The effect of different incubation temperatures on chick quality

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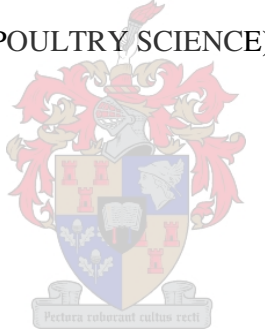

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Declaration

I, the undersigned, hereby declare that the work contained in this assignment is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

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ABSTRACT

Over the last few decades various authors have reported the influence of day old chick quality on integrated broiler industries. Although various methods of determining chick quality have been reported, defining a good or a first grade day old chick can be problematic as it involves many subjective measurements. Incubation temperature (embryo temperature) is probably the biggest, most influential factor during incubation on chick quality. High temperatures cause the most damage. It leads to poor growth, stress, black buttons, threads, weak chicks, chicks with poorly erupted down that are bleached in appearance, low hatchability, late embryonic death and early broiler mortality. This trial was designed to test whether 37.2, 37.4 or 37.5ºC was the optimum incubation temperature for hatching Hybro G+ chicks with superior quality. The parameters that were measured were the chick length, bodyweight, and the yolk residue of the day old chicks of the flocks set at different setter temperatures. After hatching, 1440 chicks (480 chicks per temperature treatment) were placed at a broiler facility where the daily mortalities, weekly bodyweight gain and feed conversion were recorded and calculated. The age of the breeder flock had a significant effect on all three parameters measured in the incubation trial with p values of <0.001, <0.001 and 0.005 respectively. There were no significant differences in chick quality parameters due to different incubation temperatures. The age x temperature interaction could be attributed to the large influence of the age of the breeder on egg size and consequently chick parameters. The results could be related to the fact that bigger eggs from older breeder flocks have higher initial egg mass, which will result in heavier embryos and thus converted to a larger day old chick. The performance trial performed after the incubation trial showed no significant effect of the incubation temperature on 7-day and daily mortalities, weekly bodyweight gain and feed conversion efficiency to 42 days of life. The lack of effects observed in these trials could be attributed to the small range of temperatures used in addition to the difficulties brought about the use of multi-stage incubators.

UITTREKSEL

Die afgelope paar dekades het verskeie skrywers die invloed van dagoud kuikenkwaliteit op geintegreerde braaikuiken produsente in diepte bespreek. Alhoewel daar verskeie maniere is om kuikenkwaliteit te bepaal bly dit moeilik om ‘n eerstegraad kuiken te definieer aangesien dit baie subjektief is. Inkubasie temperatuur of liewers embrio temperatuur is waarskynlik die grootste enkele faktor op kuikenkwaliteit. Hoë temperature veroorsaak die meeste skade. Dit lei tot swak groei, swart knoppe of dun stringe in die naaltjie area, swak en lam kuikens, kuikens met swak ontwikkelde dons wat wit en vaal in voorkoms is, lae uitbroeibaarheid, laat embrioniese sterftes en hoë eerste week braaikuiken mortaliteite. Die proef was ontwikkel om vas te stel of 37.2, 37.4 of 37.5ºC die optimum inkubasie temperatuur is om Hybro G^+ kuikens uit te broei met hoe kwaliteit. Die parameters wat gebruik was, was kuikenlengte, kuikengewig en residuele eiergeel van die kuikens by die verskillende inkubasie temperature. 1440 Dagoud kuikens (480 per temperatuur behandeling) was in ‘n braaikuiken fasiliteit geplaas waartydens die daaglikse mortaliteite, weeklikse gewigstoename en voeromset genotuleer en uitgewerk was. Die ouderdom van die teeltrop het ‘n betekenisvolle invloed gehad op die parameters wat gemeet was tydens die inkubasie proef. Die verskillende inkubasie temperature, naamlik 37.2, 37.4 en 37.5ºC, het geen betekenisvolle verskil getoon op die parameters wat gemeet was tydens die inkubasie proef nie. Die ouderdom x temperatuur interaksie kan hoofsaaklik toegeskryf word aan die feit dat ‘n ouer teeltrop groter eiers produseer en met die omskakeling van eiergeel na kuiken ‘n groter kuiken geproduseer word. Soortgelyk uit die braaikuiken resultate is dit duidelik dat die verskillende inkubasie temperature geen betekenisvolle effek gehad het op 7 dae en daaglikse mortaliteite, weeklikse gewigstoename en voeromset tot en met 42 dae in ouderdom nie. Die rede vir bogenoemde resultate kan hoofsaaklik toegeskryf word aan die feit dat die temperatuur verskille naamlik 37.2, 37.4 en 37.5ºC waarteen die eiers geinkubeer was te klein was, en dat die proef uitgevoer was met die gebruik van veelvuldige ouderdom inkubators wat opsigself sy eie probleme teweeg bring.

