pen had two 13.5 cm x 36.3 cm x 26.7 cm feeders and three nipple drinkers to provide mash feed and water for *ad libitum* consumption. During the first 5 d there was also a gallon chick font used for supplemental water and half of a 30-egg paper flat was used for supplemental feed. The brooding facility was preheated for 48 h before chick placement. Two of the brooding rooms were operated at cool brooding temperatures (Figures M-7 and M-8) and two rooms were operated at hot brooding temperatures (Figures M-9 and M-10). Litter temperatures were determined daily with a Traceable® infrared thermometer gun (Fisher Scientific, Control Company, Friendswood, TX 77546) by randomly checking two dry spots in each pen in the late afternoon every day during the brooding period. These temperatures were used to adjust the air temperature each day. Air temperatures were determined with two high-low mercury recording thermometers hung at bird level in each room. There were 14 males and 14 females chicks from the two incubation regimes equally allocated to eight pens for each sex within each brooding treatment room. Thus, the experimental design was two

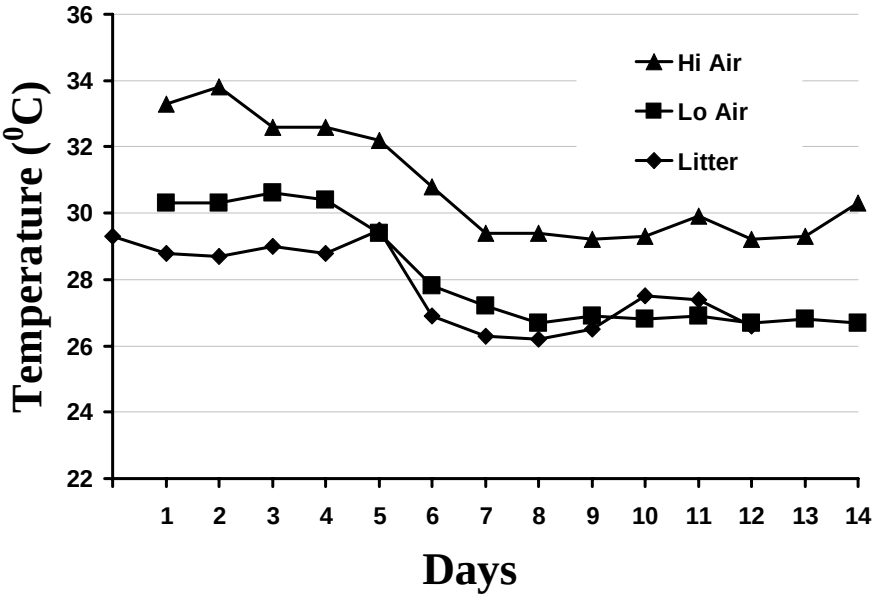

Figure M-7. Daily high air, low air, and litter temperatures in the cool brooding rooms in Experiment 4. The triangle symbols represent the daily high air (Hi-Air) temperature, the rectangle symbols represent the daily low air (Lo-Air) temperature, and the diamond symbols represent the litter temperature taken at 1300 hours each day.

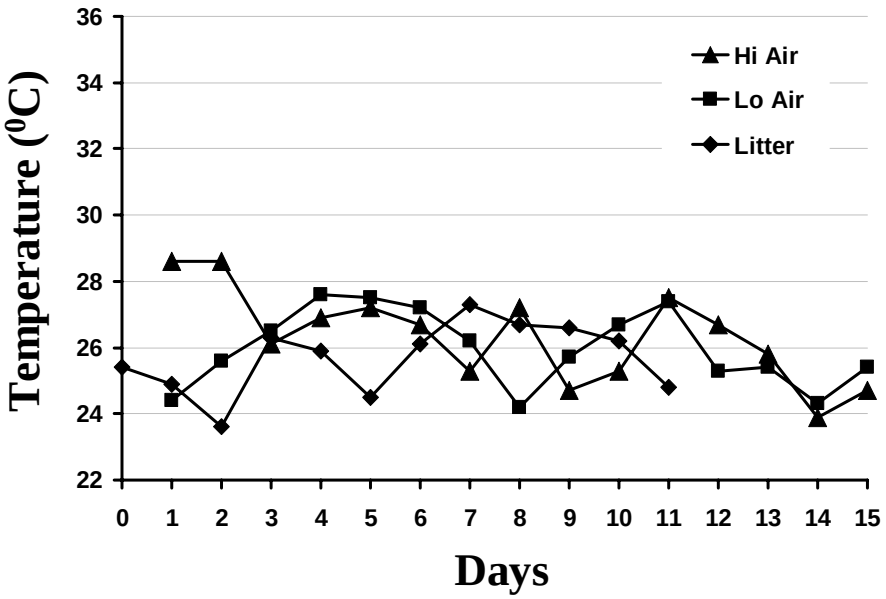

Figure M-8. Daily high air, low air, and litter temperatures in the cool brooding rooms in Experiment 5. The triangle symbols represent the daily high (Hi-Air) temperature, the rectangle symbols represent the daily low (Lo-Air) temperature, and the diamond symbols represent the litter temperature taken at 1300 hours each day.

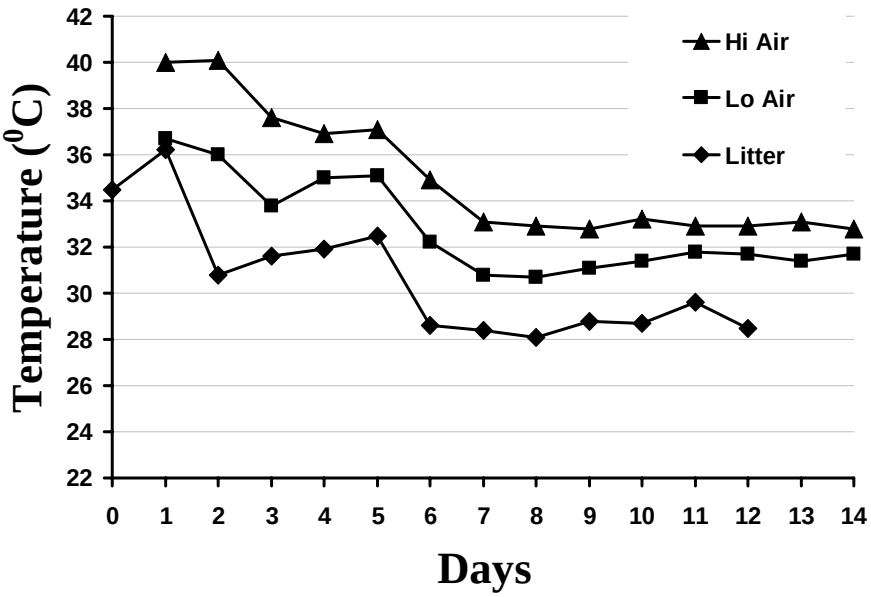

Figure M-9. Daily high air, low air, and litter temperatures in the hot brooding rooms in Experiment 4. The triangle symbols represent the daily high air (Hi-Air) temperature, the rectangle symbols represent the daily low air (Lo-Air) temperature, and the diamond symbols represent the litter temperature taken at 1300 hours each day.

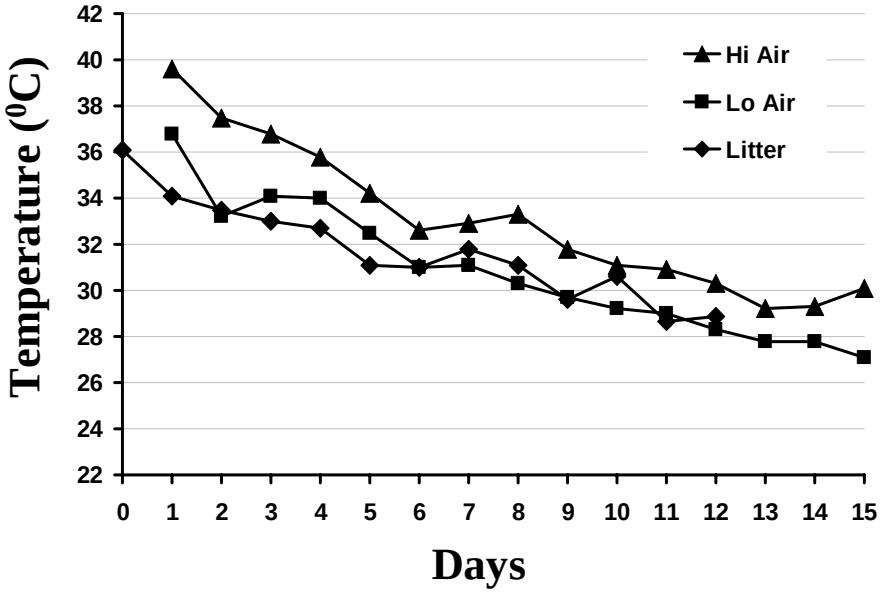

Figure M-10. Daily high air, low air, and litter temperatures in the hot brooding rooms in Experiment 5. The triangle symbols represent the daily high air (Hi-Air) temperature, the rectangle symbols represent the daily low (Lo-Air) temperature, and the diamond symbols represent the litter temperature taken at 1300 hours each day.

incubation regimes x two brooding regimes x two sexes within the 64-pen facility. Chicks were group weighed at placement and at 2, 5, 7, and 14 d of age. Feed consumption was determined at 2, 5, 7, and 14 d in Experiment 4 and at 7 and 14 d in Experiment 5, respectively, and adjusted feed conversion rate (AdjFCR) calculated. Adjusted FCR (calculated for each pen) = total feed consumed / total BW of surviving birds + total terminal BW of birds that died. At the end of Experiment 4, one chick from each pen was killed and necropsied to determine BW, and weights of the yolk sac, heart, liver, proventriculus, gizzard, and small intestines.

A split plot design was utilized taking brooding temperature as the main plot, while incubation, sex, and all the interactions were in the subplot (Steel and Torrie, 1980) with the pens as the experimental unit. When the organ weight was analyzed at 1 d in Experiment 4, the brooding factor was not included into the model. Analyses of variance using the Proc Mixed procedure were employed to evaluate the data and when the *P*-value was significant ($P \leq 0.05$) for the interaction term, the LS MEANS procedure was used (SAS Institute, 1998).

Experiment 6. Broiler hatching eggs were collected during a two-day period from a broiler breeder flock at 52 wk of age. Eggs were stored at 18.0^0C (64.4^0F) and 65% RH for 5 d before setting. There were 2,520 eggs set in a Jamesway model 252B incubator (Butler Manufacturing Co., Ft. Atkinson, WI 53538) that held fourteen 180-egg trays. Each tray contained 6 cradles that held 30 eggs each. Six eggs in the middle of the middle tray were numbered consecutively for subsequent monitoring of egg temperature. The incubator was initially operated at 37.4^0C (99.3^0F) and humidity maintained at 28.3^0C (83.0^0F) wet bulb. The machine controls were adjusted to maintain the internal egg temperature in the 37.5-37.7^0C (99.5-99.9^0F) range from set to E 13 of incubation. The machine humidity was maintained automatically by an electro-mechanical humidistat.

At E 14 of incubation half of the eggs were transferred to a second Jamesway machine designated to incubate the eggs at a high temperature of greater than 40.7^0C (105.3^0F) by E 19 of incubation and the original machine was designated to incubate the eggs at a normal temperature of 37.5^0C (99.5^0F). The eggs were transferred from the setter trays to metal hatching baskets at E 19 of incubation and returned to their respective machines. Egg temperatures were measured with a Braun Thermoscan infrared thermometer (as described previously) from E 17 to 19 of incubation (Figure M-11).

At 21.5 d of incubation the chicks that had completed the hatching process were removed from the trays, counted, group weighed, and sexed using the feather-sexing method. After processing, the chicks were permanently identified with neck tags and placed in floor pens on wood litter shavings. There were two brooding areas in the facility with 36 pens per area with 14 male and 14 females chicks per pen. Each pen had two feeders and one bell-type drinker to provide feed and water for *ad libitum* consumption. During the first 5 d there was also a gallon chick font used for supplemental water and a plastic tray used for supplemental feed. The brooding facility was preheated for 48 h before chick placement. One of the brooding areas was operated at cool brooding temperatures (litter temperature) near 25.9^0C (78.6^0F) (Figure M-12a) and the second was operated at hot brooding temperatures (litter temperature) near 33.5^0C (94.3^0F) (Figure M-12b) at placement. Litter temperatures were determined daily with a Traceable® infrared thermometer gun by randomly checking two dry spots in each pen in the late afternoon every day during the brooding period. These temperatures were used to adjust the air temperature each day. Air temperatures were determined with high-low mercury recording thermometers. Males and females from the two incubation regimes were equally allocated to eighteen pens for each sex within each brooding area. The experimental design was two incubation regimes x two brooding regimes within the 72-pen facility. Chicks were group weighed at placement and at 7, 14, and 21 d of age. Feed

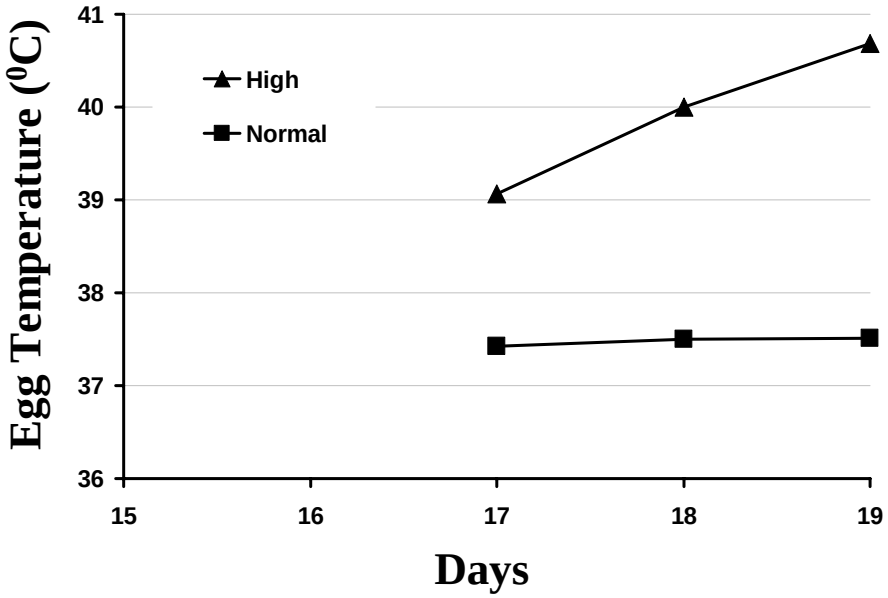

Figure M-11. Internal egg temperatures as a result of high and normal incubation treatments in Experiment 6. The triangle symbols represent the high temperature eggs and the rectangle symbols represent the normal temperature eggs.

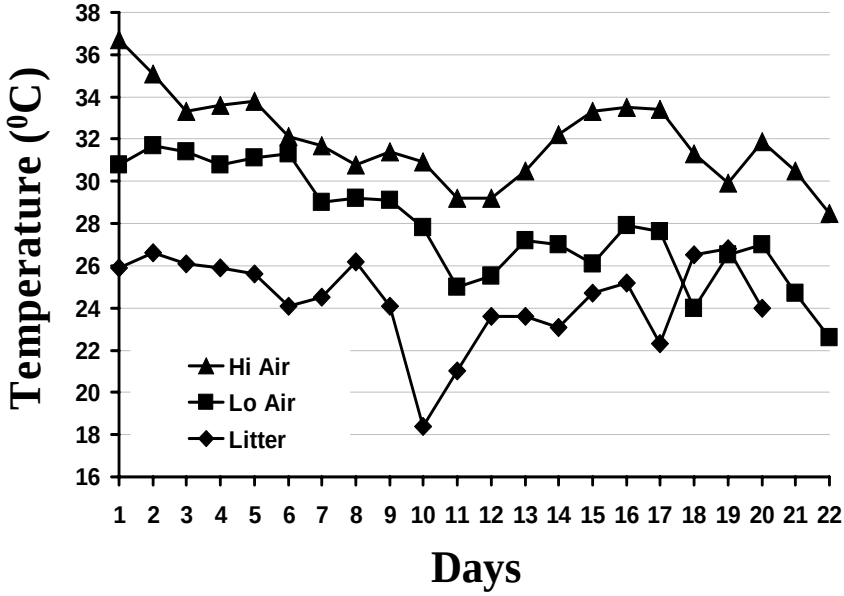

Figure M-12a. Daily high air, daily low air, and litter temperatures in the cool brooding rooms in Experiment 6. The triangle symbols represent the daily high air (Hi-Air) temperature, the rectangle symbols represent the daily low air (Lo-Air) temperature, and the diamond symbols represent the litter temperature taken at 1300 hours each day.

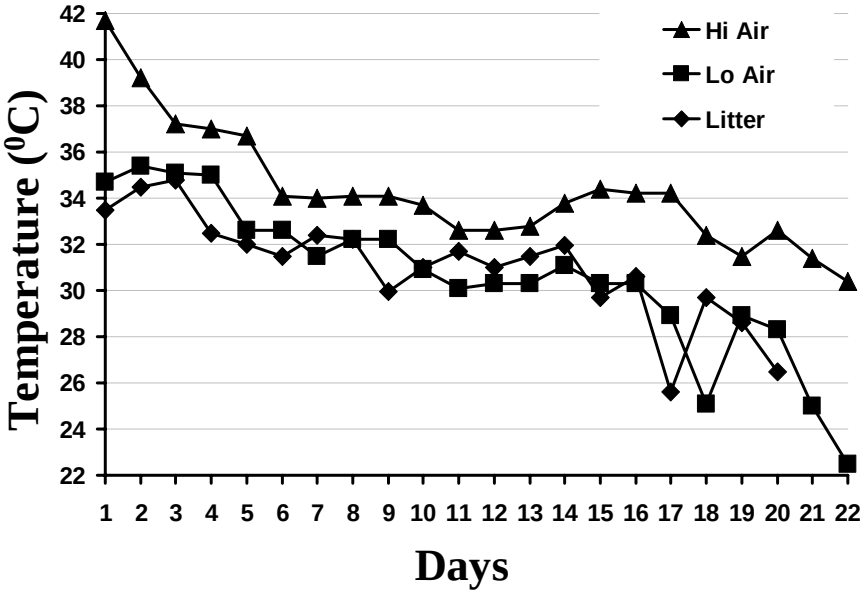

Figure M-12b. Daily high air, daily low air, and litter temperatures in the hot brooding rooms in Experiment 6. The triangle symbols represent the daily high air (Hi-Air) temperature, the rectangle symbols represent the daily low air (Lo-Air) temperature, and the diamond symbols represent the litter temperature taken at 1300 hours each day.

consumption was determined at 7, 14, and 21 d and AdjFCR calculated. A split plot design was utilized taking brooding temperature as the main factor, while incubation and all the interactions were in the subplot (Steel and Torrie, 1980) with pens as the experimental unit. One male and one female chick per pen (144 total) were killed and necropsied to determine weights of the breast, heart, liver, proventriculus, gizzard, small intestines, and yolk sac at 21 d of age. Analyses of variance using the Proc Mixed procedure were employed to evaluate the data and when the *P*-value was significant ($P \leq 0.05$) for the interaction term, the LS MEANS procedure was used (SAS Institute, 1996).

Experiment 7. Broiler hatching eggs were collected during a 3-d period from a flock of broiler breeders at 60 wk of age. Eggs were stored at 18.0^{0}C (64.4^{0}F) and 65% RH for 3 d before setting. Eggs from the second day of collection were weighed individually and the mean and standard deviation of the range in egg weight determined using the SAS Proc Means (SAS Institute, 1998). Eggs were then sorted into three groups consisting of 24 average eggs that fell into the range or the mean ± ½ SD; 24 small eggs with a weight falling below the mean -1 SD, and 24 large eggs with a weight greater than the mean +1 SD. All eggs in each category were numbered sequentially to maintain the identity of eggs within each size category.