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CHAPTER 1
LITERATURE REVIEW

1.1 Introduction

Over the last few decades various authors have reported the impact of day old chick quality on the performance of integrated broiler industries. Although various methods of determining chick quality have been reported, defining a good or a first grade day old chick can be problematic as it involves many subjective measurements. A definition that has been used by several authors (Deeming, 2000; Decuypere *et al*., 2001) that could be used with a certain degree of accuracy is the following one: "A 1-day-old chick of good quality must be clean, dry and free from dirt and contamination, with clear and bright eyes, free from deformities, with a completely sealed and clean navel. No yolk sac or dried membrane should protrude from the navel area. The body should be firm to the touch, and there should be no signs of respiratory distress. The chick should be alert and interested in its environment, responding to sounds. The legs should have the normal conformation, with no swelling and no hock or skin lesions; the beak should be well formed and the toes firm and straight". However, due to its subjectivity, and therefore open to different interpretation, this method of defining chick quality is easily challenged. In addition, there are many factors that will affect the success of the incubation process in order to produce a good quality day-old chicken. This section will review the literature pertaining to different methods for evaluating chick quality as well as those factors that will have a significant impact on the success of the incubation process and consequently, chick quality.

1.2 Methods for evaluating chick quality

1.2.1 Qualitative Methods

Meijerhof (2005) stated that the qualitative method considers the usual visual score as based on the definition by Deeming (2000) although this definition is very subjective when measuring the colour, development, navel quality and vitality of the day old chick. A deep yellow colour is favoured over a pale (light yellow to white). A large, well-developed, long feathered chick is considered better. Well-closed navels reduce the risk of infection and mortality and an alert healthy chick will find feed and water more quickly.

Many incubation managers and hatchery employees will be able to determine a chick of good quality based on subjective measurements, but the criteria supporting their selection are based purely on their stockman's experience and it is difficult to repeat (Decuypere, 2005 - Personal communication). Several methods were therefore developed in order to quantify chick quality in a more objective manner.

1.2.2 Quantitative Methods

Deeming (2000) reported that the hatchability of eggs, count of first grade chicks and the weight of chicks expressed as a percentage of initial egg mass could be used as quantitative assessments to determine chick quality. In more recent studies, up to four methods of scoring chick quality have been reported (Meijerhof, 2005). The first method, the Tona or Pasgar score, apply a standardized scoring system across a range of criteria, including chick viability, yolk sac uptake, navel closure, and the ability of the chick to recover after being placed on its back. These methods (Pasgar is an adapted form of the Tona Score) create a consistent, measurable data set that can easily be repeated. The second method, considers day old chick weight, which can easily be recorded and repeated. However, it could be argued that this method has limited value in assessing chick quality as it is mostly correlated to egg weight rather than chick development. This is due to the fact that the day old chick weight includes both the actual chick weight and the weight of the remaining yolk. If a large amount of yolk remains at hatch, this means that less of this energy source has been used during incubation and the chick is less developed as a result. The third method uses yolk free body mass (bodyweight without residual yolk), which is a better indicator of chick development, especially when corrected for initial egg weight or size. It is to be noted that this is a method that requires the birds to be killed and it is quite laborious (Lourens *et al.* 2006). The forth and last method makes use of chick length. Chick length (measured from tip of the beak to the middle toe) is considered a better indicator than day old chick weight, especially when corrected for egg weight or size and taking the age of the breeder flock into consideration. A combination of two methods with ±75% of the final score based on broiler growth potential (chick length) and the balance based on survival rate in the first week (Pasgar score), may provide a more optimal measurement of chick quality (Meijerhof, 2005).

1.3 Factors affecting chick quality

From the time of ovulation to hatching there are many factors that can affect the success of the incubation process resulting in poor chick quality. This section describes the most relevant factors that will affect chick quality during the incubation process, namely temperature, humidity, ventilation, turning and type of incubator equipment used.

1.3.1 Incubation temperature

Deeming (2000) reported that too low an incubation temperature often leads to dead but pipped, large staggering chicks. The hatch is normally late and prolonged because the chicks do not dry off normally. In addition, reports that too high an incubation temperature can also lead to dead, pipped embryos or chicks, which are small, sticky with a high incidence of unhealed navels. Often these chicks have deformed toes. Overheating in both, setters and hatchers, are one of the biggest reasons for down grading chicks. Decuypere *et al*. (2001) reported that the environmental temperature for the highest hatchability lies within the range of 37-38ºC and that tolerance to deviations to this temperature is a function of the duration to these exposures and to the stage of development. Strain and line differences also affect the tolerance to variations in the standard temperature and to temperature fluctuations occurring during incubation. There are a number of factors affecting chick quality from fertilization of the ovum to placement of the day old chick at the broiler farm. Some of these factors can be controlled while others cannot. From the point of fertilization to the start of incubation, the physical quality of the egg, the stage of development of the embryo at oviposition, the time taken and the conditions prevailing between oviposition and storage and the storage conditions of the incubating eggs all need to be considered. The quality of the egg includes its shape, size, colour, cleanliness, and the integrity of the shell and the absence of shell malformations. It is important to emphasize that good quality eggs, incubators and management need to be set at very high standards to maximize chick quality (Decuypere *et al*., 2001). Poor incubation conditions do not only result in an increased embryo mortality, but the chicks that do hatch (survive) these conditions will not be developed well and will not show the maximum growth on the broiler farm (Meijerhof, 2003). Hill (2002) reported that optimally incubated birds are able to direct resources to organ development and growth whereas those in less optimum incubation must utilize resources to survive and not to develop and grow.

Lourens (2003) suggested that incubation temperature, or more specific embryo temperature is probably the most important factor affecting chick quality. The factors, which influence embryo temperature, are heat production of the embryo itself (breed, breeder age, stage of incubation and level of overheating), air temperature in setter and hatcher, air velocity (higher air velocity more heat loss, lower air velocity less heat loss) and air humidity (moisture content of air). The control of embryo temperatures between acceptable ranges can result in a better hatchability and a better chick quality due to the fact that that the yolk uptake and the closure of navels by the embryo would be much higher and thus a reduction in first week mortality due to a lesser navel/ yolk sac and E. coli infection (Meijerhof, 2003).

Various authors have reported the effects of varying incubation temperature on chick quality. Deeming (2000) showed that high temperature increases the rate of embryonic development as well as oxygen requirements. As the embryo burns more oxygen it produces more waste heat, increasing egg temperatures further, which in turn causes an increase in metabolism and a need for more oxygen (Lourens, 2003). Consequences of this are poor growth rates, an inability to completely utilize albumen proteins and stress to the embryo. At hatch, a high rate of late embryonic mortality, low hatchability, poor chick quality with high rates of early mortality on broiler farms can be observed (Deeming, 2000). Moreover, high yield embryos are extremely sensitive to temperature variance, and very small deviations in incubation temperatures affect hatchability and chick quality (Taylor, 2000). Normal incubation time to produce a quality chick should be approximately 21 days and 6 hours. When temperatures are too high, chicks hatch too early and this leads to black buttons, threads and ectopic viscera. In an attempt to eliminate the last mentioned problem, the incubation temperature was decreased from 37.6-37.5ºC to 37.5-37.4ºC. Thus the idea was to increase the incubation time for high yield birds using lower incubation temperature to improve chick quality, which it did, because the incidence of black buttons disappeared. Harman (1922) showed that a small variation during incubation in temperatures from the optimum of 39.4ºC produced a high percentage of abnormal embryos. Decuypere (1984) postulated that a differential incubation temperature has not merely an accelerating or retarding effect on the development of an organism, but also changes the ultimate performance during growth and reproduction as well. He also indicated that research in order to determine optimal ambient temperatures has to take into account possible long term effects of exogenous influences during early periods of development and differentiation.

Byerly (1938) incubated eggs at 36.1ºC, 37.6ºC and 39.1ºC. At day 6 to 7 excessive mortality was seen in eggs incubated at 36.1ºC and at day 19 to 21 for those incubated at 37.6ºC. Those chicks that were subjected to incubation temperatures of 39.1ºC were light in weight, weak, bleached in appearance, and had poorly erupted down and their heads were under the left wing or between their legs. Embryos incubated at both 36.1ºC and 39.1ºC showed a high incidence of head in the small end of the egg, which results in poor hatchability.