Eggs were set in a Natureform Model NMC-2000 incubator that held eleven 180-egg trays. There were eight trays of experimental trays placed in the machine with one tray of "extra" eggs placed above and two trays of "extra" eggs placed below the experimental eggs to insure uniform air flow in the machine. There were 36 eggs in the middle of each tray that were numbered by size and egg number (i.e. S, #3) for subsequent determination of egg temperature. The incubator was initially operated at 37.4^{0}C (99.3^{0}F) and 53 % RH. Proper operation was assured by insertion of a reference ASTM mercury thermometer and an electronic humidity stick each day. The machine controls were adjusted to maintain the internal egg temperature in the 37.5-37.7^{0}C (99.5-99.9^{0}F) range

from set to E 12 of incubation with egg rotation every 30 minutes. At E 13 of incubation the eggs were transferred to two Natureform Model NOM-45 incubators that held five trays of 180 chicken eggs each. A tray of "extra" eggs were placed in the top position in each machine to help maintain uniform air flow. Odd numbered trays were transferred from the NMC-2000 to the NMC-45 incubator designated to incubate the eggs at a high temperature of greater than 39.4^0C (103.0^0F) by E 21 of incubation and the even numbered trays were transferred to the incubator designated to incubate the eggs at a normal temperature of 38.3^0C (101.0^0F) or less. Egg temperatures were measured with a Braun Thermoscan infrared thermometer, as described previously, from E 14 to 19. The 144 marked eggs in the middle rows of the four trays in each machine were measured daily and the machine controls adjusted to obtain the desired differences in egg temperature while maintaining the same RH throughout the experiment as previously described (Figure M-13). To prevent heat loss during egg monitoring, a plastic tent was placed in front of the doors of the incubators, as previously described.

The eggs in each tray were transferred to specially modified plastic hatching baskets to be placed within the same machine at the end of E 19 while maintaining identity of chicks hatched from individually labeled eggs. The 36 labeled eggs from each tray were placed in pedigree baskets placed in the center of each hatching basket (Figure M-14). This allowed the identity of chicks from each numbered egg to be maintained throughout the hatching and processing process without having the eggs in an abnormal environment. The hatching baskets were divided by a wire mesh divider into six sections. At E 21 of incubation, chicks from each pedigree basket were removed individually (total of 288 chicks). Any unhatched eggs from the pedigree baskets were marked and set aside for macroscopic evaluation. The chicks from each of the remaining six subsections in each hatching basket were removed and placed in individual chick boxes labeled according to their position. Unhatched eggs from each hatching basket were labeled for macroscopic

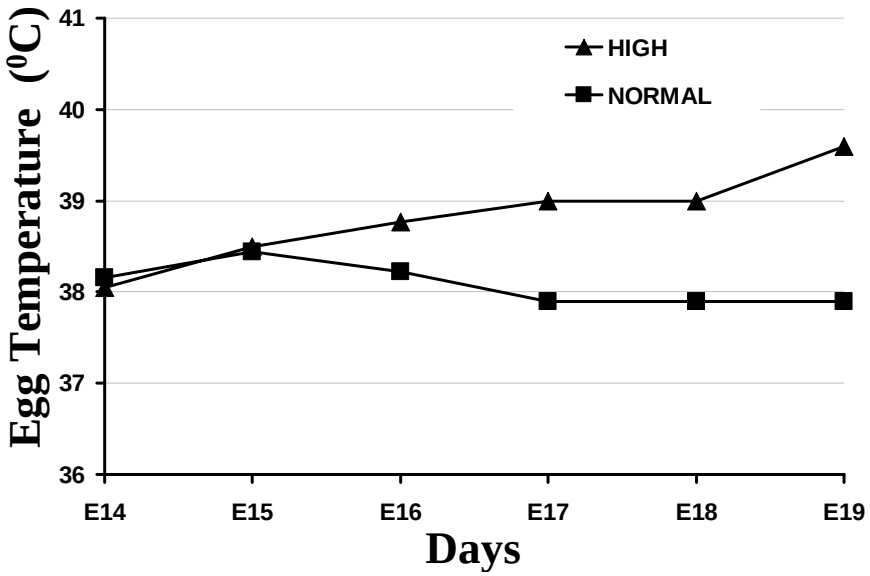

Figure M-13. Internal egg temperatures as a result of the high and normal incubation treatments in Experiment 7. The triangle symbols represent the high temperature eggs and the rectangle symbols represent the normal temperature eggs.

Figure M-14. Pedigree baskets used to hatch chicks in three egg size classes in Experiment 7. The 36 labeled eggs from each tray were placed in pedigree baskets placed in the center of each hatching basket. The remaining portion of the hatching baskets was divided by wire mesh dividers into six sections into which the 24 remaining non-labeled eggs within a given incubator tray were transferred.

examination. The chicks from each basket were sexed and counted. Subsequently, 288 chicks from the pedigree baskets were killed and necropsied to determine BW, and weights of the yolk sac, heart, liver, proventiculus, gizzard, and small intestines. Thus, the experimental design for the necropsy data was three egg sizes x two incubation regimes x two sexes.

After processing, the chicks not used for necropsy were permanently identified with neck tags and placed in floor pens on wood litter shavings. There was one brooding area with 32 pens in this experiment. Each pen had two feeders and one drinker to provide feed and water for *ad libitum* consumption. During the first 5 d there was also a gallon chick font used for supplemental water and a plastic tray used for supplemental feed. The brooding facility was preheated for only 18 h before chick placement. The brooding area was operated at 29.0^0C (84.0^0F). Males and females from the same incubation regime were mixed within the same pen. Thus, the experimental design was two incubation regimes within the 32-pen facility. Chicks were group weighed at placement and at 7, 12, 21, and 28 d of age. Feed consumption was determined at 7, 12, 21, and 28 d and AdjFCR calculated.

A randomized complete block design was utilized for organ weight data at 1 d with two incubation temperatures as treatments with four trays as blocks. A randomized complete block design was utilized for the growing period with four house sections considered as blocks and incubation temperature as the main effect with pens as the experimental unit. Analyses of variance using Proc Mixed procedure were employed to evaluate the data and when the *P*-value was significant ($P \leq 0.05$) for the interaction term, the LS MEANS procedure was used (SAS Institute, 1998).

RESULTS

Experiment 1. During the first two trials there was a small different between the mercury and infrared thermometers below 36.7^0C (98.0^0F) where the infrared thermometer read about 0.5^0C higher than the mercury thermometer. However, this difference decreased to 0.3^0C, as we gained experience during the third repetition and by the forth trial there was no difference between the mercury and infrared thermometer readings in the range between 35.8^0C (96.5^0F) and 41.2^0C (106.1^0F) (Table R-1). The results appeared to show good agreement between the invasive and non-invasive methods of internal egg temperature determination.

Experiments 2, 3, 4, 6, and 7 Concerning Organ Development. Data concerning BW and relative weights of the organs as well as yolk sac were taken on day of hatching in Experiments 2, 3, 4, 6 and 7. Similar data were taken to assess any longer term effects of incubation temperature, as well as brooding temperature, on organ development at 14 d of age in Experiment 4 and at 21 d of age in Experiment 6. These data are summarized together in the following section.

Experiment 2. The effect of incubation temperature, sex, and the incubation temperature by sex interaction on BW and relative yolk sac and organ weights on day of hatching is shown in Table R-2. BW and heart weight exhibited significant decreases due to increased incubation temperature while the liver was significantly increased. The proventriculus was significantly larger in females than in males. The yolk sac, gizzard, proventriculus, and small intestine weights were not significantly affected by incubation temperature and there were no significant incubation temperature by sex interactions.

Experiment 3. The effect of incubation temperature, sex, and the incubation temperature by

TABLE R-1. Comparison of mercury thermometer temperature and infrared thermometer temperature in Experiment 1

Trials	Machine Air Temperature	Mercury Thermometer Temperature	Infrared Thermometer Temperature
		^{0}F	
1	94.4	94.4	94.9
	96.4	96.4	97.0
	98.2	98.4	98.6
	100.2	100.0	100.3
	102.3	102.3	102.3
	104.3	104.4	104.4
	106.2	106.4	106.9
2	94.1	94.2	94.7
	96.1	96.2	96.7
	98.3	98.4	98.4
	100.3	100.3	100.3
	102.2	102.2	102.0
	104.3	104.2	104.2
	106.3	106.6	106.4
3	94.2	95.2	95.5
	96.2	96.2	96.5
	98.4	98.8	99.0
	100.3	100.2	100.3
	102.3	102.6	102.5
	104.2	104.4	104.3
	106.2	106.2	106.2
4	94.3	94.2	94.3
	96.3	96.5	96.5
	98.3	98.5	98.5
	100.3	100.7	100.7
	102.2	102.4	102.4
	104.2	104.5	104.5
	106.2	106.1	106.1

By the forth Trial there was no difference between the mercury and infrared thermometer readings in the range between 35.8^{0}C (96.5^{0}F) and 41.2^{0}C (106.1^{0}F)

TABLE R-2. Body weight and relative weights of tissues and organs from broiler chicks on day of hatching in Experiment 2 as influenced by incubation temperature, sex, and incubation temperature by sex interaction

Incubation[1] Temperature	Body Weight	Yolk Sac	Heart	Liver	Gizzard	Proventriculus	Small Intestines
	(g)	(g/100g)					
High	44.6^{B}	10.75	0.67^{B}	3.03^{A}	5.13	0.81	2.75
Normal	47.7^{A}	11.16	0.81^{A}	2.80^{B}	5.02	0.84	2.72
SEM	0.3	0.45	0.01	0.05	0.08	0.02	0.05
Probability	0.001	0.502	0.001	0.001	0.366	0.211	0.714
Sex							
Male	46.3	11.16	0.75	2.85	5.02	0.79^{B}	2.72
Female	45.9	10.75	0.72	2.98	5.14	0.86^{A}	2.75
SEM	0.3	0.46	0.02	0.05	0.08	0.02	0.05
Probability	0.545	0.500	0.405	0.098	0.344	0.003	0.605
Incubation[1] Temperature × Sex							
High Male	44.8	10.59	0.68	2.95	5.10	0.77	2.72
High Female	44.5	10.87	0.66	3.09	5.16	0.85	2.77
Normal Male	47.8	11.71	0.81	2.76	4.95	0.80	2.71
Normal Female	47.7	10.59	0.81	2.83	5.11	0.88	2.73
SEM	0.4	0.62	0.02	0.07	0.11	0.03	0.07
Probability	0.761	0.266	0.663	0.581	0.658	0.925	0.747

^{A,B} Means in columns that possess different superscripts differ significantly ($P \leq 0.01$).
[1] High incubation eggs were 39.7^{0}C (103.5^{0}F) at E19. Normal incubation eggs were 37.8^{0}C (100.0^{0}F) at E19.

sex interaction on BW and relative yolk sac and organ weights on day of hatching is shown in Table R-3. BW, heart, gizzard, proventriculus, and small intestines exhibited significant decreases in weight due to increased incubation temperature while the weight of the yolk sac was significantly increased. The proventriculus and small intestines were significantly larger in females than in males. The liver weight was not significantly affected by incubation temperature and there were no significant incubation temperature by sex interactions.

Experiment 4. The effect of incubation temperature, sex, and incubation temperature by sex interaction on BW and relative yolk sac and organs weights on day of hatching is shown in Table R-4. The heart, gizzard, proventriculus, and small intestines all exhibited significantly decreased weights due to increased incubation temperature while there were no effects on BW or weights of the yolk sac or liver. There were no significant effects due to sex or the incubation temperature by sex interaction.

Experiment 7. The effect of incubation temperature, egg size, and the incubation temperature by egg size interaction on BW and relative yolk sac and organ weights on day of hatching is shown in Table R-5. BW and heart weight exhibited significant decreases due to increased incubation temperature while weights of the yolk sac, liver, gizzard, proventriculus, and small intestines were not significantly affected. Chick BW was proportional to egg weight in a significant manner. Small eggs produced chicks with a smaller yolk sac than average and large eggs while average and large eggs produced chicks with smaller hearts and gizzards. There was no obvious relationship between incubation temperature and egg size in our measurements although the large eggs very slightly hotter up to E19 of incubation (Figure R-1a, b). However, the significant incubation temperature by egg size interaction demonstrated temperature ha a greater effect on large eggs during the final two days of incubation.

TABLE R-3. Body weight and relative weights of tissues and organs from broiler chicks on day of hatching in Experiment 3 as influenced by incubation temperature, sex, and incubation temperature by sex interaction

Incubation[1] Temperature	Sex	Body Weight	Yolk Sa	Heart	Liver	Gizzard	Proventriculus	Small Intestines
		(g)			(g/100g)			
High		44.3[B]	12.07[A]	0.63[B]	2.93	5.08[B]	0.80[B]	2.63[B]
Normal		46.6[A]	9.16[B]	0.88[A]	3.00	5.84[A]	0.93[A]	3.15[A]
SEM		0.2	0.40	0.01	0.04	0.07	0.02	0.05
Probability		0.001	0.001	0.001	0.267	0.001	0.001	0.001
Sex								
Male		45.4	10.36	0.76	2.98	5.43	0.84[b]	2.81[b]
Female		45.6	10.79	0.75	2.95	5.51	0.89[a]	2.98[a]
SEM		0.3	0.44	0.02	0.04	0.08	0.02	0.06
Probability		0.601	0.414	0.741	0.495	0.436	0.018	0.015
Incubation[1] Temperature	Sex							
High	Male	44.0	11.38	0.62	2.96	5.03	0.77	2.53
High	Female	44.5	12.72	0.63	2.90	5.14	0.82	2.73
Normal	Male	46.8	9.37	0.89	3.01	5.81	0.90	3.09
Normal	Female	46.5	8.97	0.87	2.99	5.86	0.96	3.21
SEM		0.3	0.56	0.03	0.06	0.10	0.02	0.07
Probability		0.236	0.130	0.473	0.733	0.740	0.812	0.490

[A,B] Means in columns that possess different superscripts differ significantly ($P \leq 0.01$).
[a,b] Means in columns that possess different superscripts differ significantly ($P \leq 0.05$).
[1] High incubation eggs were 39.9^{0}C (103.8^{0}F) at E19. Normal incubation eggs were 37.9^{0}C (100.2^{0}F) at E19.

TABLE R-4. Body weight and relative weights of tissues and organs from broiler chicks on day of hatching in Experiment 4 as influenced by incubation temperature, sex, and incubation temperature by sex interaction

Incubation[1] Temperature		Body Weight	Yolk Sac	Heart	Liver	Gizzard	Proventriculus	Small Intestines
		(g)	(g/100g)					
High		43.1	10.06	0.72^{B}	2.59	4.90^{B}	0.89^{b}	3.00^{B}
Normal		44.2	9.52	0.86^{A}	2.65	5.41^{A}	0.96^{a}	3.33^{A}
SEM		0.8	0.42	0.02	0.05	0.09	0.02	0.07
Probability		0.350	0.375	0.001	0.582	0.002	0.035	0.004
Sex								
Male		44.1	9.93	0.81	2.65	5.17	0.92	3.08
Female		43.2	9.66	0.77	2.59	5.13	0.93	3.24
SEM		0.8	0.42	0.02	0.05	0.09	0.02	0.07
Probability		0.388	0.660	0.262	0.603	0.767	0.602	0.078
Incubation[1] Temperature	Sex							
High	Male	43.9	10.35	0.72	2.67	4.81	0.86	2.85
High	Female	42.4	9.77	0.73	2.51	4.98	0.92	3.14
Normal	Male	44.4	9.50	0.90	2.63	5.53	0.97	3.31
Normal	Female	43.9	9.54	0.82	2.67	5.28	0.94	3.35
SEM		0.8	0.60	0.03	0.05	0.13	0.03	0.09
Probability		0.649	0.610	0.131	0.371	0.106	0.156	0.160

[A,B] Means in columns that possess different superscripts differ significantly ($P \leq 0.01$).
[a,b] Means in columns that possess different superscripts differ significantly ($P \leq 0.05$).
[1] High incubation eggs were 39.5^{0}C (103.1^{0}F) at E19. Normal incubation eggs were 37.9^{0}C (100.2^{0}F) at E19.

TABLE R-5. Body weight and relative weights of tissues and organs from broiler chicks on day of hatching in Experiment 7 as influenced by incubation temperature, egg size, and incubation temperature by egg size interaction

Incubation[1] Temperature		Body Weight	Yolk Sac	Heart	Liver	Gizzard	Proventriculus	Small Intestines
		(g)	(g/100g)					
High		39.9^{B}	7.65	0.71^{B}	2.65	5.01	0.91	2.92
Normal		41.2^{A}	7.81	0.85^{A}	2.56	5.02	0.89	2.95
SEM		0.2	0.34	0.01	0.06	0.07	0.03	0.05
Probability		0.001	0.659	0.001	0.257	0.560	0.357	0.251
Egg Size								
Large		44.4^{A}	8.34^{A}	0.75^{B}	2.62	4.96^{b}	0.88	2.89
Average		40.8^{B}	8.05^{A}	0.78^{B}	2.59	4.94^{b}	0.93	2.86
Small		36.6^{C}	6.80^{B}	0.81^{A}	2.61	5.14^{a}	0.89	3.05
SEM		0.2	0.31	0.01	0.05	0.08	0.04	0.05
Probability		0.323	0.001	0.006	0.800	0.023	0.357	0.800
Incubation[1] Temperature	Egg Size							
Normal	Large	45.4^{a}	8.53	0.81	2.56	4.88	0.87	2.90
Normal	Average	41.2^{c}	8.16	0.85	2.57	5.05	0.89	2.90
Normal	Small	37.0^{e}	6.75	0.88	2.56	5.13	0.90	3.05
High	Large	43.2^{b}	8.15	0.70	2.68	5.05	0.88	2.89
High	Average	40.3^{d}	7.94	0.70	2.62	4.83	0.97	2.82
High	Small	36.2^{f}	6.85	0.73	2.65	5.16	0.87	3.04
SEM		0.3	0.43	0.02	0.07	0.10	0.05	0.07
Probability		0.830	0.802	0.117	0.858	0.174	0.381	0.729

^{A,B} Means in columns that possess different superscripts differ significantly ($P \leq 0.01$).
^{a,b} Means in columns that possess different superscripts differ significantly ($P \leq 0.05$).
[1] High incubation eggs were 39.7^{0}C (103.5^{0}F) at E19. Normal incubation eggs were 37.8^{0}C (100.0^{0}F) at E19.

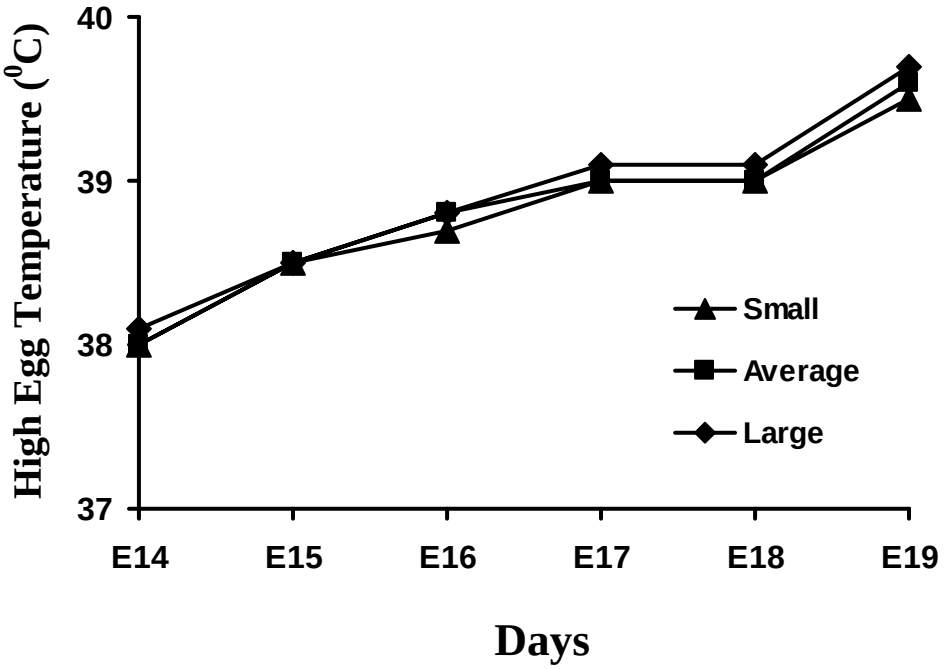

Figure R-1a. Comparison of the internal temperature of small, medium, and large internal eggs in the high temperature incubator in Experiment 7. Triangle symbols represent the small size eggs, rectangle symbols represent the medium size eggs, and diamond symbols represent the large size eggs.

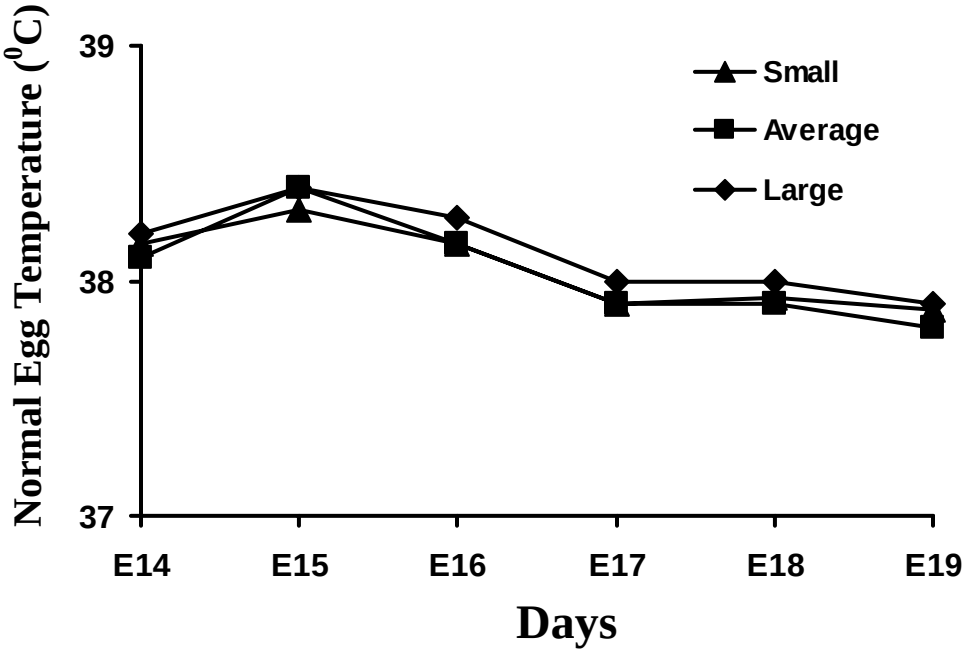

Figure R-1b. Comparison of the internal egg temperature of small, medium, and large eggs in the normal temperature incubator in Experiment 7. Triangle symbols represent the small size eggs, rectangle symbols represent the medium size eggs, and diamond symbols represent the large size eggs.

Experiment 4. The effect of incubation temperature, brooding temperature, sex, interaction temperature by brooding temperature interaction brooding temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction on BW and the relative weights of organs at 14 d of age is shown in Table R-6. BW was significantly decreased by increased incubation temperature while the liver weight was significantly increased. BW and heart weight were significantly larger in males than females.

There were no significant effects due to brooding temperature, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, or incubation temperature by brooding temperature by sex interaction.

Experiment 6. The effect of incubation temperature, brooding temperature, and incubation temperature by brooding temperature interaction on BW and relative weights of the yolk sac, breast, and organs at 21 d of age is shown in Table R-7. BW exhibited a significant decrease due to increased incubation temperature. Heart and small intestines weights exhibited significant decreases due to increased brooding temperature while BW, liver, gizzard, proventriculus, yolk sac and breast were not affected by brooding temperature. The weight of the yolk sac was significantly heavier due to increased incubation temperature by brooding temperature interaction. Chicks that were incubated at a normal temperature and brooded cool possessed significantly larger yolk sacs than those incubated in the normal incubation temperature and brooded hot or incubated at high temperature and brooded cool, while those incubated at the high temperature and brooded hot were intermediate.

Experiments 4, 5, 6, and 7 Concerning Chick Growth. Data concerning chick growth, feed consumption, feed conversion, and mortality were taken in Experiments 4, 5, 6, and 7. These data are summarized in the following section.

TABLE R-6. Body weight and relative weights of tissues and organs from broiler chickens at 14 d of age in Experiment 4 as influenced by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction

Incubation[1] Temperature	Body Weight	Heart	Liver	Gizzard	Proventriculus	Small Intestines
	(g)			(g/100g)		
High	485.3^{B}	0.53	2.97^{a}	2.33	0.63	3.87
Normal	511.0^{A}	0.51	2.81^{b}	2.30	0.62	4.02
SEM	7.5	0.01	0.06	0.06	0.02	0.09
Probability	0.008	0.248	0.012	0.709	0.602	0.200
Brooding[2] Temperature						
Hot	499.5	0.49	2.85	2.30	0.62	3.88
Cool	496.8	0.55	2.92	2.34	0.63	4.00
SEM	8.3	0.01	0.07	0.06	0.02	0.10
Probability	0.839	0.085	0.525	0.725	0.765	0.473
Sex						
Male	520.1^{A}	0.54^{a}	2.85	2.32	0.63	3.88
Female	476.2^{B}	0.50^{b}	2.93	2.32	0.62	3.93
SEM	8.3	0.02	0.06	0.06	0.02	0.09
Probability	0.001	0.017	0.184	0.976	0.696	0.822

^{A,B} Means in columns that possess different superscripts differ significantly ($P \leq 0.01$).
^{a,b} Means in columns that possess different superscripts differ significantly ($P \leq 0.05$).
[1] High incubation eggs were 39.5^{0}C (103.1^{0}F) at E19. Normal incubation eggs were 37.9^{0}C (100.2^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 28.9^{0}C (84.0^{0}F) at placement.

TABLE R-6 (continued). Body weight and relative weights of tissues and organs from broiler chickens at 14 d of age in Experiment 4 as influenced by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction

Incubation[1] Temperature	Brooding[2] Temperature	Body Weight	Heart	Liver	Gizzard	Proventriculus	Small Intestines
		(g)			(g/100g)		
High	Hot	488.0	0.50	2.99	2.31	0.63	3.86
High	Cool	482.7	0.56	2.95	2.36	0.63	3.87
Normal	Hot	511.1	0.48	2.71	2.29	0.61	3.90
Normal	Cool	510.9	0.54	2.90	2.32	0.62	4.14
SEM		10.6	0.02	0.08	0.09	0.02	0.13
Probability		0.783	0.940	0.666	0.933	0.968	0.350
Brooding[2] Temperature	Sex						
Hot	Female	473.5	0.48	2.91	2.36	0.63	3.90
Hot	Male	525.6	0.50	2.79	2.24	0.61	3.87
Cool	Female	478.9	0.52	2.95	2.27	0.61	3.96
Cool	Male	514.7	0.59	2.90	2.40	0.65	4.04
SEM		10.6	0.02	0.08	0.09	0.02	0.13
Probability		0.380	0.120	0.530	0.140	0.280	0.640

[1] High incubation eggs were 39.5^{0}C (103.1^{0}F) at E19. Normal incubation eggs were 37.9^{0}C (100.2^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 28.9^{0}C (84.0^{0}F) at placement.

TABLE R-6 (continued). Body weight and relative weights of tissues and organs from broiler chickens at 14 d of age in Experiment 4 as influenced by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction

Incubation[1] Temperature	Brooding[2] Temperature	Sex	Body Weight	Heart	Liver	Gizzard	Proventriculus	Small Intestines
			(g)			(g/100g)		
High	Hot	Female	473.3	0.49	3.00	2.43	0.62	3.84
High	Hot	Male	502.8	0.52	2.99	2.19	0.63	3.88
High	Cool	Female	472.0	0.52	2.97	2.31	0.60	3.83
High	Cool	Male	493.4	0.60	2.92	2.40	0.67	3.90
Normal	Hot	Female	473.8	0.48	2.83	2.29	0.63	3.95
Normal	Hot	Male	548.4	0.48	2.60	2.28	0.59	3.85
Normal	Cool	Female	485.9	0.51	2.92	2.23	0.62	4.09
Normal	Cool	Male	536.0	0.57	2.88	2.40	0.63	4.19
	SEM		14.1	0.02	0.10	0.12	0.03	0.18
	Probability		0.450	0.819	0.320	0.630	0.990	0.733

[1] High incubation eggs were 39.5^{0}C (103.1^{0}F) at E19. Normal incubation eggs were 37.9^{0}C (100.2^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 28.9^{0}C (84.0^{0}F) at placement.

TABLE R-7. Body weight and relative weights of tissues and organs from broiler chickens at 21 d of age in Experiment 6 as influenced by incubation temperature, brooding temperature, and incubation temperature by brooding temperature interaction

Incubation Temperature[1]		Body Weight	Heart	Liver	Gizzard	Proventriculus	Small Intestines	Yolk Sac	Breast[3]
		(g)	(g/100g)						
High		728.9^{B}	0.53	3.10	5.64	3.61	10.05	4.57	20.53
Normal		773.2^{A}	0.56	3.08	5.76	3.56	10.01	3.74	20.43
SEM		16.8	0.01	0.09	0.07	0.07	0.08	0.86	0.37
Probability		0.002	0.104	0.200	0.123	0.071	0.313	0.186	0.49
Brooding Temperature[2]									
Hot		720.1	0.51^{b}	2.87	5.55	3.37	9.74^{b}	3.65	20.52
Cool		774.9	0.58^{a}	3.29	6.02	3.77	10.29^{a}	4.65	20.46
SEM		21.8	0.01	0.06	0.09	0.10	0.08	1.10	0.51
Probability		0.221	0.039	0.071	0.058	0.089	0.030	0.252	1.000
Incubation[1] Temperature	Brooding[2] Temperature								
High	Hot	704.8	0.50	2.90	5.66	3.43	9.79	5.36^{AB}	20.43
High	Cool	751.8	0.56	3.28	6.01	3.78	10.30	3.82^{B}	20.63
Normal	Hot	739.6	0.52	2.82	5.41	3.30	9.68	1.44^{B}	20.64
Normal	Cool	799.2	0.60	3.29	6.03	3.76	10.28	5.53^{A}	20.27
SEM		23.3	0.01	0.09	0.10	0.10	0.10	0.20	0.52
Probability		0.751	0.119	0.137	0.081	0.125	0.310	0.004	0.386

^{A,B} Means in columns that possess different superscripts differ significantly ($P \leq 0.01$).
^{a,b} Means in columns that possess different superscripts differ significantly ($P \leq 0.05$).
[1] High incubation eggs were 40.6^{0}C (105.1^{0}F) at E19. Normal incubation eggs were 37.7^{0}C (99.9^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 26.7^{0}C (80.1^{0}F) at placement.
[3] Whole breast with bone.

Experiment 4. The effect of incubation, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction on feed consumption of male and female broiler at 0-2 d, 2-5 d, 5-7 d, 0-7 d, and 7-14 d of age is shown in Table R-8. Feed consumption was significantly decreased by increased incubation temperature at all ages. Males consumed less feed than females during the 0-2 d period but consumed more feed during the 7-14 d period. There was an incubation temperature by brooding temperature interaction at 0-2 d ($P < 0.052$) largely due to chicks initially consuming less feed after they had been incubated at the high temperature followed by cool brooding while chick incubated at normal temperature followed by hot brooding consumed the most feed. There were no significant effects due to brooding temperature, brooding temperature by sex interaction, or incubation temperature by brooding temperature by sex interaction.

The effect of incubation temperature, brooding temperature, sex incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction on BW of male and female broilers at 0, 2, 5, 7, and 14 d of age is shown in Table R-9. BW was significantly decreased by increased incubation temperature at all ages but brooding temperature had no overall effect. Males exhibited heavier BW than did females at 0, 5, 7, and 14 d of age. BW at 14 d was significantly affected by the incubation temperature by brooding temperature by sex interaction. Males with a combination of normal incubation temperature and cool brooding temperature exhibited greater BW than males from high incubation temperature and cool brooding while there was little differentiation among the females. There were no significant

TABLE R-8. Feed consumption of broiler chickens as affected by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction in Experiment 4

Incubation[1] Temperature	Feed Consumption For Ages Shown				
	0-2 days	2-5 days	5-7 days	0-7 days	7-14 days
	(g)				
High	27.6^{B}	78.4^{B}	79.5^{b}	185.5^{B}	425.0^{b}
Normal	30.4^{A}	85.8^{A}	86.2^{a}	202.5^{A}	462.8^{a}
SEM	0.8	1.8	2.3	4.0	19.1
Probability	0.001	0.006	0.024	0.001	0.011
Brooding[2] Temperature					
Hot	31.7	85.5	83.8	201.1	434.5
Cool	26.2	78.7	82.0	187.0	453.3
SEM	1.0	1.8	2.5	4.6	25.1
Probability	0.057	0.079	0.655	0.161	0.650
Sex					
Male	28.2^{b}	81.8	83.6	194.4	463.6^{A}
Female	29.7^{a}	82.5	82.2	193.7	424.2^{B}
SEM	0.8	1.8	2.3	4.0	19.1
Probability	0.031	0.789	0.614	0.877	0.008

^{A,B} Means in columns that possess different superscripts differ significantly ($P \leq 0.01$).
^{a,b} Means in columns that possess different superscripts differ significantly ($P \leq 0.05$).
[1] High incubation eggs were 39.5^{0}C (103.1^{0}F) at E19. Normal incubation eggs were 37.9^{0}C (100.2^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 28.9^{0}C (84.0^{0}F) at placement.

TABLE R-8 (continued). Feed consumption of broiler chickens as affected by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction in Experiment 4

Incubation[1] Temperature	Brooding[2] Temperature	Feed Consumption For Ages Shown				
		0-2 days	2-5 days	5-7 days	0-7 days	7-14 days
		(g)				
High	Hot	30.9[ab]	80.9	78.6	190.6	416.3
Normal	Hot	32.5[a]	90.1	89.0	211.7	452.7
High	Cool	24.0[c]	75.9	80.5	180.5	433.7
Normal	Cool	28.3[b]	81.5	83.5	193.4	472.8
SEM		1.1	2.6	3.6	5.7	27.0
Probability		0.052	0.494	0.201	0.390	0.926
Brooding[2] Temperature	Sex					
Hot	Female	32.6	85.2	82.9	200.8	428.0
Hot	Male	30.8	85.8	4.7	201.4	441.1
Cool	Female	26.8	79.7	81.5	188.0	420.4
Cool	Male	25.5	77.7	82.5	186.0	486.1
SEM		1.1	2.6	3.3	5.7	27.0
Probability		0.700	0.617	0.889	0.788	0.072

[1] High incubation eggs were 39.5^{0}C (103.1^{0}F) at E19. Normal incubation eggs were 37.9^{0}C (100.2^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 28.9^{0}C (84.0^{0}F) at placement.

TABLE R-8 (continued). Feed consumption of broiler chickens as affected by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction in Experiment 4

Incubation[1] Temperature	Brooding[2] Temperature	Sex	Feed Consumption For Ages Shown				
			0-2 days	2-5 days	5-7 days	0-7 days	7-14 days
			(g)				
Normal	Hot	Female	33.6	88.7	86.3	208.6	455.0
Normal	Cool	Female	29.8	83.5	82.4	195.6	422.0
High	Hot	Female	31.6	81.7	79.4	193.0	400.9
High	Cool	Female	23.8	76.0	80.5	180.3	418.8
Normal	Hot	Male	31.4	91.5	91.7	214.7	450.5
Normal	Cool	Male	26.9	79.6	84.5	191.3	523.6
High	Hot	Male	30.2	80.1	77.7	188.1	431.8
High	Cool	Male	24.2	75.8	80.5	180.7	448.6
	SEM		1.3	3.7	4.4	7.4	30.6
	Probability		0.390	0.443	0.667	0.405	0.091

[1] High incubation eggs were 39.5^{0}C (103.1^{0}F) at E19. Normal incubation eggs were 37.9^{0}C (100.2^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 28.9^{0}C (84.0^{0}F) at placement.

TABLE R-9. Body weight of broiler chickens as affected by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction in Experiment 4

Incubation[1] Temperature	Body Weight For Ages Shown				
	0 day	2 day	5 day	7 day	14 day
	(g)				
High	45.6^{B}	79.2^{B}	149.2^{B}	206.7^{B}	494.2^{B}
Normal	46.7^{A}	80.8^{A}	152.4^{A}	211.4^{A}	508.5^{A}
SEM	0.2	0.4	0.9	1.7	7.2
Probability	0.001	0.009	0.004	0.002	0.004
Brooding[2] Temperature					
Hot	46.2	80.7	151.0	208.7	498.9
Cool	46.0	79.3	150.6	209.4	503.7
SEM	0.2	0.4	1.1	2.1	9.7
Probability	0.530	0.078	0.824	0.833	0.760
Sex					
Male	46.6^{A}	80.1	152.8^{A}	213.5^{A}	522.9^{A}
Female	45.7^{B}	79.9	148.8^{B}	204.6^{B}	479.8^{B}
SEM	0.2	0.4	0.9	1.2	7.2
Probability	0.001	0.690	0.001	0.001	0.001

^{A,B} Means in columns that possess different superscripts differ significantly ($P \leq 0.01$).
[1] High incubation eggs were 39.5^{0}C (103.1^{0}F) at E19. Normal incubation eggs were 37.9^{0}C (100.2^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 28.9^{0}C (84.0^{0}F) at placement.

TABLE R-9 (continued). Body weight of broiler chickens as affected by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction in Experiment 4

Incubation[1] Temperature	Brooding[2] Temperature	Body Weight For Ages Shown				
		0 day	2 day	5 day	7 day	14 day
		(g)				
High	Hot	45.6	79.7	149.5	206.0	492.7
Normal	Hot	46.9	81.6	152.5	211.4	505.3
High	Cool	45.6	78.6	148.9	207.4	495.7
Normal	Cool	46.5	80.0	152.3	211.4	511.8
SEM		0.3	0.6	1.3	2.4	34.4
Probability		0.523	0.642	0.860	0.636	0.710
Brooding[2] Temperature	Sex					
Hot	Female	45.7	80.3	148.6	204.2	477.0
Hot	Male	46.8	81.0	153.3	213.2	521.0
Cool	Female	45.6	79.4	148.9	205.0	482.5
Cool	Male	46.4	79.2	152.2	213.8	524.9
SEM		0.3	0.6	1.3	2.4	10.2
Probability		0.593	0.379	0.493	0.940	0.875

[1] High incubation eggs were 39.5^{0}C (103.1^{0}F) at E19. Normal incubation eggs were 37.9^{0}C (100.2^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 28.9^{0}C (84.0^{0}F) at placement.

TABLE R-9 (continued). Body weight of broiler chickens as affected by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction in Experiment 4

Incubation[1] Temperature	Brooding[2] Temperature	Sex	Body Weight For Ages Shown				
			0 day	2 day	5 day	7 day	14 day
			(g)				
Normal	Hot	Female	46.4	81.3	150.3	207.0	483.8^{cd}
Normal	Cool	Female	45.8	80.1	149.3	205.2	481.2^{d}
High	Hot	Female	45.1	79.3	146.9	201.5	470.2^{d}
High	Cool	Female	45.5	78.8	148.6	204.9	483.8^{cd}
Normal	Hot	Male	47.3	81.9	154.7	215.8	526.7^{ab}
Normal	Cool	Male	47.1	79.8	155.3	217.6	542.4^{a}
High	Hot	Male	46.2	80.2	152.0	210.6	515.2^{ab}
High	Cool	Male	45.7	78.5	149.2	210.0	507.5^{bc}
SEM			0.4	0.8	1.7	2.8	11.3
Probability			0.222	0.890	0.161	0.192	0.040

[a,b] Means in columns that possess different superscripts differ significantly ($P \leq 0.05$).