The effects of low and high incubation temperatures are also severe when embryos are subjected to fluctuations in temperature. Ande & Wilson (1981) conducted two experiments in which chicken embryos of various ages were subjected to acute high temperature stress to determine the effect on embryonic mortality and hatchability. Embryos were incubated at a temperature of 37.5ºC (control) until they were 3, 7, 11, 16 or 19 days of age. Embryos of each age were separated into 5 groups and exposed to an incubation stress temperature of 43.3ºC for various lengths of time. After exposure, the embryos were placed back into control incubators until hatching. Exposing 3-day-old embryos for 12 hours to a temperature of 43.3ºC decreased the hatchability of fertile eggs to approximately 50% of controls. A similar decrease occurred after 7 hours of stress. More than 50% reduction in hatchability occurred after 5 hours of heat stress with 19-day-old embryos. These results indicated that 3-day-old embryos were more resistant to heat stress whilst 7-day-old embryos were less resistant. Chicks that hatched after exposed to heat stress were less alert, with a high incidence of wiry and/or matted down, curled toes, weak legs, and had a general lack of balance.

In addition to temperature fluctuation, the age at which the change in temperature is applied has an impact on chick quality. Thompson *et al*. (1976) conducted two experiments to determine the effect of acute heat stress on late-stage chicken embryos. Embryos were incubated at a normal control temperature (37.5ºC) for 16 days and were subjected to 40.6, 43.3, 46.1 or 48.9ºC for various periods of time in another incubator of the same type. After stressing the embryos, they were replaced in the control incubator.

Embryos at 40.6ºC for 24h showed no major detrimental effect. Exposure for 6h at 43.3ºC decreased hatchability with a severe decline in hatchability after 9h. Exposure to 46.1ºC for 3h or 48.9ºC for 1h killed all embryos. Chicks that hatched after heat stress were weaker with a higher incidence of culls as the severity of stress increased. Chicks hatched under these conditions were also less alert when compared to controls. In a similar

experiment, Alsop (1919) reported that excessive heat (40 – 42.2ºC) produces death in chicks and many embryos had various forms of abnormalities in the nervous system. Excessive temperature hastened the development of embryos, while low temperature retarded their rate of growth. Temperatures between 39.4ºC and 42.2ºC produced 90% abnormal embryos and of these abnormalities 46% were in the head region while 54% were in the neural tube. Barrott (1937) concluded that the optimum temperature for the chicken embryo (White Leghorn fowls) was 37.8ºC, which produced the highest quality chick as well as the best hatch. Lundy (1969) suggested that the optimum temperature for hatch is between 37.0 and 38.0ºC for eggs in forced-draft incubators. It is to be noted that the optimum incubator temperature may vary with many other factors or conditions like changes in relative humidity, air velocity and the type of incubator. The results of this trial were in agreement with those of Barrott (1938). When temperatures are raised above the optimum, hatchability falls and the number of malformed and crippled chicks rises. In Barrott's (1938) experiments no embryos survived incubation at 40.5ºC. Temperatures at 41.0ºC for very short periods caused irreversible damage and continuous incubation in the range of 26.0 to 35ºC caused embryonic losses, disproportionate development, absence of organs and malformations.

Hyper- and hypothermic effects depend largely upon temperature, duration of exposure and embryonic age (Wilson, 1991). Disproportionate development, circulation disruption, abnormalities and reduced growth are common consequences of high or low temperatures (Wilson, 1991). Michels *et al.* (1974) have shown that different incubation temperatures and variation in temperature during incubation can affect the growth and development of embryos, hatching time and hatchability. Romanoff (1936) studying the effects of different temperature in the latter part of incubation showed that turkeys were more affected during the first days after hatching by abnormal temperature (incubation conditions) than were chicks. Geers *et al*. (1983) incubated chick embryos at 24.7ºC from days 1 to 10 and at 37.8ºC from day 11 to hatching. Control embryos were incubated at 37.8ºC. Other environmental conditions were standardized. Embryos incubated at 24.7ºC had shown compensatory growth when compared to embryos of the control group and showed a higher heat production (kJ / embryo / hr) expressed as a linear function of dry embryo weight (g) or incubation time (days). After hatching, the compensatory growth of the chickens incubated at 24.7ºC (days 1 to 10) continued, as demonstrated by analyses of the weight of the body, liver, and the gastrointestinal tract. Decuypere & Michels (1992) indicated that the best hatchability must be synonymous with the highest chick quality; including the best post-hatching growth, feed