[1] High incubation eggs were 39.5^{0}C (103.1^{0}F) at E19. Normal incubation eggs were 37.9^{0}C (100.2^{0}F) at E19.

[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 28.9^{0}C (84.0^{0}F) at placement

effects due to brooding temperature, incubation temperature by brooding temperature interaction, or brooding temperature by sex interaction.

The effect of incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction on AdjFCR of male and female broilers at 0-2, 2-5, 0-5, 5-7, 0-7, 7-14, and 0-14 d of age is shown in Table R-10. The AdjFCR for the 0-2, 0-5, 0-7, and 0-14 d periods was significantly decreased (improved) by increased incubation temperature. The AdjFCR was increased (worsened) by increased brooding temperature during the 2-5 d period while there were no effects during the other time periods. Males and female exhibited no differences. There was a significant incubation temperature by brooding temperature interaction for the initial 0-2 d period only. Chicks that were incubated in a high incubation temperature and brooded in a cool room had significantly lower (better) AdjFCR than the other chicks. There were no effects due to sex, brooding temperature by sex interaction, or incubation temperature by brooding temperature by sex interaction.

The effect of incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction on percentage mortality of male and female broilers at 0-2, 2-5, 0-5, 5-7, 0-7, 7-14, and 0-14 d of age is shown in Table R-11. Mortality was generally low and there were no significant effects observed.

Experiment 5. The effect of incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, incubation temperature by sex interaction, and incubation temperature by brooding

TABLE R-10. Adjusted feed conversion ratio (AdjFCR) of broiler chickens as affected by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction in Experiment 4

Incubation[1] Temperature	AdjFCR For Ages Shown						
	0-2 days	2-5 days	0-5 days	5-7 days	0-7 days	7-14 days	0-14 days
	(g:g)						
High	0.82[B]	1.13	1.03[B]	1.38	1.15[b]	1.48	1.36[b]
Normal	0.89[A]	1.21	1.10[A]	1.47	1.23[a]	1.56	1.44[a]
SEM	0.02	0.03	0.02	0.04	0.02	0.06	0.04
Probability	0.001	0.054	0.009	0.113	0.014	0.101	0.019
Brooding[2] Temperature							
Hot	0.92	1.22[a]	1.12	1.45	1.24	1.50	1.41
Cool	0.79	1.11[b]	1.01	1.40	1.15	1.53	1.39
SEM	0.03	0.03	0.02	0.04	0.02	0.07	0.06
Probability	0.091	0.034	0.502	0.381	0.119	0.789	0.893
Sex							
Male	0.84	1.13	1.04	1.38	1.16	1.49	1.38
Female	0.87	1.20	1.09	1.47	1.22	1.54	1.47
SEM	0.02	0.03	0.02	0.04	0.02	0.06	0.04
Probability	0.211	0.098	0.080	0.078	0.060	0.281	0.140

[A,B] Means in columns that possess different superscripts differ significantly ($P \leq 0.01$).
[a,b] Means in columns that possess different superscripts differ significantly ($P \leq 0.05$).
[1] High incubation eggs were 39.5^{0}C (103.1^{0}F) at E19. Normal incubation eggs were 37.9^{0}C (100.2^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 28.9^{0}C (84.0^{0}F) at placement.

TABLE R-10 (continued). Adjusted feed conversion ratio (AdjFCR) of broiler chickens as affected by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction in Experiment 4

Incubation[1] Temperature	Brooding[2] Temperature	AdjFCR For Ages Shown						
		0-2 days	2-5 days	0-5 days	5-7 days	0-7 days	7-14 days	0-14 days
		(g:g)						
High	Hot	0.91[a]	1.17	1.08	1.39	1.19	1.46	1.36
Normal	Hot	0.94[a]	1.28	1.16	1.38	1.29	1.50	1.45
High	Cool	0.72[b]	1.09	0.97	1.51	1.12	1.54	1.36
Normal	Cool	0.85[a]	1.14	1.04	1.42	1.18	1.57	1.43
SEM		0.03	0.04	0.03	0.05	0.03	0.08	0.06
Probability		0.037	0.489	0.890	0.423	0.558	0.807	0.702
Brooding[2] Temperature	Sex							
Hot	Female	0.94	1.25	1.15	1.49	1.27	1.57	1.46
Hot	Male	0.90	1.19	1.10	1.42	1.21	1.43	1.36
Cool	Female	0.79	1.15	1.03	1.45	1.18	1.52	1.39
Cool	Male	0.78	1.07	0.98	1.34	1.11	1.55	1.40
SEM		0.03	0.04	0.03	0.05	0.03	0.08	0.06
Probability		0.499	0.884	0.986	0.709	0.858	0.072	0.104

[a,b] Means in columns that possess different superscripts differ significantly ($P \leq 0.05$).
[1] High incubation eggs were 39.5^{0}C (103.1^{0}F) at E19. Normal incubation eggs were 37.9^{0}C (100.2^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 28.9^{0}C (84.0^{0}F) at placement.

TABLE R-10 (continued). Adjusted feed conversion ratio (AdjFCR) of broiler chickens as affected by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction in Experiment 4

Incubation[1] Temperature	Brooding[2] Temperature	Sex	AdjFCR For Ages Shown						
			0-2 days	2-5 days	0-5 days	5-7 days	0-7 days	7-14 days	0-14 days
			(g:g)						
Normal	Hot	Female	0.96	1.29	1.18	1.52	1.30	1.64	1.52
Normal	Cool	Female	0.87	1.21	1.10	1.48	1.23	1.53	1.42
High	Hot	Female	0.93	1.21	1.12	1.45	1.23	1.49	1.40
High	Cool	Female	0.72	1.09	0.97	1.43	1.13	1.50	1.37
Normal	Hot	Male	0.91	1.26	1.15	1.50	1.28	1.45	1.39
Normal	Cool	Male	0.83	1.07	0.99	1.36	1.13	1.60	1.44
High	Hot	Male	0.89	1.12	1.04	1.33	1.15	1.42	1.32
High	Cool	Male	0.73	1.08	0.97	1.32	1.10	1.50	1.36
	SEM		0.04	0.06	0.04	0.07	0.05	0.09	0.07
	Probability		0.604	0.221	0.200	0.567	0.280	0.274	0.505

[1] High incubation eggs were 39.5^{0}C (103.1^{0}F) at E19. Normal incubation eggs were 37.9^{0}C (100.2^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 28.9^{0}C (84.0^{0}F) at placement.

TABLE R-11. Percentage mortality (deaths) of broiler chickens as affected by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction in Experiment 4

Incubation[1] Temperature	Deaths For Ages Shown						
	0-2 days	2-5 days	0-5 days	5-7 days	0-7 days	7-14 days	0-14 days
	(%)						
High	0.00	0.45	0.45	0.00	0.45	0.22	0.67
Normal	0.00	0.22	0.22	0.00	0.22	0.45	0.67
SEM	0.00	0.31	0.31	0.00	0.31	0.38	0.64
Probability	-	0.561	0.561	-	0.561	0.551	1.000
Brooding[2] Temperature							
Hot	0.00	0.22	0.22	0.00	0.22	0.00	0.22
Cool	0.00	0.45	0.45	0.00	0.45	0.67	1.12
SEM	0.00	0.35	0.35	0.00	0.35	0.47	0.80
Probability	-	0.699	0.699	-	0.699	0.423	0.515
Sex							
Male	0.00	0.45	0.45	0.00	0.45	0.22	0.67
Female	0.00	0.22	0.22	0.00	0.22	0.45	0.67
SEM	0.00	0.31	0.31	0.00	0.31	0.38	0.64
Probability	-	0.566	0.566	-	0.789	0.566	1.000

[1] High incubation eggs were 39.5^{0}C (103.1^{0}F) at E19. Normal incubation eggs were 37.9^{0}C (100.2^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 28.9^{0}C (84.0^{0}F) at placement.

TABLE R-11 (continued). Percentage mortality (deaths) of broiler chickens as affected by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction in Experiment 4

Incubation[1] Temperature	Brooding[2] Temperature	Deaths For Ages Shown						
		0-2 days	2-5 days	0-5 days	5-7 days	0-7 days	7-14 days	0-14 days
		(%)						
High	Hot	0.00	0.45	0.45	0.00	0.45	0.00	0.45
Normal	Hot	0.00	0.00	0.00	0.00	0.00	0.00	0.00
High	Cool	0.00	0.45	0.45	0.00	0.45	0.45	0.89
Normal	Cool	0.00	0.45	0.45	0.00	0.45	0.89	1.34
SEM		0.00	0.44	0.44	0.00	0.44	0.54	0.91
Probability		-	0.561	0.562	-	0.561	0.551	0.463
Brooding[2] Temperature	Sex							
Hot	Female	0.00	0.45	0.45	0.00	0.45	0.00	0.45
Hot	Male	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cool	Female	0.00	0.00	0.00	0.00	0.00	0.89	0.89
Cool	Male	0.00	0.89	0.89	0.00	0.89	0.45	1.34
SEM		0.00	0.44	0.44	0.00	0.44	0.54	0.91
Probability		-	0.085	0.085	-	0.085	0.551	0.463

[1] High incubation eggs were 39.5^{0}C (103.1^{0}F) at E19. Normal incubation eggs were 37.9^{0}C (100.2^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 28.9^{0}C (84.0^{0}F) at placement.

TABLE R-11 (continued). Percentage mortality (deaths) of broiler chickens as affected by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction in Experiment 4

Incubation[1] Temperature	Brooding[2] Temperature	Sex	Deaths For Ages Shown						
			0-2 days	2-5 days	0-5 days	5-7 days	0-7 days	7-14 days	0-14 days
			(%)						
Normal	Hot	Female	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Normal	Cool	Female	0.00	0.00	0.00	0.00	0.00	0.89	0.89
High	Hot	Female	0.00	0.89	0.89	0.00	0.89	0.00	0.89
High	Cool	Female	0.00	0.00	0.00	0.00	0.00	0.89	0.89
Normal	Hot	Male	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Normal	Cool	Male	0.00	0.89	0.89	0.00	0.89	0.89	1.79
High	Hot	Male	0.00	0.00	0.00	0.00	0.00	0.00	0.00
High	Cool	Male	0.00	0.89	0.89	0.00	0.89	0.00	0.89
	SEM		0.00	0.59	0.59	0.00	0.66	0.66	1.09
	Probability		-	0.561	0.561	-	0.551	0.551	1.000

[1] High incubation eggs were 39.5^{0}C (103.1^{0}F) at E19. Normal incubation eggs were 37.9^{0}C (100.2^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 28.9^{0}C (84.0^{0}F) at placement.

temperature by sex interaction on feed consumption of male and female broilers at 0-7, 7-14, and 0-14 d of age is shown in Table R-12. Feed consumption for the 0-7, 7-14, and 0-14 d periods was significantly decreased by increased incubation temperature but brooding temperature and sex had no effects. Feed consumption for the 0-7 d period exhibited a significant incubation temperature by brooding temperature interaction. Chicks from the normal incubator subject to either hot or cool brooding exhibited better feed intake than chicks from the other combinations with the lowest feed intake exhibited by the high incubation-cool brooded chicks. Feed consumption for the 7-14 and 0-14 d periods exhibited a significant incubation temperature by sex interaction due to incubation temperature affecting feed consumption of females slightly more than males. There were no significant effects due to the brooding temperature by sex interaction or incubation temperature by brooding temperature by sex interaction.

The effect of incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, incubation temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction on BW of male and female broilers at 0, 7, and 14 d of age is shown in Table R-13. BW was significantly decreased by increased incubation temperature at all ages and BW at 7 d was significantly affected by the incubation temperature by brooding temperature interaction because there was greater difference in feed intake due to incubation temperature in the cool brooded chicks than in the hot brooded chicks. There were no significant effects due to brooding temperature, sex, brooding temperature by sex interaction, incubation temperature by sex interaction, or incubation temperature by brooding temperature by sex interaction.

TABLE R-12. Feed consumption of broiler chickens as affected by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, incubation temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction in Experiment 5

Incubation Temperature[1]	Feed Consumption For Ages Shown		
	0-7 days	7-14 days	0-14 days
	(g)		
High	112.2[B]	319.4[B]	432.4[B]
Normal	131.1[A]	339.7[A]	471.3[A]
SEM	1.1	3.8	4.2
Probability	0.001	0.001	0.001
Brooding Temperature[2]			
Hot	124.0	326.7	451.1
Cool	119.3	334.8	455.7
SEM	1.1	3.8	4.2
Probability	0.093	0.275	0.638
Sex			
Male	121.5	326.7	451.1
Female	121.8	334.8	455.7
SEM	1.1	3.8	4.2
Probability	0.829	0.638	0.638

[A,B] Means in columns that possess different superscripts differ significantly ($P \leq 0.01$).
[1] High incubation eggs were 39.9^{0}C (103.8^{0}F) at E19. Normal incubation eggs were 37.6^{0}C (99.7^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 26.7^{0}C (80.1^{0}F) at placement.

TABLE R-12 (continued). Feed consumption of broiler chickens as affected by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interactions, incubation temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction in Experiment 5

Incubation[1] Temperature	Brooding[2] Temperature	Feed Consumption For Ages Shown		
		0-7 days	7-14 days	0-14 days
		(g)		
High	Hot	116.4[b]	318.0	434.5
Normal	Hot	131.6[a]	335.4	467.7
High	Cool	108.0[c]	321.6	429.8
Normal	Cool	130.7[a]	345.0	475.7
SEM		1.5	5.3	6.0
Probability		0.018	0.718	0.132
Brooding[2] Temperature	Sex			
Hot	Female	123.8	321.6	445.4
Hot	Male	124.3	331.8	456.7
Cool	Female	119.9	331.2	450.8
Cool	Male	118.7	338.3	457.9
SEM		1.6	5.4	6.0
Probability		0.610	0.775	0.725

[a,b,c] Means in columns that possess different superscripts differ significantly ($P \leq 0.05$).
[1] High incubation eggs were 39.9^{0}C (103.8^{0}F) at E19. Normal incubation eggs were 37.6^{0}C (99.7^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 26.7^{0}C (80.1^{0}F) at placement.

TABLE R-12 (continued). Feed consumption of broiler chickens as affected by incubation temperature, brooding temperature, sex,incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, incubation temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction in Experiment 5

Incubation[1] Temperature	Sex	Feed Consumption For Ages Shown		
		0-7 days	7-14 days	0-14 days
		(g)		
High	Female	111.6	311.2[b]	422.9[c]
Normal	Female	132.0	341.7[a]	473.4[a]
High	Male	112.8	331.0[ab]	444.2[b]
Normal	Male	130.3	339.1[a]	470.5[a]
	SEM	1.5	5.4	6.0
	Probability	0.351	0.043	0.049

Incubation[1] Temperature	Brooding[2] Temperature	Sex			
Normal	Hot	Female	131.7	332.3	464.0
Normal	Cool	Female	132.3	351.0	482.8
High	Hot	Female	115.9	311.0	426.8
High	Cool	Female	107.4	311.4	418.9
Normal	Hot	Male	131.5	338.5	471.3
Normal	Cool	Male	129.0	339.7	469.6
High	Hot	Male	117.0	325.1	442.1
High	Cool	Male	108.5	336.9	446.2
	SEM		2.2	7.6	8.4
	Probability		0.617	0.188	0.184

[a,b,c] Means in columns that possess different superscripts differ significantly ($P \leq 0.05$).
[1] High incubation eggs were 39.9^{0}C (103.8^{0}F) at E19. Normal incubation eggs were 37.6^{0}C (99.7^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 26.7^{0}C (80.1^{0}F) at placement.

TABLE R-13. Body weight of broiler chickens as affected by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, incubation temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction in Experiment 5

Incubation Temperature[1]	Body Weight For Ages Shown		
	0 day	7 day	14 day
	(g)		
High	37.4[B]	133.2[B]	378.8[B]
Normal	39.4[A]	151.4[A]	399.1[A]
SEM	0.2	1.5	7.0
Probability	0.001	0.001	0.005
Brooding Temperature[2]			
Hot	38.7	142.8	386.3
Cool	38.2	142.8	393.9
SEM	0.2	1.5	6.9
Probability	0.144	0.992	0.520
Sex			
Male	38.6	142.7	393.9
Female	38.3	143.0	385.3
SEM	0.2	1.5	7.4
Probability	0.226	0.856	0.188

[A,B] Means in columns that possess different superscripts differ significantly ($P \leq 0.01$).
[1] High incubation eggs were 39.9^{0}C (103.8^{0}F) at E19. Normal incubation eggs were 37.6^{0}C (99.7^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 26.7^{0}C (80.1^{0}F) at placement.

TABLE R-13 (continued). Body weight of broiler chickens as affected by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, incubation temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction in Experiment 5

Incubation[1] Temperature	Brooding[2] Temperature	Body Weight For Ages Shown		
		0 day	7 day	14 day
		(g)		
High	Hot	37.6	135.3[b]	376.6
Normal	Hot	39.7	149.4[a]	396.0
High	Cool	37.3	132.1[b]	382.3
Normal	Cool	39.1	153.5[a]	402.9
SEM		0.2	2.0	9.0
Probability		0.514	0.030	0.973
Brooding[2] Temperature	Sex			
Hot	Female	38.5	142.7	383.2
Hot	Male	38.9	142.9	389.3
Cool	Female	38.1	143.2	387.4
Cool	Male	38.3	142.4	398.7
SEM		0.2	2.0	7.7
Probability		0.661	0.774	0.689

[a,b] Means in columns that possess different superscripts differ significantly ($P \leq 0.05$).
[1] High incubation eggs were 39.9^{0}C (103.8^{0}F) at E19. Normal incubation eggs were 37.6^{0}C (99.7^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 26.7^{0}C (80.1^{0}F) at placement.

TABLE R-13 (continued). Body weight of broiler chickens as affected by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, incubation temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction in Experiment 5

Incubation[1] Temperature	Sex	Body Weight For Ages Shown		
		0 day	7 day	14 day
		(g)		
High	Female	37.3	135.3	372.0
Normal	Female	39.3	150.7	398.7
High	Male	37.6	133.2	388.2
Normal	Male	39.5	152.1	399.8
	SEM	0.2	2.0	7.1
	Probability	0.823	0.360	0.254

Incubation[1] Temperature	Brooding[2] Temperature	Sex			
Normal	Hot	Female	39.6	148.9	394.1
Normal	Cool	Female	39.1	152.6	403.2
High	Hot	Female	37.4	136.6	372.4
High	Cool	Female	37.1	133.9	371.6
Normal	Hot	Male	39.9	149.8	397.8
Normal	Cool	Male	39.1	154.4	401.8
High	Hot	Male	37.8	136.1	380.8
High	Cool	Male	37.4	130.3	395.5
	SEM		0.3	2.8	10.0
	Probability		0.808	0.588	0.431

[1] High incubation eggs were 39.9^{0}C (103.8^{0}F) at E19. Normal incubation eggs were 37.6^{0}C (99.7^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 26.7^{0}C (80.1^{0}F) at placement.

The effect of incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, incubation temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction on AdjFCR of male and female broilers at 0-7, 7-14, and 0-14 d periods is shown in Table R-14. The AdjFCR for the 7-14 and 0-14 d periods was significantly decreased (improved) by increased incubation temperature. The AdjFCR for the 0-7 d period was significantly affected by the incubation temperature by sex interaction because high incubation worsened female AdjFCR while it improved male AdjFCR. There were no significant effects due to brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, or incubation temperature by brooding temperature by sex interactions.

The effect of incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, incubation temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction on percentage mortality of male and female broilers is shown in Table R-15. There was incubation temperature by brooding temperature interaction at 0-7 d period ($P < 0.050$) due to chicks having greatest mortality when they had been incubated at the high temperature followed by cool brooding. There was brooding temperature by sex interaction at 0-7 d period ($P < 0.050$) due to males with a combination of cool brooding temperature exhibit greater death than females. There was incubation temperature by sex interaction at 0-7 d period ($P < 0.050$) due to males with a combination of high incubation temperature exhibit greater death than females. There were no significant effects due to incubation

TABLE R-14. Adjusted feed conversion ratio (AdjFCR) of broiler chickens as affected by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, incubation temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction in Experiment 5

Incubation Temperature[1]	AdjFCR For Ages Shown		
	0-7 days	7-14 days	0-14 days
		(g:g)	
High	1.17	1.32[B]	1.27[B]
Normal	1.18	1.38[A]	1.32[A]
SEM	0.02	0.02	0.02
Probability	0.850	0.003	0.006
Brooding Temperature[2]			
Hot	1.19	1.35	1.30
Cool	1.15	1.35	1.28
SEM	0.03	0.02	0.02
Probability	0.380	0.880	0.540
Sex			
Male	1.18	1.36	1.30
Female	1.16	1.34	1.29
SEM	0.02	0.02	0.06
Probability	0.370	0.730	0.970

[A,B] Means in columns that possess different superscripts differ significantly ($P \leq 0.01$).
[1] High incubation eggs were 39.9^{0}C (103.8^{0}F) at E19. Normal incubation eggs were 37.6^{0}C (99.7^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 26.7^{0}C (80.1^{0}F) at placement.

TABLE R-14 (continued). Adjusted feed conversion ratio (AdjFCR) of broiler chickens as affected by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, incubation temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction in Experiment 5

Incubation[1] Temperature	Brooding[2] Temperature	AdjFCR For Ages Shown		
		0-7 days	7-14 days	0-14 days
		(g:g)		
High	Hot	1.18	1.33	1.28
Normal	Hot	1.21	1.37	1.32
High	Cool	1.16	1.31	1.25
Normal	Cool	1.14	1.39	1.31
SEM		0.03	0.03	0.02
Probability		0.290	0.350	0.440
Brooding[2] Temperature	Sex			
Hot	Female	1.19	1.34	1.29
Hot	Male	1.20	1.36	1.31
Cool	Female	1.14	1.36	1.29
Cool	Male	1.17	1.35	1.27
SEM		0.03	0.03	0.02
Probability		0.627	0.532	0.352

[1] High incubation eggs were 39.9^{0}C (103.8^{0}F) at E19. Normal incubation eggs were 37.6^{0}C (99.7^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 26.7^{0}C (80.1^{0}F) at placement.

TABLE R-14 (continued). Adjusted feed conversion ratio (AdjFCR) of broiler chickens as affected by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, incubation temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction in Experiment 5

Incubation[1] Temperature	Sex	AdjFCR For Ages Shown		
		0-7 days	7-14 days	0-14 days
		(g:g)		
High	Female	1.34[a]	1.31	1.26
Normal	Female	1.19[b]	1.32	1.32
High	Male	1.20[b]	1.38	1.27
Normal	Male	1.16[b]	1.39	1.31
SEM		0.03	0.02	0.02
Probability		0.022	0.959	0.703

Incubation[1] Temperature	Brooding[2] Temperature	Sex			
Normal	Hot	Female	1.21	1.36	1.31
Normal	Cool	Female	1.17	1.40	1.32
High	Hot	Female	1.17	1.32	1.27
High	Cool	Female	1.11	1.31	1.25
Normal	Hot	Male	1.20	1.38	1.33
Normal	Cool	Male	1.12	1.39	1.30
High	Hot	Male	1.19	1.33	1.29
High	Cool	Male	1.21	1.30	1.24
	SEM		0.04	0.03	0.03
	Probability		0.146	0.800	0.790

[a,b] Means in columns that possess different superscripts differ significantly ($P \leq 0.05$).
[1] High incubation eggs were 39.9^{0}C (103.8^{0}F) at E19. Normal incubation eggs were 37.6^{0}C (99.7^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 26.7^{0}C (80.1^{0}F) at placement.

TABLE R-15. Percentage mortality (deaths) of broiler chickens as affected by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, incubation temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction in Experiment 5

Incubation Temperature[1]	Deaths For Ages Shown		
	0-7 days	7-14 days	0-14 days
		(%)	
High	1.12	0.00	1.12
Normal	0.22	0.22	0.44
SEM	0.66	0.20	0.27
Probability	0.198	0.412	0.248
Brooding Temperature[2]			
Hot	0.22	0.22	0.44
Cool	1.12	0.00	1.12
SEM	0.80	0.19	0.27
Probability	0.515	0.507	0.363
Sex			
Male	1.12	0.22	1.34
Female	0.22	0.00	0.22
SEM	0.66	0.19	0.27
Probability	0.198	0.412	1.000

[1] High incubation eggs were 39.9^{0}C (103.8^{0}F) at E19. Normal incubation eggs were 37.6^{0}C (99.7^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 26.7^{0}C (80.1^{0}F) at placement.

TABLE R-15 (continued). Percentage mortality (deaths) of broiler chickens as affected by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, incubation temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction in Experiment 5

Incubation[1] Temperature	Brooding[2] Temperature	Deaths For Ages Shown		
		0-7 days	7-14 days	0-14 days
		(%)		
High	Hot	0.00[b]	0.00	0.00
Normal	Hot	0.45[b]	0.45	0.90
High	Cool	2.23[a]	0.00	2.23
Normal	Cool	0.00[b]	0.00	0.00
SEM		0.94	0.28	0.38
Probability		0.050	0.412	0.248
Brooding[2] Temperature	Sex			
Hot	Female	0.45[b]	0.00	0.45
Hot	Male	0.00[b]	0.45	0.45
Cool	Female	0.00[b]	0.00	0.00
Cool	Male	2.23[a]	0.00	2.23
SEM		0.94	0.28	0.38
Probability		0.050	0.412	1.000

[a,b] Means in columns that possess different superscripts differ significantly ($P \leq 0.05$).
[1] High incubation eggs were 39.9^{0}C (103.8^{0}F) at E19. Normal incubation eggs were 37.6^{0}C (99.7^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 26.7^{0}C (80.1^{0}F) at placement.

TABLE R-15 (continued). Percentage mortality (deaths) of broiler chickens as affected by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, incubation temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction in Experiment 5

Incubation[1] Temperature	Sex	Deaths For Ages Shown		
		0-7 days	7-14 days	0-14 days
		(%)		
High	Female	0.00[b]	0.00	0.00
Normal	Female	0.45[b]	0.00	0.45
High	Male	2.23[a]	0.00	2.23
Normal	Male	0.00[b]	0.45	0.45
SEM		0.82	0.27	0.38
Probability		0.050	0.412	1.000

Incubation[1] Temperature	Brooding[2] Temperature	Sex			
Normal	Hot	Female	0.89	0.00	0.89
Normal	Cool	Female	0.00	0.00	0.00
High	Hot	Female	0.00	0.00	0.00
High	Cool	Female	0.00	0.00	0.00
Normal	Hot	Male	0.00	0.89	0.89
Normal	Cool	Male	0.00	0.00	0.00
High	Hot	Male	0.00	0.00	0.00
High	Cool	Male	4.46	0.00	4.46
SEM			0.04	0.38	0.54
Probability			0.146	0.412	1.000

[a,b] Means in columns that possess different superscripts differ significantly ($P \leq 0.05$).
[1] High incubation eggs were 39.9^{0}C (103.8^{0}F) at E19. Normal incubation eggs were 37.6^{0}C (99.7^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 26.7^{0}C (80.1^{0}F) at placement.

temperature, brooding temperature, sex and incubation temperature by brooding temperature by sex interactions.

Experiment 6. The effect of incubation temperature, brooding temperature, and incubation temperature by brooding temperature on feed consumption of male and female broilers at 0-7, 7-14, and 14-21 d of age is shown in Table R-16. Feed consumption was significantly decreased by increased incubation temperature at all ages. Feed consumption was increased by increased brooding temperature during the 0-7 d period but decreased during the 7-14 d period. Feed consumption for the 0-7 and 14-21 d periods was significantly affected by the incubation temperature by brooding temperature interaction. Hot brooded chicks that had been incubated in the normal incubator consumed the most feed while cool brooded chicks that had been incubated in the hot incubator consumed the least amount of feed during the 0-7 d period. Cool brooded chicks that were incubated in the normal incubator consumed the most feed while hot brooded chicks that were incubated in the high incubator consumed the least amount of feed during the 14-21 d period.

The effect of incubation temperature, brooding temperature, and the incubation temperature by brooding temperature interaction on BW of male and female broilers at 0, 7, 14, and 21 d of age is shown in Table R-17. BW was significantly decreased by increased incubation temperature at all ages and by increased brooding temperature at 7 and 14 d of age. There was a significant incubation by brooding interaction at 7 d because cool brooding increased BW more than did hot brooding for normal incubated chicks while the high incubated chicks were not affected by brooding. By 14 d the high incubation-hot brooding chicks were smaller than all other groups while the normal incubated-cool brooded chicks were larger than all other groups.

TABLE R-16. Feed consumption of broiler chickens as affected by incubation temperature, brooding temperature, and incubation temperature by brooding temperature interaction in Experiment 6

Incubation Temperature[1]		Feed Consumption For Ages Shown		
		0-7 days	7-14 days	14-21 days
		(g)		
High		119.9^{B}	302.8^{B}	498.3^{B}
Normal		138.9^{A}	337.0^{A}	538.1^{A}
SEM		1.7	2.1	5.7
Probability		0.001	0.001	0.001
Brooding Temperature[2]				
Hot		137.4^{a}	302.7^{B}	498.9
Cool		121.4^{b}	337.1^{A}	537.5
SEM		1.7	2.3	7.4
Probability		0.021	0.009	0.066
Incubation[1] temperature	Brooding[2] Temperature			
High	Hot	132.0^{B}	287.9	484.2^{c}
Normal	Hot	142.7^{A}	317.4	513.5^{b}
High	Cool	107.8^{C}	317.7	512.3^{b}
Normal	Cool	135.0^{B}	356.6	562.7^{a}
SEM		2.3	3.0	8.1
Probability		0.001	0.088	0.0327

^{A,B,C} Means in columns that possess different superscripts differ significantly ($P \leq 0.01$).
$^{a,b.c}$ Means in columns that possess different superscripts differ significantly ($P \leq 0.05$).
[1] High incubation eggs were 40.6^{0}C (105.1) at E19. Normal incubation eggs were 37.7^{0}C (99.9^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 26.7^{0}C (80.1^{0}F) at placement.

TABLE R-17. Body weight of broiler chickens as affected by incubation temperature, brooding temperature, and incubation temperature by brooding temperature interaction in Experiment 6

Incubation Temperature[1]		Body Weight For Ages Shown			
		0 day	7 day	14 day	21 day
		(g)			
High		43.7^{B}	138.8^{B}	380.7^{B}	772.8^{B}
Normal		45.5^{A}	150.7^{A}	411.5^{A}	777.0^{A}
SEM		0.1	0.9	2.9	5.6
Probability		0.001	0.001	0.001	0.001
Brooding Temperature[2]					
Hot		44.6	141.9^{b}	384.5^{b}	721.9
Cool		44.6	147.7^{a}	407.8^{a}	775.7
SEM		0.1	1.0	3.2	6.2
Probability		0.800	0.050	0.036	0.255
Incubation[1] Temperature	Brooding[2] Temperature				
High	Hot	43.8	138.1^{C}	372.9^{c}	698.7
Normal	Hot	45.4	145.7^{B}	396.1^{b}	745.0
High	Cool	43.7	139.6^{C}	388.6^{b}	746.8
Normal	Cool	45.6	155.7^{A}	427.0^{a}	809.0
SEM		0.1	1.6	4.0	7.9
Probability		0.181	0.002	0.033	0.330

^{A,B,C} Means in columns that possess different superscripts differ significantly ($P \leq 0.01$).
^{a,b,c} Means in columns that possess different superscripts differ significantly ($P \leq 0.05$).
[1] High incubation eggs were 40.6^{0}C (105.1) at E19. Normal incubation eggs were 37.7^{0}C (99.9^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 26.7^{0}C (80.1^{0}F) at placement.

The effect of incubation temperature, brooding temperature, and incubation temperature by brooding temperature interaction on AdjFCR of male and female broilers at 0-7, 7-14, 0-14, 14-21, 0-21 d of age is shown in Table R-18. The AdjFCR for the 0-7, 7-14, 0-14, and 0-21 d periods was significantly decreased (improved) by increased incubation temperature while there were no effects during the 14-21 d period. The AdjFCR for the 0-7 d period was significantly increased (worsened) by increased brooding temperature. There were no effects during the 0-14, 14-21, and 0-21 d periods. There were no significant effects due to the incubation temperature by brooding temperature interaction.

The effect of incubation temperature, brooding temperature, and the incubation temperature by brooding temperature interaction on percentage mortality of male and female broilers at 0-7, 0-14, 0-14, 14-21, and 0-21 d of age is shown in Table R-19. Mortality for the 0-7 and 0-14 d periods was significantly increased by increased incubation temperature. There were no effects due to brooding temperature or the incubation temperature by brooding temperature interaction.

Experiment 7. The effect of incubation temperature on feed consumption of male and female broilers at 0-7, 7-12, 12-21, and 21-28 d of age is shown in Table R-20. Feed consumption for the 21-28 and 0-28 d periods was significantly decreased by increased incubation temperature but there were no effects during any other period.

The effect of incubation temperature on BW of male and female broilers at 0, 7, 12, 21, and 28 d of age is shown in Table R-21. BW was significantly decreased by increased incubation temperature at 0 and 21 d of age but not at the other ages.

TABLE R-18. Adjusted feed conversion ratio (AdjFCR) of broiler chickens as affected by incubation temperature, brooding temperature, and incubation temperature by brooding temperature interaction in Experiment 6

Incubation Temperature[1]		AdjFCR For Ages Shown				
		0-7 days	7-14 days	0-14 days	14-21 days	0-21 days
		(g:g)				
High		1.27[b]	1.26[B]	1.26[B]	1.46	1.36[b]
Normal		1.33[a]	1.29[A]	1.30[A]	1.48	1.39[a]
SEM		0.02	0.01	0.01	0.02	0.01
Probability		0.037	0.009	0.001	0.429	0.033
Brooding Temperature[2]						
Hot		1.42[a]	1.25	1.30	1.48	1.39
Cool		1.18[b]	1.30	1.26	1.45	1.36
SEM		0.02	0.01	0.01	0.02	0.01
Probability		0.013	0.053	0.108	0.388	0.120
Incubation[1] Temperature	Brooding[2] Temperature					
High	Hot	1.41	1.23	1.28	1.49	1.38
Normal	Hot	1.43	1.27	1.31	1.48	1.40
High	Cool	1.13	1.28	1.24	1.44	1.34
Normal	Cool	1.23	1.31	1.20	1.47	1.38
SEM		0.03	0.01	0.01	0.02	0.01
Probability		0.134	0.800	0.461	0.230	0.208

[A,B] Means in columns that possess different superscripts differ significantly ($P \leq 0.01$).
[a,b] Means in columns that possess different superscripts differ significantly ($P \leq 0.05$).
[1] High incubation eggs were 40.6^{0}C (105.1) at E19. Normal incubation eggs were 37.7^{0}C (99.9^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 26.7^{0}C (80.1^{0}F) at placement.

TABLE R-19. Percentage mortality (deaths) of broiler chickens as affected by incubation temperature, brooding temperature, and incubation temperature by brooding temperature interaction in Experiment 6

Incubation Temperature[1]		Deaths For Ages Shown				
		0-7 days	7-14 days	0-14 days	14-21 days	0-21 days
		(%)				
High		1.97[a]	0.93	2.89[a]	0.12	3.01
Normal		0.69[b]	0.50	1.19[b]	0.40	1.59
SEM		0.41	0.47	0.51	0.16	0.54
Probability		0.031	0.281	0.022	0.208	0.068
Brooding Temperature[2]						
Hot		0.66	0.35	1.01	0.20	1.21
Cool		2.00	1.07	3.08	0.31	3.39
SEM		0.41	0.60	0.51	0.16	0.54
Probability		0.146	0.483	0.103	0.650	0.104
Incubation[1] Temperature	Brooding[2] Temperature					
High	Hot	0.93	0.69	1.62	0.00	1.62
Normal	Hot	0.40	0.00	0.40	0.40	0.79
High	Cool	3.01	1.16	4.17	0.23	4.40
Normal	Cool	0.99	0.99	1.98	0.40	2.38
SEM		0.58	0.66	0.72	0.22	0.76
Probability		0.202	0.510	0.509	0.602	0.439

[a,b] Means in columns that possess different superscripts differ significantly ($P \leq 0.05$).
[1] High incubation eggs were 40.6^{0}C (105.1) at E19. Normal incubation eggs were 37.7^{0}C (99.9^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 26.7^{0}C (80.1^{0}F) at placement.

TABLE R-20. Feed consumption of broiler chickens as affected by incubation temperature in Experiment 7

Incubation[1] Temperature	Feed Consumption For Ages Shown				
	0-7 days	7-12 days	12-21 days	21-28 days	0-28 days
			(g)		
High	138.6	235.3	830.8	784.9[b]	1990.5[b]
Normal	142.2	241.2	855.7	816.4[a]	2061.0[a]
SEM	2.4	4.1	10.5	6.4	14.8
P > *F*	0.430	0.320	0.203	0.040	0.040

[a,b] Means in columns that possess different superscripts differ significantly ($P \leq 0.05$).
[1] High incubation eggs were 39.7^{0}C (103.5^{0}F) at E19. Normal incubation eggs were 37.8^{0}C (100.4^{0}F) at E19.

TABLE R-21. Body weight of broiler chickens as affected by incubation temperature in Experiment 7

Incubation[1] Temperature	Body Weight For Ages Shown				
	0 day	7 day	12 day	21 day	28 day
	(g)				
High	38.1[B]	151.2	327.7	818.2[b]	1313.9
Normal	40.4[A]	155.0	340.6	854.1[a]	1357.0
SEM	0.2	2.1	5.0	7.6	9.9
Probability	0.003	0.272	0.168	0.047	0.056

[A,B] Means in columns that possess different superscripts differ significantly ($P \leq 0.01$).
[a,b] Means in columns that possess different superscripts differ significantly ($P \leq 0.05$).
[1] High incubation eggs were 39.7^{0}C (103.5^{0}F) at E19. Normal incubation eggs were 37.8^{0}C (100.4^{0}F) at E19.

The effect of incubation temperature on AdjFCR of male and female broilers at 0-7, 7-12, 12-21, 21-28, and 0-28 d of age is shown in Table R-22. There were no significant effects found.

The effect of incubation temperature on percentage mortality of male and female broilers at 0-7, 7-12, 12-21, 21-28, and 0-28 d of age is shown in Table R-23. There were no significant effects of incubation temperature observed.

TABLE R-22. Adjusted feed conversion ratio (AdjFCR) of broiler chickens as affected by incubation temperature in Experiment 7

Incubation[1] Temperature	AdjFCR Weight For Ages Shown				
	0-7 days	7-12 days	12-21 days	21-28 days	0-28 days
	(g:g)				
High	1.23	1.34	1.70	1.58	2.56
Normal	1.25	1.31	1.67	1.63	2.53
SEM	0.02	0.03	0.02	0.02	0.02
Probability	0.780	0.600	0.410	0.160	0.450

[1] High incubation eggs were 39.7^{0}C (103.5^{0}F) at E19. Normal incubation eggs were 37.8^{0}C (100.4^{0}F) at E19.

TABLE R-23. Percentage mortality (deaths) of broiler chickens as affected by incubation temperature in Experiment 7

Incubation[1] Temperature	Deaths For Ages Shown				
	0-7 days	7-12 days	12-21 days	21-28 days	0-28 days
	(%)				
High	1.11	0.00	0.22	0.00	1.33
Normal	0.83	0.63	0.42	0.21	2.08
SEM	0.47	0.27	0.39	0.16	0.86
Probability	0.732	0.220	0.810	0.390	0.600

[1] High incubation eggs were 39.7^{0}C (103.5^{0}F) at E19. Normal incubation eggs were 37.8^{0}C (100.4^{0}F) at E19.