conversion, liveability, thermoregulatory abilities, stress susceptibility and reproductive performance. Barrott (1938) found that 37.8ºC was the optimum temperature giving the best hatch and the highest chick quality. Romanoff (1935) showed that lowering the temperature in forced-shaft incubators by as much as 3ºC after the 16th day, produces no ill effects, and is safer than exposing them to temperatures higher than 37.5ºC. Chicks hatched at temperatures below 33.5ºC and showed high viability and no ill effects up to 3 weeks of age. The ratio of the weight of chick at hatching to the original egg weight was the highest for temperatures, which gave the best hatch. Crippled chicks increased at higher/lower temperatures.

1.3.2 Humidity

The relationship between temperature and environmental humidity is well known. Humidity has a significant impact on incubation temperature and subsequent chick quality. Deeming (2000) reported that if humidity is too low, chicks tend to be small dehydrated and sticky. Conversely, if the humidity is too high, chicks are large and weak, and often sticky. Unhealed navels are also a common problem of high humidity during incubation. The capacity of air to absorb and hold moisture increases rapidly as temperature rises. Lundy (1969) reported that optimum humidity appears to lie in the range 40 to 70 %, while some workers would place it in the range of 58 to 61 %. Relative humidity influences the water loss from the egg, but egg temperature, weight and shell porosity also contribute. The optimum range of water loss is about 10 to 12% of the egg weight. Humidity levels inside incubators are highly influenced by ventilation (air quality and speed) within the machines. This factor will be described in the following section.

1.3.3 Ventilation

Commercial incubators are enclosed machines that provide the conditions for embryonic development to occur as it would be done by a breeding hen. Additionally to the controlled temperature and humidity, ventilating the incubator is to exchange oxygen, carbon dioxide and heat produced by embryonic metabolism. Deeming (2000) reported that inadequate ventilation of the setters as well as the hatchers or even the room in which the machines are located, can lead to large numbers of small embryos surrounded by fluids. The accumulation of fluids around the embryo is caused by the low levels of oxygen and high concentration of

carbon dioxide resulting from inappropriate ventilation. Decuypere *et al*. (2001) reported that a carbon dioxide concentration of 0.1-0.4% is optimal in a multi stage setter, where it rises from 0.5% to 0.8% in the hatchers, close to the limits of liveability for the chicks.

1.3.4 Turning

Turning of hatching eggs has been reported to be essential for the correct development of extra embryonic membranes (Deeming, 1989). Eggs must be placed in the incubating trays with the blunt end and air cell upwards at a 45 degree angle. Angle and frequency are relevant aspects of incubational turning. Deeming et al. (1987) and Deeming (1989) agreed that the most critical period for turning was from 3 to 7 days of incubation. These results were in disagreement with a previous report by Kaltofen (1961) who reported that frequent turning was most important from 7 to 14 days. Wilson and Wilmering (1988) reported that turning after 13 days of incubation (after closure of the chorioallantoic membrane) had little, if any, beneficial effect. Later, in a review by Wilson (1991), it was reported that three time periods (1 to 3, 4 to 7 and 7 to 14 days of incubation) are the most critical for turning of chicken eggs.

Wilson (1991) stated that maximum hatch is achieved with 96 turning times per day, but 24 times (every hour) is obviously more practical. The absence of turning results in embryo adhesion to the inner shell membrane, embryonic malpositions, retarded growth of the area vasculosa, decreased utilization of yolk and albumen, a deficiency of sub-embryonic fluid and decreased oxygen exchange. Wilson (1991) further reported that the most critical period for turning is 3-7 days of incubation, with little, if any, beneficial effect after 13 days. Complete lack of turning during the incubation process causes low hatchability and those chicks which do hatch are often late, and do not dry off normally (Deeming, 2000).

1.3.5 Multi stage vs. Single stage machines

There are two basic type of incubation equipment available for hatching commercial poultry eggs, namely single and multi stage incubators. Single-stage systems are comprised of machines that will be loaded with the hatching eggs at one time and these will be incubated at the same time till day 18, when they will be transfer to the hatchers. All embryos are of the same age and the conditions within the incubator are more easily controlled. It has been shown that incubation in single stage machines can improve

hatchability as much as 3%, decrease labour costs, allow for more flexibility, lower bacterial counts and better sanitation control (Kortuem, 2004).