DISCUSSION

Calibration. The internal egg temperature measured by direct shell with the contract infrared thermometer exhibited no significant difference from the mercury thermometer when it was used properly. One potential problem was not allowing the infrared thermometer to adequately equilibrate to incubator temperature. The infrared thermometer was developed to be used at room temperature and could not be moved from room temperature directly to incubator temperature and function properly. We experienced this problem in the first repetition and this explains why there was a difference in temperature readings between the mercury thermometer and infrared thermometer at that time. We subsequently changed the process and placed the thermometer in the incubator for at least 15 minutes before use. The difference between the mercury and infrared thermometers decreased to 0.1^0C (0.3^0F) or less during the second and third repetition. For the final repetition we changed our process of calibration again and left the infrared thermometer in the incubator during the entire experiment, only removing it to take the necessary readings. This procedure presented almost identical readings between the infrared and mercury thermometers.

When dealing with infertile eggs or recording temperatures of eggs for a long period of time with the incubator door open, it was essential to create a stable atmosphere outside the incubator to match that inside the incubator. We accomplished this by creating a plastic tent around the incubator door. This tent was heated to match the internal temperature before the door was opened and egg temperatures recorded. The tent allowed egg temperatures to remain stable and allowed the incubator door to remain open for an extended period of time.

It was concluded that the infrared thermometer has a place in incubation management and that it was just as accurate as a standard mercury thermometer, as long as it was allowed to

equilibrate with machine temperature properly. The ideal equilibration would be to allow the thermometer to reside inside an incubation atmosphere constantly. However, this may not always be practical or feasible. In the present experiment, if the thermometer was allowed at least 15 minutes to equilibrate, there were no significant differences between infrared and mercury temperatures.

Effects Of Incubation Temperature On Chick BW and Organs. The information gained during these experiments showed that elevated incubation temperature significantly and adversely affected the development of the chick embryo. Chick embryos have previously been reported to respond to high incubation temperature with accelerated growth and development (Romanoff, 1960; Ricklefs, 1987; Christensen *et al.*, 1999). This accelerated development has been reported to negatively impact hatchability, feed conversion, BW, and general post-hatch performance (Gladys *et al.*, 2000). Although high incubation temperature can accelerate embryo growth, an interference with proper embryo development can occur due to, among other things, the interference with albumen transfer from the egg into the amniotic cavity, i.e. due to an induced nutritional (energy) deficiency (Romanoff, 1960) that has been evidenced by the presence of residual albumen in the egg shell after hatching.

Incubation has been not only characterized as one of the most critical components of overall broiler performance from hatching to the end of the growing period but has become one of the most difficult stages of broiler management. The reason for this difficulty was because it can no longer be assumed that the internal egg temperature will be the same as the machine air temperature as demonstrated by the example in Figure D-1. Figure D-1 shows that when the machine air temperature was 37.3^0C (99.2^0F) on E 14 in Experiment 7, the internal egg temperature reached 38.2^0C (100.7^0F). In order to maintain the internal egg temperature at

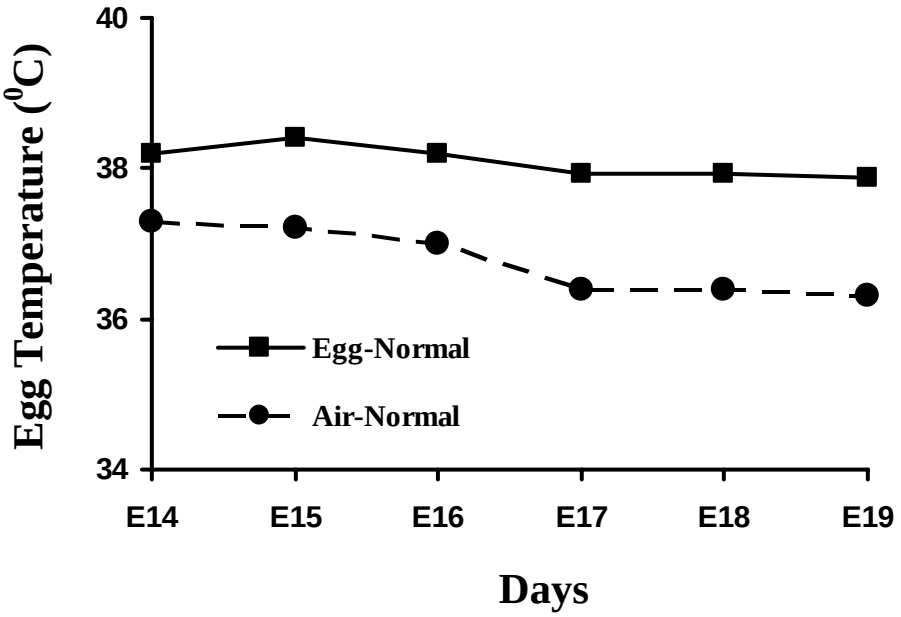

Figure D-1. Comparison of machine air temperature and internal egg temperature in Experiment 7. The rectangle symbols represent the internal egg temperature and the circle symbols represent the machine air temperature in the normal temperature incubator.

37.9^{0}C (100.2^{0}F) on E 19, the machine air temperature had to be reduced to 36.3^{0}C (97.3^{0}F) in Experiment 7. Therefore, the machine air temperature was about 1.6^{0}C (2.9^{0}F) lower than the internal egg temperature at E 19 of incubation in this example taken from Experiment 7. These findings were in agreement with Meijerhof and Van Beek (1993) who stated that air temperature was simply not equal to embryo temperature and that these two temperatures could vary independently. In other words, embryo development and hatchability were more influenced by embryo temperature than by air temperature (Lourens *et al.,* 2005).

It should be noted at this point that the entire discussion concerning high or normal incubation temperatures in this manuscript refers only to the internal egg temperature and not to the machine air temperature, as the two were not the same and could not be compared in a consistent and logical. This was in contrast to many other experiments reported in the literature where the authors based their observations and conclusions on the machine air temperature. Consequently, the differences between air and egg temperature measurements may lead to inaccuracies in conclusions concerning what temperatures represented critical points for effects on organ development and chick BW at hatching.

During the early incubation period, embryo temperature was observed to be slightly lower than incubator temperature but from mid-incubation onwards metabolic heat production from the embryo increased embryo temperature above incubator temperature in a manner similar to that reported by French (1997). French (1997) suggested that care must be taken to prevent egg temperature exceeding the optimum in late incubation. High egg temperature resulted in accelerated embryo growth and early hatching but reduced hatchability in the present study (Table D-1). This was agreement with early work of Romanoff (1936) that

Table D-1. Number of pipped eggs and hatched chicks at E 20 of incubation, as an indicator of hatching time, in Experiment 7[1]

High Machine Temperature			Normal Machine Temperature		
Tray	**Number of Pipped**	**Number of Hatched**	**Tray**	**Number of Pipped**	**Number of Hatched**
1	63	4	2	29	1
3	94	3	4	32	0
5	87	2	6	37	0
7	55	2	8	16	0
Total	**299**	**11**	**Total**	**114**	**1**

[1] There were four trays of 180 eggs each for a total of 720 eggs set in each incubator.

high incubation temperature accelerated embryonic development and hatching time, but decreased the maximum hatchability.

The most common sign of chicks having been incubated at a high temperature was their white color (Figure D-2) due to apparently poor absorption of the yolk sac pigments. As an example, our data indicated that when the internal egg temperature reached 39.9^0C (103.8^0F) on E 19 of incubation in Experiment 3, the yolk sac was significantly heavier (12.07 g) than when eggs were incubated at a normal temperature (9.16 g) (Table R-3); therefore, some white chicks were observed on the day of hatching. These white chicks were easily distinguishable from the yellow chicks produced by the normal incubation temperature. Thus, this sign could be used to easily identify possible poor quality chicks and higher than optimum incubation temperature. Other chick quality problems observed were similar to those reported by others and included excessive blood inside the eggshell, some blood on the down and feathers, short feathers, red hocks, unhealed navels, externalized yolk sac remnants ("black buttons"), cross beaks, and ectopic viscera (Lourens *et al.*, 2005).

Our data also demonstrated that BW was significantly reduced when incubation temperature reached 39.7^0C (103.5^0F) at E 19 of incubation in Experiment 2 (Table R-2). This might have been due to the reduction in yolk sac absorption that reduced the nutrients available for embryo development. This was also in agreement with Romanoff (1960) who reported that the size of the chick varied with incubation conditions, as 60 g eggs, with varying incubation conditions, could produce chicks with BW that ranged from 21.9 g to 41.4 g.

The organ most affected by high incubation temperature was the heart. The heart was the only organ that showed significant differences at hatch of up to 29 percent in all of our experiments where we had temperatures from 39.7^0C (103.0^0F) to 39.9^0C (103.8^0F)

Figure D-2. Comparison of chicks incubated at high and normal incubation temperatures. Chicks that were incubated and hatched at the lower internal egg temperature of ~37.8°C (100.0^0F) exhibited the yellow color and chicks incubated at a higher temperature of >38.9°C (102.0^0F) exhibited the white color in many instances.

(Tables R-2, 3, 4, 5). This was in agreement with Wineland *et al.* (2000) who found that with high setter and hatcher temperatures, the heart was smaller and chicks possessed greater residual yolk sac. The reason why the heart was most frequently affected might be because the response to heat stress has been suggested to occur most dramatically in tissues that were most important for the normal function of the body (Flanaga *et al.,* 1995). Normal embryological development of the heart has been shown to begin as early as the two-somite stage (Graper, 1907) and the heart has been shown to continue to be mitotically active up until 10 d post hatch (Olivo, 1928; Olivo and Slavich, 1930). Mitotic division has been shown to play a crucial role in the growth of the ventricles of the heart such that the ventricular thickness from the middle of E 8 of incubation until hatching increased from 100 microns to about 1100 microns (Romanoff, 1960). Increasing or decreasing incubation temperatures has also been shown to significantly affect the number of mitotically active myocytes (Olivo, 1931).

The small intestines, proventriculus, and gizzard of chicks incubated in high temperature were also smaller when egg temperature was 39.9^0C (103.8^0F) in Experiment 3 (Table R-3) and again when egg temperature was 39.5^0C (103.1^0F) in Experiment 4 (Table R-4). The rate of cell division in these organs might also have been affected by excessive egg temperature.

The liver was the only organ to be larger when chicks were incubated at high temperature (39.7^0C (103.5^0F) as was the case in Experiment 2 (Table R-2). This may have been because the liver has been shown to undergo its most rapid rate of mitotic growth before E 12 of incubation (Schmalhusen, 1926: Dumm and Leavy, 1949) and we did not increase machine temperature until E 14 or E 15 in our experiments. Therefore, high incubation temperature

later in incubation, where such an elevation in temperature could most easily occur, would not normally be expected to affect liver weight.

Some organs showed significant effects due to sex if the incubation temperature was severe enough. As found in Experiment 2 at an egg temperature of 39.7^0C (103.5^0F) on E 19, the proventriculus of males was smaller than that of females (Table R-2) and a similar effect was found at an egg temperature of 39.9^0C (103.8^0F) on E 19 in Experiment 3 (Table R-3). This was in agreement with Fronda and Marielo (1938) who reported that the proventriculus of females was slightly longer than in males at hatching. The small intestines were also smaller in males than in females in Experiments 2 (Table R-2) and 3 (Table R-3). The probable reason that we found no differences between sexes in heart weight at hatching in these experiments was because egg temperatures of 39.7^0C (103.5^0F) and 39.9^0C (103.8^0F) at E 19 were sufficiently excessive to decrease heart weight in both sexes such that a sex effect could not be discerned.

Egg size also played an important role in the incubation temperature effect on embryonic growth and development as shown by the data of Experiment 7 (Table R-5). Small eggs hatched smaller chicks that possessed smaller yolk sacs as well as larger hearts and gizzards than average or large sized eggs although the average internal egg temperature did not differ before E 19. This suggested that average and large sized eggs produced more heat and were less easily cooled during the final two days in the hatcher (Meijerhof and van Beek, 1993 and French, 1997). However, it must be kept in mind that the eggs in Experiment 7 were from a 60-wk-old breeder flock and that the small sized eggs would not be as small as the eggs from a young breeder flock. Thus, the effect of relative egg size may have varied with flock age and average egg weight.

The effect on the heart remained apparent up to 14 d of age in Experiment 4 (Table R-6) and up to 21 d of age in Experiment 6 (Table R-7). The heart appeared to be smaller when brooded under hot conditions. This was in agreement with Olivo (1928) and Olivo and Slavich (1930) that the heart continued to be mitotically active up until 10 d post hatch and that high brooding temperature for more than 2 d depressed the rate of cell division in the heart.

Males exhibited heavier BW and larger hearts than females at 14 d in Experiment 4 (Table R-6). This may be due to the fact that males consumed more feed (463.6 g) than females (424.2 g) during 7-14 d of the growing period (Table R-8).

Effect Of Incubation Temperature and Brooding Temperature On Chick Growth, Feed Consumption, and Mortality. Chickens that were exposed to high incubation temperatures appeared to be more sensitive to cool brooding conditions than chicks hatched from eggs subjected to normal incubation temperatures (Tables R-8, 12, 13, 15, 16, 17). Day-old chicks have been reported to have a body temperature of approximately 40.0^0C (104.0^0F) but have been characterized as poikilotherms that do not have the ability to control their body temperature relative to changes in environmental temperature until a few days of age when the chicks become more homoeothermic, *i.e.,* can better adjust their heat production relative to ambient temperature (Weytjens *et al.,* 1999). Based on the inability of the chick to effectively regulate its body temperature immediately following hatching, it could reasonably be expected that brooding conditions during this period would be critical to subsequent performance. This was substantiated by Moraes *et al.* (2002) who showed chick development during the first week of life to be important for future performance. This conclusion was based on physiological processes such as cell hyperplasia and hypertrophy, maturation of the

thermoregulatory and immunological systems, and growth and differentiation in the gastrointestinal tract (GI tract), all of which had a marked effect on BW and feed conversion of the birds until market age.

The most influential factors affecting BW and feed consumption of chicks have been suggested to be 1. the age of the breeder flock (Peebles *et al.,* 1999); 2. incubation temperature (Ricklefs, 1987); 3. brooding temperature (Renwick *et al.,* 1985; Scott and Washburn, 1985; Bruzual *et al.,* 2000); 4. light intensity (May and Lott, 1994); 5. feeder space (Van Krey and Weaver, 1988); and 6. feed particle size (Lott *et al.,* 1992). Since eggs in our Experiments 4, 5, 6, and 7 were from breeder flocks of 48, 35, 52, and 60 wk of age, respectively, the effect of breeder flock age must be taken into account when comparing data from the different experiments reported in this study. An example of this can be seen by the fact that eggs derived from a young breeder flock, and subjected to the high incubation temperature in Experiment 5 (Table R-13), weighed 37.4 g at 0 d (hatched) while chickens from Experiments 4, 6, and 7 weighed 45.6, 43.7, and 38.1 g, respectively (Tables R-9, 17, 21). The differences in day-old chick weights between experiments were still evident at 7 d in the various experiments, as should be expected. This observation was in agreement with Gladys *et al.* (2000) who found that parent stock age had an effect on the development of the embryo, hatchability, and chick weights at hatch. These authors showed that chicks originating from the younger breeder flock had a significantly lower BW than the chicks from old breeder flocks and that these chicks gained significantly more weight than chicks from the young breeder flock (Weytjens *et al.,* 1999). Bruzual *et al.* (2000) suggested that small chicks had high surface-to-BW ratios and were therefore more easily dehydrated than larger chicks.

This was illustrated by the comparatively small chicks hatched in our Experiment 7 from an old breeder flock (60 wk) and having a hatching BW of 38.1 g on the high incubation temperature treatment and 40.4 g on the normal incubation temperature treatment (Table R-21). Stated another way, it can be seen that the high incubation treatment resulted in a substantial weight depression relative to chicks on the normal incubation treatment and that this can explain the small BW of the chicks in question. The low BW of chicks in Experiment 7 may also be attributed to the fact that chicks from older parent flocks had been shown to hatch faster (Crittenden and Bohren, 1962; Smith and Bohren, 1975; Lowe and Garwood, 1977). This would, in turn, result in the chicks being subjected to a longer drying time in the hatcher that would lead to increased moisture loss and a lower BW at removal from the machine.

The effects of incubation on BW may be different due to sex. Male chicks in Experiment 4 had heavier BW than female chicks at hatching (Table R-9) even though the temperature of the high incubation only reached 39.4^0C (102.9^0F) at E 19. This data in Experiment 4 was in agreement with findings by other authors who concluded male chicks to be heavier than female chicks (Godfrey and Jaap, 1952; Zawalsky, 1962; Whiting and Pesti, 1983). The difference in hatching BW (actually BW at removal from incubator) between the sexes was explained in part by several authors (Williams *et al.*, 1951; Zawalsky, 1962; Mather and Laughlin; 1979; Burke, 1992; Reis *et al*., 1997) who reported that female chicks hatched earlier than male chicks, with a difference of about 3 h between peak hatching times, and that male and female chicks had similar initial and final BW at hatching from eggs of similar size, but that weight loss between the hatching time and the point of removal from the machine at

514 h post incubation was significantly greater in females, because these chicks had to wait a longer period between hatching and removal from the machine (Reis *et al.,* 1997).

In contrast to the above observations, the BW at hatching of male and female chicks in Experiment 5 was not different (Table R-13). These data were also in agreement with several authors (Jult and Quinn, 1925; Morris *et al.,* 1968; Burke, 1992). The probable reason that we found no differences in BW at hatch between sexes in Experiment 5 was that the recorded internal egg temperature in this experiment reached 39.9^0C (103.8^0F) at E 19. This temperature was probably excessive and led to excessive moisture lost from both male and female chicks prior to the chicks being removed from the incubator. This diminished the differences between male and female chick BW.

Our data also showed that high incubation temperature also affected the feed intake of chicks during the first week of brooding (Tables R-8, R-12, R-16) and this continued to 4 wk of age in Experiment 7 (Table R-20). Chicks subjected to normal incubation temperatures during brooding consumed more feed and had heavier BW than chicks hatched from high incubation temperatures at all ages in all experiments (Tables R-8, 12, 16). From our personal observations, the differences in feed intake could largely be explained by the normal incubation chicks being apparently more active than the high incubation chicks from the moment of placement. This in turn allowed these chicks to access the feed and water faster, thereby providing these chicks with an advantage that chicks incubated under high temperature regimens were not able to overcome.

Brooding temperature has long been known to be very important on the first day of the life of chicks because as poikilotherms they cannot effectively regulate their heat production relative to ambient temperatures (Decuypere and Kuhn, 1988). It was important to note at

this point that the discussion concerning hot or cool brooding temperatures refers only to the litter temperature and not the air temperature because it was apparent that the temperature that chicks experienced through their contact with the litter probably determined their activity patterns to a greater extent than did air temperature. Our work was in contrast to most other experiments reported in the literature where the authors based their conclusions on the room air temperature and not litter temperature. Consequently, the differences in the point at which the temperatures were measured may lead to differences in the conclusions of what the optimum temperatures were for maximum chick growth and development. This was well illustrated in Figure D-3 (Experiment 4) above, where it could be seen that although the daily high air temperature was as high as 39.6^0C (103.3^0F) and the daily low air temperature decreased to 36.8^0C (98.2^0F), the recorded litter temperatures during the same period was only 34.1^0C (93.4^0F) at 0800 hours on the first day of the brooding period and the afternoons of the remaining days. This showed that the difference between air temperature and litter temperature was within the range of 2.7-5.5^0C (4.8-9.9^0F) under the conditions of this experiment.