Conversely, multi stage setters accommodate eggs at different stages of incubation. Eggs are placed in the same machine at different times. The advantage of this practice is that eggs that have been incubating for some time have already produced heat to warm the starting eggs. In addition the new, relative cold eggs help to cool down the eggs that are at the end of incubation process. The machine thus uses less cooling and heating capacity, and the machine is believed to run more stable because the average stage of incubation is more constant over time. The disadvantages of this type of equipment are that a multi stage machine does not get empty frequently, and therefore regular cleaning is more difficult. The correct environment within a multi stage machines also depends on adequate heat transfer between eggs at different stages of incubation, therefore when heat transfer does not occur as expected, eggs may get overheated at the end of incubation or, when the machine temperature is lowered to correct this, eggs at the start will be to cold. These alterations in incubation temperatures and its effects on embryonic development have been discussed in section 1.3.1. On the contrary, in a single stage machine the temperature can be controlled much better (Hulet and Meijerhof, 2001). The temperature can be adjusted to optimise heat transfer and therefore create an optimum embryo temperature at any given moment. Many single stage machines experience a wide range in embryo temperatures, mainly due to differences in air velocity, local spraying and evaporation of water. All this factors needs to be more or less uniform to be able to adjust the temperature profile towards the need of the embryo.

1.4 Conclusions

Regardless of the chick evaluation method used, whether it is by using qualitative (visual score) or quantitative (Tona or Pasgar score, chick weight, yolk free body mass and chick length) methods, the objective is to ensure good subsequent broiler performance. Due to their subjectivity, some of these methods can be easily argued against, and will probably be for years to come. In addition, with the constant changing in broiler genotypes, the pressure on incubation processes will continue to increase to ensure that maximum performance is obtained for each particular breed. With this in mind, all factors that can influence chick quality must be managed at very high standards. These factors are important from fertilization of the ovum to the placement of the chick at the broiler farm. Egg quality

must be maintained in all steps of the collection and incubation process to secure the production of quality day-old chicks. The literature reviewed in this chapter singled out incubation temperature (embryo temperature) as the most influential factor during incubation on chick quality. If temperatures are maintained at the optimum, the uptake of yolk would be better as will be the closure of navels. High temperatures, in opposition to cold temperature, are more detrimental to the embryo. Whether it is a long term or short term exposure to high temperatures, the results observed in the newly hatched chicks is similar. It leads to poor growth, stress, black buttons, threads, weak chicks, chicks with poorly erupted down that are bleached in appearance, low hatchability, late embryonic death and early broiler mortality. It is important to remember that the environmental conditions during incubation (e.g. temperature, humidity, ventilation, and turning) are not independent from one another, although each may have its own optimum for chick quality.

Due to the complexity of the process and practical problems observed in a commercial hatchery, an experiment was designed to determine the ideal temperature conditions for the particular equipment and management conditions.

CHAPTER 2

EVALUATION OF DIFFERENT INCUBATION TEMPERATURES ON DAY-OLD CHICK QUALITY AND FURTHER BROILER PERFORMANCE

2.1 Introduction

Poor incubation conditions will result in a wide hatching spread, where a large number of chicks hatched too early and some too late. A hatching window of 18 hours or longer before takeoff will result in dehydrated chicks with poorly closed navels, large residue of yolk, red hocks and beaks, poorly erupted down, below average day old weight and high first week mortalities. The length of the hatching window is affected by two main factors, of which severe variation in incubation temperature seems to be the most important. A wide spread of hatching can be most likely caused by severe increases in temperature during the incubation process. The quality of the incubating eggs is also very relevant. For example, eggs from old breeders hatch earlier than those from young flocks and chicks from smaller eggs hatch earlier than those from large eggs (Decuypere *et al*., 2001). Therefore, mixing eggs from different storing conditions or times, and differences in the incubators (temperature, humidity, turning and ventilation) can affect this spread. The consequences of an increased spread are that a larger number of chicks will be forced to stay without food or water for longer times. A commercial hatchery has been experiencing wide hatching windows in spite of the efforts to control the incubation process. In order to improve this parameter and subsequent chick quality an experiment was performed. The incubation conditions that lead embryos to hatch as close as possible to each other are complex to manage. Therefore, to guarantee that the hatching occurred at the same time, a reduction in incubation temperature was applied. The decision to manipulate incubation temperature was based on the fact that the eggs remain 18 to 19 days in the setters. Therefore it is to be expected to have a larger impact on embryonic development compare to the time spent in the hatcher, which is only 3 days. Thus this trial was designed to test whether 37.2, 37.4 or 37.5ºC was the optimum incubation temperature for hatching Hybro G+ chicks with superior quality, using different quantitative parameters i.e. chick length, weight, yolk residue as indicators of chick quality. Further broiler performance (body weight, mortality, average daily gain, feed conversion rate, daily feed intake, and cumulative feed intake) was evaluated in a 42-day performance trial.

2.2 Materials and Methods

2.2.1 Incubation trial

Six Isis multistage (fixed rack) Chick Master setters were programmed to function at optimum embryo development, avoiding extreme embryo temperatures. In two setters the cooling system was set to come on at 37.7ºC, the heating system at 37.5ºC. In two setters, the cooling system was set to come on at 37.5ºC, the heating system at 37.4ºC. In the remaining two setters, the cooling system was set to come on at 37.4ºC, the heating system at 37.2ºC. All the setters were thus running at the same humidity (83%), but differed in terms of mean temperature, being the heating settings between setters 3 and 4 (37.5ºC) and 5 and 6 (37.4ºC), and between setters 5 and 6 (37.4ºC) and setters 7 and 8 (37.2ºC). The eggs were set at 19h00. All the eggs were first fumigated with 1.8l of formalin and 2Kg of potassium for 20 minutes after which they were pre- heated for 6 hours (13h00-19h00) to reach a temperature of 27ºC. Table 2.1 shows the origin and outlay of these eggs in the respective setters at the different incubation temperatures.

The total number of eggs per setter was thus 15552 (3 trolleys). The setters used for this trial take a maximum of 3 trolleys per setting twice a week. This insures that "fresh" eggs are distributed throughout the entire setter with the "older" eggs around it. The "fresh eggs", which are set at a much lower temperature, do create a cooling effect to the "older" eggs. On the contrary, the "older" eggs provide heat to the "fresh" eggs to help them achieve and maintain the correct incubation temperature. This, together with the setter's ventilation system helps to maintain a continuous pattern of air circulation and a consistent temperature and it ensures that heat transfer (exchange) occurs naturally (Taylor & Havran, 2000). When eggs were introduced to the machine, embryo temperature was measured. The embryo temperatures of 180 eggs per setter machine were measured with a "Braun" thermo-scanner. Measurements were taken on the shells more or less in the middle of the egg. The temperatures were taken from six trays at the front (top, middle and bottom section), in the middle (top, middle and bottom section) and at the back (top, middle and bottom section) for each setter. These trays were at the same exact position within each of the six setters and were colour coded for easy identification. Eggs were measured at the same position within each setter, and embryo temperatures per section of setter were recorded. Ten eggs per tray were randomly measured and the temperatures were recorded on a daily basis.

Table 2.1 Origin and outlay of eggs in setters at different incubation temperatures

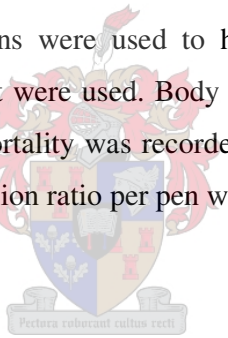
Breeder Flock	Flock Age (Weeks)	Setter Number	Incubation Temperature (ºC)	Number of Eggs	Colour Code
Mountainview House 1	39	3	37.5	13608	Red
Mountainview House 2	38	4	37.5	14418	Red
Mountainview House 5	27	3+4	37.5	2268	Red
Mountainview House 6	26	3+4	37.5	810	Red
Bergsig House 1	37	5	37.4	5184	Green
Bergsig House 2	36	5	37.4	5184	Green
Bergsig House 3	35	5	37.4	5184	Green
Bergsig House 4	34	6	37.4	5184	Green
Môredou House 1	33	6	37.4	5184	Green
Môredou House 3	31	6	37.4	5184	Green
Môredou House 1	33	7	37.2	5184	Blue
Môredou House 2	32	7	37.2	10368	Blue
Môredou House 3	31	8	37.2	5184	Blue
Môredou House 4A	30	8	37.2	5184	Blue
Môredou House 4B	30	8	37.2	5184	Blue