Our data showed that chicks that were brooded under cool brooding conditions on the first day consumed less feed and had lower BW during the first week than those that were brooded under hot brooding conditions. The effects of brooding temperatures can be seen by comparing the data in Experiment 5 (Table R-13), where litter temperatures decreased below 26.0^0C (78.8^0F) during the first 3 d and the 7 d BW of chicks reached only 142.8 grams. In contrast to these data, in Experiment 4, where litter temperatures were consistently above 26.7^0C (80.0^0F), the 7 d BW of chicks was about 209 grams (Table R-9). These findings

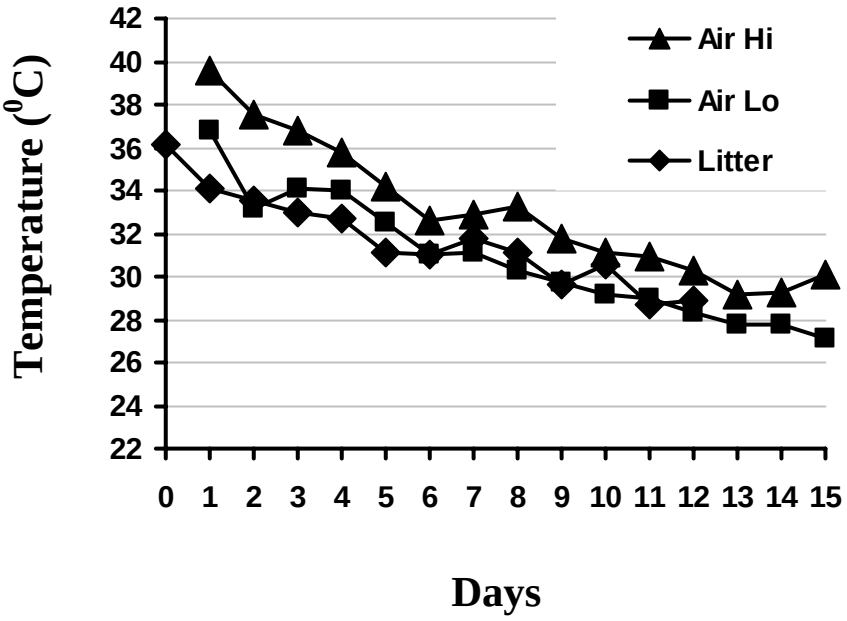

Figure D-3. Room air and litter temperature in the hot brooding room of Experiment 4. On the first day of the brooding period, when the daily high (Hi) air temperature (triangle symbols) reached about 40.0^0C (104.0^0F) and the daily low (Lo) air temperature (Rectangular symbols) decreased to about 36.5^0C (97.7^0F), the litter temperature (diamond symbols) was only 34.5^0C (94.1^0F).

were in agreement with others (Renwich *et al.*, 1985; Scott and Washburn, 1985) who found that low brooding temperatures during the first week significantly depressed 1 to 7 d BW gain, and was also in agreement with a report by the USDA (1955) in which it was stated that chicks chilled at 19.4^{0}C (66.9^{0}F) tended to huddle together to keep their body and feet warm and did not eat nor drink normally while chicks maintained at 29.4^{0}C (84.9^{0}F) were more active and consumed feed normally.

The difficulty in comparing conclusions drawn by other authors concerning the optimal brooding temperatures for the broiler chick lies, as previously stated, in the fact that one can assume that most of these authors only recorded air temperature and not litter temperatures. Therefore, for purposes of discussion the room air temperature of 19.4^{0}C (66.9^{0}F) reported by the USDA (1955) may have approximated a litter temperature of as low as 16.0^{0}C (60.0^{0}F). This temperature can be considered to be excessively cool and would explain why a significant effect on the feed consumption and BW was reported in this experiment. Also, in Experiment 6, the litter temperature was 34.4^{0}C (93.9^{0}F) for the hot brooding treatment and 26.7^{0}C (80.1^{0}F) for the cool brooding treatment at placement. This resulted in a significant brooding temperature effect on BW, feed consumption, and feed conversion (AdjFCR) at 7 d (Tables R-16, 17, 18). It was important to note that the chicks that hatched in this experiment were judged to be in very poor condition as an apparent result of being hatched in metal incubator trays that had fewer holes and therefore lower ventilation rates than would be the case for the plastic hatching baskets used in other experiments. Consequently, it could be expected that brooding temperature on the first day of placement would have played an important role in the successful acclimation of the chicks to the broiler house environment. An anomaly in Experiment 6 was that chicks brooded under hot

brooding conditions consumed more feed (137.4 g) than chicks brooded under cool conditions (121.4 g) (Table R-17). However, in spite of the lower feed intake, chicks that were brooded in the cool conditions exhibited heavier BW (147.7 g) than their counterparts that had been brooded in hot conditions (141.9 g) (Table R-17). However, the effect was reversed in the second week of brooding period during which chicks in the cool brooding treatment consumed more feed (337.1 versus 302.7 g; (Table R-16)) and gained more weight (407.8 versus 384.5 g; (Table R-17)) than chicks brooded under hot conditions. This can be interpreted to mean that hot brooding temperatures for the first few days allowed chicks to consume more feed, but if hot brooding temperatures were maintained too long, there was the negative effect of suppressed feed consumption and BW. Our data showed no significance difference in percentage mortality in all experiments.

In Experiment 5 there were significant incubation by brooding interactions for feed consumption, BW, and mortality up to 7 d (Tables R-12, 13, 15). In Experiment 6 there was an incubation by brooding interaction for feed consumption to 7 d (Table R-16) and on BW at 14 d of age (Table R-17). These data suggested that chicks that were incubated at a high temperature and subsequently placed in cool brooding conditions in Experiments 4, 5, 6 consumed the least amount of feed (Table 8, 12, 16) and had the lowest BW up to 7 d of age (Table 13, 17) while exhibiting the greatest percentage mortality (Table R-15). This was in agreement with conclusions drawn by Ernst *et al*. (1984) that chicks that had survived exposure to high incubation temperatures consumed less feed, had lower BW, and a greater incidence of mortality compared to chicks that were exposed to lower incubation temperatures after arrival at a farm. The positive hot brooding temperature effect on feed intake continued to 7 d, but was reversed by 14 d in Experiment 6 (Table R-16). This can be

explained on the basis of the hot brooding continuing too long and exerting a negative effect on feed intake of the chicks that had passed their poikilothermic stage.

Our data suggested that if the room temperature was increased to achieve a litter temperature above 34.0^0C (93.2^0F) at placement, fewer problems were observed with the chicks. The general recommendation that can be drawn from our data was that litter temperatures should reach >33.0^0C (93.0^0F) on the day of placement and be decreased below 32.2^0C (90.0^0F) by the second day of brooding period and further decreased to below 29.4^0C (85.0^0F) by 6 d of the brooding period (Figure D-4) to result in maximum BW and feed consumption at 7 d as in Experiment 4 (Tables R-8, 9). Figure D-5 shows a comparison of the hot brooding temperature for Experiments 4, 5, and 6. As can be seen, the litter in all experiments reached in excess of 32.2^0C (90.0^0F) at placement and resulted in chicks being more active and consuming more feed immediately following placement. With the exception of Experiment 6, as discussed above, BW generally followed feed consumption. Further, while hot brooding temperatures were beneficial during the first week of life they had a detrimental effects if the litter temperature remained above 32.2^0C (90.0^0F) for an extended period of time (as in Experiment 6) since the high temperatures after 7 d exerted a negative effect on feed intake. These findings were in agreement with Teeter *et al.* (1985) and Sandercock *et al.* (2001) who showed that high ambient temperatures had a negative effect on broiler production efficiency while behavioral, physiological, hormonal, and molecular changes have also been reported to occur (Etches *et al.*, 1995). Van Der Hel *et al.* (1991) stated that weight loss of neonatal chicks during the first 24 hour period was dependent upon brooding temperature. Weight loss increased from 3.5 g/d at 30.8^0C (87.4^0F) to 4.1 g/d at 35.1^0C

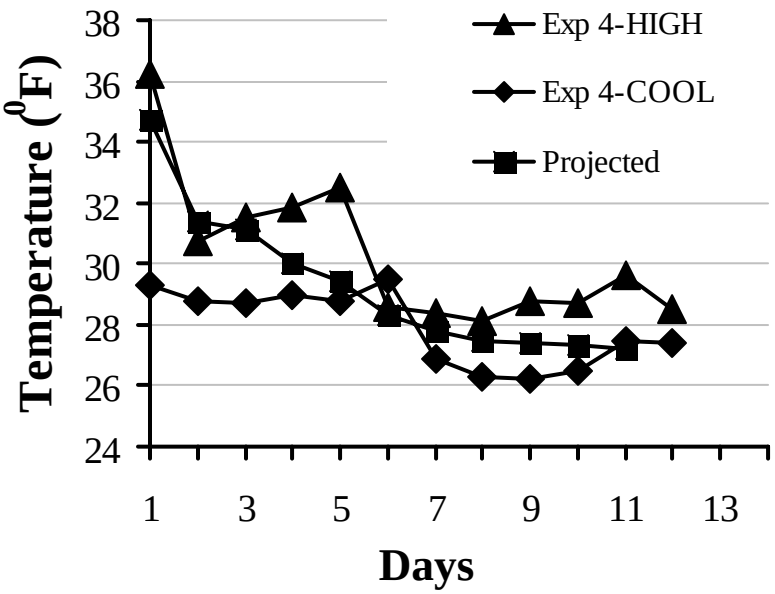

Figure D-4. General Recommendation for Litter Temperature. Triangle symbols represent the High litter temperature in Experiment 4, diamond symbols represent the Cool litter temperature in Experiment 4, and rectangle symbols represent the projected temperature.

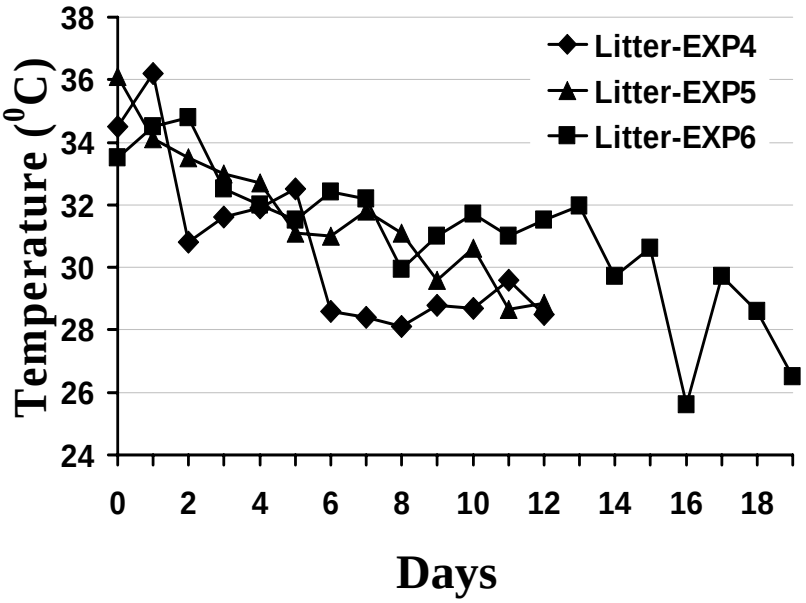

Figure D-5. Comparison of litter temperature from Experiments 4, 5, and 6 from 0 d (placement) to 12 d (Experiments 4 and 5) and 18 d (Experiment 6) during the growing period. Diamond symbols represent the litter temperature in Experiment 4, triangle symbols represent the litter temperature in Experiment 5, and rectangle symbols represent the litter temperature in Experiment 6.

(95.2^{0}F) and up to 5.7 g/d at 38.8^{0}C (101.8^{0}F) and was shown to be due to moisture losses from both the yolk sac and from the remainder of the body (Hoogerbrugge and Ormel, 1982).

SUMMARY AND CONCLUSIONS

With modern lines of broilers it was clear that the incubator machine air temperature may not indicate the true internal egg temperature during the later stages of incubation. Machine air temperatures in our experiments were from approximately 1.6^0C (2.9^0F) lower than the internal egg temperature by E 19 of the incubation period. The most striking feature of the chicks that developed at an elevated temperature was their white color due to poor yolk sac absorption. Other features observed were short feathers, bloody feathers, cross beaks, red hocks, unhealed navels, "black buttons", and ectopic viscera.

The present studies suggested that elevated incubation temperature generally accelerated hatching time but this was not in concert with the development of the organs. Our data showed that BW, and weights of the heart, gizzard, proventriculus, and small intestines were frequently reduced under the influence of high incubation temperature (>39.5^0C (103.1^0F)), but yolk sac and liver weights were often larger.

Small sized eggs were also affected differently by high incubation temperature when compared to average and large sized eggs as shown in Experiment 7 (Table R-5). Chick weight was proportional to egg weight and the heart and gizzard of small sized eggs were larger, and the yolk sac smaller, than in average and large sized eggs, which suggested that embryos in small sized eggs possessed a lower temperature during the final two days of incubation as there were no differences in egg temperature up to E 19. A difference in temperature would be most likely due to increased convective heat loss due to a greater egg surface area to volume ratio during the period of maximum heat production.

Chicks appeared to be very sensitive to cold brooding temperatures, even for short periods of time; therefore, the first day of the brooding period was very critical. Our data showed that

the brooding air temperature was not equivalent to litter temperature and that the difference between air and litter temperature was within the range of 2.7 to 5.5^{0}C (4.8-9.9^{0}F). We suggest that initial brooding conditions should be adjusted based upon the litter temperature rather than the air temperature because the temperature that chicks experience through their contact with the litter (feet) probably determines activity patterns and feed intake.

A hot brooding temperature at placement helped chicks to move and consume more feed while cool brooded chicks were often observed to huddle together rather than consume feed normally. Our results showed that when we had what we considered to be very poor quality chicks at hatching due to high incubation temperature (Experiment 6), the hot brooding temperature considerably improved the performance of these chicks. Apparently, chicks were more active and consumed more feed and the percentage mortality was dramatically decreased as a result. The general recommendation that can be drawn from our data was that litter temperatures should reach >34.0^{0}C (93.2^{0}F) at the time of placement and be decreased to 32.2^{0}C (90.0^{0}F) or slightly below by the second day of brooding period to achieve maximum BW and feed consumption. Further reductions in brooding temperature to about 27^{0}C (80.6^{0}F) was required during the second week in order to maintain a high level of feed consumption and growth.

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Appendix

TABLE A-1. Body weight and gross weights of tissues and organs from broiler chicks on day of hatching in Experiment 2 as influenced by incubation temperature, sex, and incubation temperature by sex interaction

Incubation[1] Temperature	Body Weight	Yolk Sac	Heart	Liver	Gizzard	Proventriculus	Small Intestines
	(g)			(g)			
High	44.6^{B}	4.80	0.30^{B}	1.35	2.29^{b}	0.36^{B}	1.22^{b}
Normal	47.7^{A}	5.31	0.39^{A}	1.33	2.40^{a}	0.40^{A}	1.29^{a}
SEM	0.3	0.20	0.01	0.02	0.04	0.01	0.02
Probability	0.001	0.075	0.001	0.671	0.044	0.009	0.018
Sex							
Male	46.3	5.16	0.35	1.32	2.32	0.36^{B}	1.25
Female	45.9	4.95	0.33	1.36	2.35	0.40^{A}	1.26
SEM	0.3	0.20	0.01	0.02	0.04	0.01	0.02
Probability	0.545	0.480	0.337	0.127	0.484	0.005	0.701
Incubation[1] Temperature × Sex							
High Male	44.8	4.76	0.30	1.32	2.28	0.34	1.22
High Female	44.5	4.84	0.29	1.37	2.29	0.38	1.23
Normal Male	47.8	5.54	0.39	1.32	2.36	0.38	1.29
Normal Female	47.7	5.06	0.38	1.35	2.43	0.42	1.30
SEM	0.4	0.28	0.01	0.03	0.06	0.01	0.03
Probability	0.761	0.322	0.638	0.668	0.586	0.919	0.867

^{A,B} Means in columns that possess different superscripts differ significantly ($P \leq 0.01$).
^{a,b} Means in columns that possess different superscripts differ significantly ($P \leq 0.05$).
[1] High incubation eggs were 39.7^{0}C (103.5^{0}F) at E19. Normal incubation eggs were 37.8^{0}C (100.0^{0}F) at E19.

TABLE A-2. Body weight and gross weights of tissues and organs from broiler chicks on day of hatching in Experiment 3 as influenced by incubation temperature, sex, and incubation temperature by sex interaction

Incubation[1] Temperature	Body Weight	Yolk Sac	Heart	Liver	Gizzard	Proventriculus	Small Intestines
	(g)			(g)			
High	44.3^{B}	5.35^{A}	0.28^{B}	1.29^{B}	2.25^{B}	0.35^{B}	1.17^{B}
Normal	46.6^{A}	4.29^{B}	0.41^{A}	1.40^{A}	2.72^{A}	0.43^{A}	1.47^{A}
SEM	0.2	0.19	0.01	0.02	0.04	0.01	0.02
Probability	0.001	0.002	0.001	0.001	0.001	0.001	0.001
Sex							
Male	45.4	4.70	0.35	1.35	2.47	0.38^{B}	1.28^{b}
Female	45.6	4.91	0.34	1.34	2.51	0.41^{A}	1.36^{a}
SEM	0.3	0.20	0.01	0.02	0.05	0.01	0.03
Probability	0.601	0.396	0.762	0.588	0.370	0.009	0.012
Incubation[1] Temperature × Sex							
High Male	44.0	5.00	0.27	1.30	2.21	0.34	1.11
High Female	44.5	5.67	0.28	1.29	2.29	0.37	1.22
Normal Male	46.8	4.40	0.41	1.40	2.71	0.42	1.44
Normal Female	46.5	4.19	0.40	1.39	2.72	0.44	1.49
SEM	0.3	0.27	0.01	0.03	0.05	0.01	0.03
Probability	0.236	0.297	0.310	0.920	0.486	0.936	0.326

[A,B] Means in columns that possess different superscripts differ significantly ($P \leq 0.01$).
[a,b] Means in columns that possess different superscripts differ significantly ($P \leq 0.05$).
[1] High incubation eggs were 39.9^{0}C (103.8^{0}F) at E19. Normal incubation eggs were 37.9^{0}C (100.2^{0}F) at E19.

TABLE A-3. Body weight and gross weights of tissues and organs from broiler chicks on day of hatching in Experiment 4 as influenced by incubation temperature, sex, and incubation temperature by sex interaction

Incubation[1] Temperature	Sex	Body Weight	Yolk Sac	Heart	Liver	Gizzard	Proventriculus	Small Intestines
		(g)			(g)			
High		43.1	4.33	0.31[B]	1.11	2.09[B]	0.38[B]	1.28[B]
Normal		44.2	4.24	0.38[A]	1.17	2.38[A]	0.42[A]	1.46[A]
SEM		0.8	0.21	0.01	0.03	0.04	0.01	0.03
Probability		0.350	0.749	0.001	0.301	0.001	0.001	0.001
Sex								
Male		44.1	4.37	0.35	1.16	2.26	0.40	1.35
Female		43.2	4.20	0.33	1.12	2.21	0.40	1.40
SEM		0.8	0.21	0.01	0.04	0.05	0.01	0.03
Probability		0.388	0.588	0.140	0.384	0.342	0.946	0.158
Incubation[1] Temperature	Sex							
High	Male	43.9	4.49	0.31	1.16	2.08	0.37	1.23
High	Female	42.4	4.18	0.31	1.07	2.11	0.39	1.33
Normal	Male	44.4	4.25	0.40	1.17	2.45	0.43	1.46
Normal	Female	43.9	4.22	0.36	1.17	2.31	0.41	1.46
SEM		0.8	0.30	0.01	0.04	0.05	0.01	0.04
Probability		0.649	0.647	0.130	0.329	0.121	0.181	0.168

[A,B] Means in columns that possess different superscripts differ significantly ($P \leq 0.01$).
[1] High incubation eggs were 39.5^{0}C (103.1^{0}F) at E19. Normal incubation eggs were 37.9^{0}C (100.2^{0}F) at E19.

TABLE A-4. Body weight and gross weights of tissues and organs from broiler chicks on day of hatching in Experiment 7 as influenced by incubation temperature, egg size, and incubation temperature by egg size interaction

Incubation[1] Temperature		Body Weight	Yolk Sac	Heart	Liver	Gizzard	Proventriculus	Small Intestines
		(g)				(g)		
High		39.9^{B}	3.08	0.28^{B}	1.06	2.00	0.37	1.16
Normal		41.2^{A}	3.29	0.35^{A}	1.05	2.05	0.36	1.21
SEM		0.2	0.14	0.01	0.02	0.03	0.01	0.02
Probability		0.005	0.319	0.001	0.969	0.202	0.853	0.110
Egg Size								
Large		44.4^{A}	3.70^{A}	0.33^{A}	1.16^{A}	2.20^{A}	0.39^{A}	1.28^{A}
Average		40.8^{B}	3.31^{B}	0.32^{A}	1.05^{B}	2.00^{B}	0.38^{A}	1.15^{B}
Small		36.6^{C}	2.53^{C}	0.30^{B}	0.96^{C}	1.89^{C}	0.32^{B}	1.12^{B}
SEM		0.2	0.13	0.01	0.02	0.09	0.01	0.02
Probability		0.001	0.001	0.001	0.001	0.001	0.002	0.001
Incubation[1] Temperature	Egg Size							
Normal	Large	45.4^{a}	3.90	0.36	1.16	2.20	0.40	1.30
Normal	Average	41.2^{c}	3.39	0.35	1.05	2.05	0.36	1.20
Normal	Small	37.0^{e}	2.58	0.33	0.95	1.90	0.33	1.13
High	Large	43.2^{b}	3.51	0.30	1.17	2.19	0.38	1.26
High	Average	40.3^{d}	3.23	0.28	1.05	1.93	0.40	1.11
High	Small	36.2^{f}	2.49	0.26	0.94	1.87	0.32	1.10
SEM		0.3	0.18	0.01	0.03	0.04	0.02	0.03
Probability		0.047	0.486	0.575	0.966	0.338	0.339	0.541

^{A,B,C} Means in columns that possess different superscripts differ significantly ($P \leq 0.01$).
^{a,b,c,d,e,f} Means in columns that possess different superscripts differ significantly ($P \leq 0.05$).
[1] High incubation eggs were 39.7^{0}C (103.5^{0}F) at E19. Normal incubation eggs were 37.8^{0}C (100.0^{0}F) at E19.

TABLE A-5. Body weight and gross weights of tissues and organs from broiler chickens at 14 d of age in Experiment 4 as influenced by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction

Incubation[1] Temperature	Body Weight	Heart	Liver	Gizzard	Proventriculus	Small Intestines
	(g)			(g)		
High	485.3^{B}	2.58	14.41	11.23	3.06	18.77
Normal	511.0^{A}	2.61	14.36	11.78	3.16	20.53
SEM	7.5	0.08	0.32	0.32	0.12	0.65
Probability	0.008	0.696	0.909	0.281	0.483	0.014
Brooding[2] Temperature						
Hot	499.5	2.45	14.23	11.43	3.09	19.38
Cool	496.8	2.74	14.54	11.62	3.13	19.92
SEM	8.3	0.09	0.32	0.32	0.14	0.77
Probability	0.839	0.153	0.563	0.717	0.859	0.671
Sex						
Male	520.1^{A}	2.81^{A}	14.80	12.02^{a}	3.27^{a}	20.60^{A}
Female	476.2^{B}	2.38^{B}	13.97	11.03^{b}	2.96^{b}	18.70^{B}
SEM	8.3	0.08	0.32	0.32	0.12	0.65
Probability	0.001	0.001	0.073	0.035	0.024	0.008

^{A,B} Means in columns that possess different superscripts differ significantly ($P \leq 0.01$).
^{a,b} Means in columns that possess different superscripts differ significantly ($P \leq 0.05$).
[1] High incubation eggs were 39.5^{0}C (103.1^{0}F) at E19. Normal incubation eggs were 37.9^{0}C (100.2^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 28.9^{0}C (84.0^{0}F) at placement.

TABLE A-5 (continued). Body weight and gross weights of tissues and organs from broiler chickens at 14 d of age in Experiment 4 as influenced by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction

Incubation[1] Temperature	Brooding[2] Temperature	Body Weight	Heart	Liver	Gizzard	Proventriculus	Small Intestines
		(g)			(g)		
High	Hot	488.0	2.45	14.59	11.17	3.05	18.83
High	Cool	482.7	2.46	14.23	11.39	3.08	18.70
Normal	Hot	511.1	2.71	13.86	11.70	3.14	19.92
Normal	Cool	510.9	2.77	14.85	11.86	3.18	21.13
SEM		10.6	0.11	0.45	0.46	0.17	0.92
Probability		0.783	0.767	0.144	0.950	0.974	0.335
Brooding[2] Temperature	Sex						
Hot	Female	473.5	2.29	13.82	11.18	2.98	18.45
Hot	Male	525.6	2.62	14.63	11.68	3.20	20.30
Cool	Female	478.9	2.48	14.11	10.88	2.93	18.94
Cool	Male	514.7	3.00	14.96	12.37	3.33	20.90
SEM		10.6	0.11	0.45	0.46	0.17	0.92
Probability		0.380	0.315	0.660	0.286	0.495	0.940

[1] High incubation eggs were 39.5^{0}C (103.1^{0}F) at E19. Normal incubation eggs were 37.9^{0}C (100.2^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 28.9^{0}C (84.0^{0}F) at placement.

TABLE A-5 (continued). Body weight and gross weights of tissues and organs from broiler chickens at 14 d of age in Experiment 4 as influenced by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction

Incubation[1] Temperature	Brooding[2] Temperature	Sex	Body Weight	Heart	Liver	Gizzard	Proventriculus	Small Intestines
			(g)			(g)		
High	Hot	Female	473.3	2.29	14.17	11.50	2.95	18.20
High	Hot	Male	502.8	2.61	15.01	10.84	3.14	19.47
High	Cool	Female	472.0	2.46	14.03	10.89	2.85	18.10
High	Cool	Male	493.4	2.95	14.43	11.89	3.31	19.31
Normal	Hot	Female	473.8	2.29	13.47	10.87	3.02	18.71
Normal	Hot	Male	548.4	2.63	14.26	12.52	3.26	21.13
Normal	Cool	Female	485.9	2.49	14.19	10.87	3.01	19.78
Normal	Cool	Male	536.0	3.05	15.50	12.84	3.35	22.48
	SEM		14.1	0.143	0.64	0.64	0.21	1.15
	Probability		0.450	0.882	0.599	0.467	0.755	0.902

[1] High incubation eggs were 39.5^{0}C (103.1^{0}F) at E19. Normal incubation eggs were 37.9^{0}C (100.2^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 28.9^{0}C (84.0^{0}F) at placement.

TABLE A-6. Body weight and gross weights of tissues and organs from broiler chickens at 21 d of age in Experiment 6 as influenced by incubation temperature, brooding temperature, and incubation temperature by brooding temperature interaction

Incubation Temperature[1]	Body Weight	Heart	Liver	Gizzard	Proventriculus	Small Intestines	Yolk Sac	Breast[3]
	(g)	(g)						
High	728.9[B]	3.86[B]	22.55[b]	42.50	26.28	73.07[b]	33.48	119.87[b]
Normal	773.2[A]	4.25[A]	23.43[a]	44.05	27.14	76.32[a]	27.52	157.23[a]
SEM	16.8	0.10	0.98	1.38	1.10	2.01	7.33	4.09
Probability	0.002	0.001	0.049	0.053	0.094	0.012	0.306	0.025
Brooding Temperature[2]								
Hot	720.1	3.64[b]	20.49	39.87	24.16	69.73	25.39	148.17
Cool	774.9	4.47[a]	25.49	46.69	29.25	79.66	35.60	158.93
SEM	21.8	0.12	1.35	1.87	1.50	2.70	9.52	5.31
Probability	0.221	0.039	0.119	0.123	0.139	0.122	0.527	0.288
Incubation[1] Temperature / Brooding[2] Temperature								
High / Hot	704.8	3.55	20.41	39.72	24.12	68.76	39.81	143.97
High / Cool	751.8	4.17	24.69	45.29	28.44	77.39	27.14	155.76
Normal / Hot	739.6	3.73	20.57	40.02	24.21	70.70	10.97	152.38
Normal / Cool	799.2	4.76	26.29	48.08	30.07	81.94	44.07	162.09
SEM	23.3	0.15	1.39	1.94	1.54	2.81	10.36	5.79
Probability	0.751	0.079	0.107	0.118	0.134	0.305	0.001	0.749

[A,B] Means in columns that possess different superscripts differ significantly ($P \leq 0.01$).
[a,b] Means in columns that possess different superscripts differ significantly ($P \leq 0.05$).
[1] High incubation eggs were 40.6^{0}C (105.1^{0}F) at E19. Normal incubation eggs were 37.7^{0}C (99.9^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 26.7^{0}C (80.1^{0}F) at placement.
[3] Whole breast with bone.

TABLE A-7. Feed conversion ratio (FCR) of broiler chickens as affected by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction in Experiment 4

Incubation[1] Temperature	FCR For Ages Shown						
	0-2 days	2-5 days	0-5 days	5-7 days	0-7 days	7-14 days	0-14 days
	(g:g)						
High	0.82[B]	1.13	1.03[B]	1.38	1.15[b]	1.48	1.36[b]
Normal	0.89[A]	1.21	1.10[A]	1.47	1.23[a]	1.56	1.44[a]
SEM	0.02	0.03	0.02	0.37	0.02	0.05	0.04
Probability	0.001	0.058	0.010	0.113	0.016	0.081	0.015
Brooding[2] Temperature							
Hot	0.92	1.22	1.12	1.45	1.24	1.50	1.41
Cool	0.79	1.11	1.01	1.40	1.15	1.55	1.40
SEM	0.03	0.03	0.02	0.37	0.02	0.07	0.05
Probability	0.091	0.115	0.059	0.406	0.121	0.692	0.960
Sex							
Male	0.84	1.13	1.04	1.38	1.16	1.50	1.38
Female	0.87	1.20	1.09	1.47	1.23	1.55	1.43
SEM	0.02	0.03	0.02	0.37	0.02	0.05	0.04
Probability	0.235	0.094	0.082	0.078	0.059	0.292	0.142

[A,B] Means in columns that possess different superscripts differ significantly ($P \leq 0.01$).
[a,b] Means in columns that possess different superscripts differ significantly ($P \leq 0.05$).
[1] High incubation eggs were 39.5^{0}C (103.1^{0}F) at E19. Normal incubation eggs were 37.9^{0}C (100.2^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 28.9^{0}C (84.0^{0}F) at placement.

TABLE A-7 (continued). Feed conversion ratio (FCR) of broiler chickens as affected by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction in Experiment 4

Incubation[1] Temperature	Brooding[2] Temperature	FCR For Ages Shown						
		0-2 days	2-5 days	0-5 days	5-7 days	0-7 days	7-14 days	0-14 days
		(g:g)						
High	Hot	0.91[a]	1.17	1.08	1.38	1.19	1.46	1.36
Normal	Hot	0.94[a]	1.28	1.16	1.42	1.29	1.54	1.45
High	Cool	0.73[c]	1.09	0.97	1.38	1.12	1.51	1.37
Normal	Cool	0.85[b]	1.14	1.05	1.42	1.18	1.58	1.44
SEM		0.03	0.04	0.03	0.05	0.03	0.77	0.06
Probability		0.036	0.512	0.925	0.423	0.579	0.859	0.752
Brooding[2] Temperature	Sex							
Hot	Female	0.94	1.26	1.15	1.49	1.27	1.57	1.46
Hot	Male	0.90	1.19	1.09	1.42	1.21	1.43	1.36
Cool	Female	0.79	1.15	1.03	1.45	1.18	1.53	1.40
Cool	Male	0.78	1.08	0.98	1.34	1.12	1.57	1.41
SEM		0.03	0.04	0.03	0.05	0.03	0.77	0.06
Probability		0.454	0.967	0.938	0.708	0.907	0.060	0.084

[a,b] Means in columns that possess different superscripts differ significantly ($P \leq 0.05$).
[1] High incubation eggs were 39.5^{0}C (103.1^{0}F) at E19. Normal incubation eggs were 37.9^{0}C (100.2^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 28.9^{0}C (84.0^{0}F) at placement.

TABLE A-7 (continued). Feed conversion ratio (FCR) of broiler chickens as affected by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction in Experiment 4

Incubation[1] Temperature	Brooding[2] Temperature	Sex	FCR For Ages Shown						
			0-2 days	2-5 days	0-5 days	5-7 days	0-7 days	7-14 days	0-14 days
			(g:g)						
Normal	Hot	Female	0.96	1.29	1.18	1.52	1.30	1.64	1.52
Normal	Cool	Female	0.87	1.21	1.10	1.48	1.23	1.54	1.42
High	Hot	Female	0.93	1.22	1.12	1.45	1.24	1.49	1.40
High	Cool	Female	0.72	1.09	1.97	1.43	1.13	1.51	1.37
Normal	Hot	Male	0.91	1.26	1.15	1.50	1.28	1.45	1.39
Normal	Cool	Male	0.83	1.07	0.99	1.36	1.13	1.62	1.45
High	Hot	Male	0.91	1.12	1.04	1.32	1.15	1.42	1.32
High	Cool	Male	0.74	1.09	/.97	1.32	1.10	1.51	1.36
SEM			0.04	0.06	0.04	0.07	0.05	0.09	0.07
Probability			0.555	0.194	0.183	0.567	0.267	0.256	0.492

[1] High incubation eggs were 39.5^{0}C (103.1^{0}F) at E19. Normal incubation eggs were 37.9^{0}C (100.2^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 28.9^{0}C (84.0^{0}F) at placement.

TABLE A-8. Feed conversion ratio (FCR) of broiler chickens as affected by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, incubation temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction in Experiment 5

Incubation Temperature[1]	FCR For Ages Shown		
	0-7 days	7-14 days	0-14 days
		(g:g)	
High	2.89[A]	1.32[B]	1.77
Normal	2.72[B]	1.38[A]	1.80
SEM	0.03	0.02	0.02
Probability	0.001	0.003	0.276
Brooding Temperature[2]			
Hot	2.86	1.35	1.80
Cool	2.74	1.35	1.77
SEM	0.03	0.02	0.03
Probability	0.091	0.876	0.520
Sex			
Male	2.78	1.35	1.78
Female	2.82	1.35	1.79
SEM	0.03	0.02	0.02
Probability	0.280	0.724	0.684

[A,B] Means in columns that possess different superscripts differ significantly ($P \leq 0.01$).
[1] High incubation eggs were 39.9^{0}C (103.8^{0}F) at E19. Normal incubation eggs were 37.6^{0}C (99.7^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 26.7^{0}C (80.1^{0}F) at placement.

TABLE A-8 (continued). Feed conversion ratio (FCR) of broiler chickens as affected by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, incubation temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction in Experiment 5

Incubation[1] Temperature	Brooding[2] Temperature	FCR For Ages Shown		
		0-7 days	7-14 days	0-14 days
		(g:g)		
High	Hot	2.93	1.33	1.79
Normal	Hot	2.79	1.37	1.81
High	Cool	2.84	1.33	1.75
Normal	Cool	2.64	1.40	1.79
SEM		0.03	0.03	0.03
Probability		0.439	0.351	0.666
Brooding[2] Temperature	Sex			
Hot	Female	2.90	1.34	1.80
Hot	Male	2.88	1.36	1.80
Cool	Female	2.75	1.36	1.78
Cool	Male	2.68	1.35	1.76
SEM		0.03	0.03	0.03
Probability		0.271	0.533	0.461

[1] High incubation eggs were 39.9^{0}C (103.8^{0}F) at E19. Normal incubation eggs were 37.6^{0}C (99.7^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 26.7^{0}C (80.1^{0}F) at placement.

TABLE A-8 (continued). Feed conversion ratio (FCR) of broiler chickens as affected by incubation temperature, brooding temperature, sex, incubation temperature by brooding temperature interaction, brooding temperature by sex interaction, incubation temperature by sex interaction, and incubation temperature by brooding temperature by sex interaction in Experiment 5

Incubation[1] Temperature	Sex	FCR For Ages Shown		
		0-7 days	7-14 days	0-14 days
		(g:g)		
High	Female	2.90	1.32	1.78
Normal	Female	2.75	1.38	1.80
High	Male	2.88	1.32	1.76
Normal	Male	2.68	1.39	1.80
	SEM	0.04	0.02	0.03
	Probability	0.492	0.957	0.816

Incubation[1] Temperature	Brooding[2] Temperature	Sex			
Normal	Hot	Female	2.91	1.32	1.80
Normal	Cool	Female	2.88	1.31	1.77
High	Hot	Female	2.81	1.36	1.80
High	Cool	Female	2.69	1.40	1.80
Normal	Hot	Male	2.95	1.33	1.80
Normal	Cool	Male	2.81	1.31	1.73
High	Hot	Male	2.77	1.38	1.81
High	Cool	Male	2.59	1.39	1.78
	SEM		0.05	0.03	0.04
	Probability		0.738	0.796	0.900

[a,b] Means in columns that possess different superscripts differ significantly ($P \leq 0.05$).
[1] High incubation eggs were 39.9^{0}C (103.8^{0}F) at E19. Normal incubation eggs were 37.6^{0}C (99.7^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 26.7^{0}C (80.1^{0}F) at placement.

TABLE A-9. Feed conversion ratio (FCR) of broiler chickens as affected by incubation temperature, brooding temperature, and incubation temperature by brooding temperature interaction in Experiment 6

Incubation Temperature[1]		FCR For Ages Shown				
		0-7 days	7-14 days	0-14 days	14-21 days	0-21 days
		(g:g)				
High		1.28[b]	1.26[B]	1.27[B]	1.46	1.37[b]
Normal		1.33[a]	1.30[A]	1.31[A]	1.48	1.40[a]
SEM		0.02	0.01	0.01	0.02	0.01
Probability		0.072	0.009	0.003	0.253	0.015
Brooding Temperature[2]						
Hot		1.42[a]	1.25	1.30	1.49	1.39
Cool		1.19[b]	1.31	1.27	1.46	1.37
SEM		0.02	0.01	0.01	0.02	0.01
Probability		0.015	0.052	0.165	0.474	0.172
Incubation[1] Temperature	Brooding[2] Temperature					
High	Hot	1.42	1.23	1.32	1.48	1.39
Normal	Hot	1.43	1.27	1.30	1.44	1.40
High	Cool	1.14	1.29	1.28	1.48	1.36
Normal	Cool	1.23	1.33	1.25	1.48	1.39
SEM		0.03	0.01	0.01	0.02	0.01
Probability		0.222	0.997	0.493	0.124	0.155

[A,B] Means in columns that possess different superscripts differ significantly ($P \leq 0.01$).
[a,b] Means in columns that possess different superscripts differ significantly ($P \leq 0.05$).
[1] High incubation eggs were 40.6^{0}C (105.1) at E19. Normal incubation eggs were 37.7^{0}C (99.9^{0}F) at E19.
[2] Hot brooding room was 34.4^{0}C (93.9^{0}F) at placement. Cool brooding room was 26.7^{0}C (80.1^{0}F) at placement.

TABLE A-10. Feed conversion ratio (FCR) of broiler chickens as affected by incubation temperature in Experiment 7

Incubation[1] Temperature	FCR Weight For Ages Shown				
	0-7 days	7-12 days	12-21 days	21-28 days	0-28 days
	(g:g)				
High	1.24	1.33	1.70	1.59	1.56
Normal	1.25	1.31	1.67	1.63	1.57
SEM	0.02	0.03	0.02	0.02	0.01
Probability	0.777	0.602	0.410	0.161	0.580

[1] High incubation eggs were 39.7^{0}C (103.5^{0}F) at E19. Normal incubation eggs were 37.8^{0}C (100.4^{0}F) at E19.