All measurements were taken at 06h00. This procedure was followed from day 1 (12 hours after the eggs were set) to day 19, the day the eggs were transferred to the hatchers. The eggs from setter 3 and 4 (37.5ºC) were transferred to hatcher 12 and 15, eggs from setter 5 and 6 (37.4ºC) to hatcher 13 and 16 and the eggs from setter 7 and 8 (37.2ºC) were transferred to hatcher 14 and 17. All six hatchers were set to run at 36.7ºC with a humidity of 85%. On day 20, one day after the eggs were transferred to the hatchers, the number of chicks per hatcher that had fully hatched was recorded and this number was expressed as a percentage of the total number of eggs (162) in the basket. This recording was done in 1 basket per flock per hatcher. At chick takeoff also referred to as “pulling of chicks”(this being the process of removing of chicks from the hatcher when all have hatched and are 95% dry. The last 5-10% of the batch may be wet around the neck. In broiler hatcheries, chicks are selected for second grade chicks, vaccinated and boxed, whereas in layer hatcheries the chicks are first sexed then vaccinated and boxed), a sample of 20 chicks per flock per hatcher was randomly taken for the measurement of chick length. Each chick was stretched and the length (from the beak to the tip of the toe nail) was measured with a ruler.

Chicks were subsequently placed on a scale and the bodyweight (including the yolk) was measured. A sample of 10 chicks per flock was taken in order to weigh remaining yolk. Chicks were killed by cervical dislocation and the remaining yolk was removed. These yolk residues were placed on a scale and the weights were recorded. At chick takeoff the 6 hatchers (12 to 17) were pulled separately to ensure that no mixing of chicks could have taken place while they were graded on the carousel. The number of first grade chicks and culls were calculated. From this figures the hatch %, total hatch % and cull % were calculated and recorded. These calculations were made on the total number of eggs set per flock and not on the number of fertile eggs.

2.2.2 Growth Trial

On the day of hatch, 1440 chicks (480 chicks per temperature treatment) were placed in a broiler facility to measure and record the differences in growth, mortality and feed conversion ratio. Thirty-six litter pens were used to house 40 chicks per pen. Thus 12 replications per temperature treatment were used. Body weight was recorded on arrival and then on a weekly basis thereafter. Mortality was recorded on a daily basis. Feed intake was measured weekly and the feed conversion ratio per pen was calculated weekly.



2.3 Statistical analysis

Due to the commercial nature of the hatchery used for this trial, the eggs were of different origin. Although every effort was made to gather eggs from the same flock this was impossible at the time of performing the trial. Therefore, the eggs used in this experiment were gathered from different breeder flocks. It could be argued that the age of the breeder hen will have an impact on chick size; therefore breeder age was brought into the model as a potential source of variation. Due to the unbalanced nature of the data for the incubation trial, the results were analysed using REML from GENSTAT 8.1 Edition (2005). This programme allows for the prediction of missing values and permits to perform an analysis of variance on the data collected. Data for the growth trial were subjected to an analysis of variance, using the GLM option in GENSTAT 8.1 Edition (2005). Significant differences between treatment means were identified by using a Student's t test.

2.4 Results and discussion

2.4.1 Incubation trial

The results for chick length, chick weight and residual yolk are shown in Table 2.2. Incubation temperature did not have a significant effect in chick length or weight as well as in residual yolk at hatch. As expected, the age of the breeder flock had a significant influence on chick weight and length. Eggs produced by older breeding hens yielded larger and heavier chicks at hatch. Egg size is affected by a number of management and nutritional factors but, also by the age and genotype of the breeder hens. The size of the egg is important because of its direct relationship with the size of day old chick, which comprises 64-70% of the weight of the egg (Decuypere *et al*., 2001).

The only factor having a significant effect on chick parameters was the age of the breeding hens. All parameters measured showed a significant influence by the age of the breeder flock with p values of <0.001, <0.001 and 0.005 respectively. The different incubation temperatures used for this trial had no significant effect on the parameters studied. The significant interaction between age of breeding hen and incubation temperature can be explained due to the large effect of age of the hens in the parameters measured.

The lack of significant effect of incubation temperature was unexpected and could be attributed to a number of factors. Firstly, the fact that multistage incubators were used for this trial and not single stage could have contributed to the results obtained. The advantages of using single stage incubators for a better control of the incubation environment were discussed in section 1.3.5. But briefly, a single stage incubator can be regulated much more efficiently as to meet the embryo's specific environmental needs. In a single stage setter temperature can be adjusted, as the embryos get older, which is not the case with multi stage incubators (Hulet and Meijerhof, 2001). Single stage incubators have embryos of exactly the same stage of development at any given time and thus similar requirements (Kortuem, 2004).

Table 2.2 The effects of breeder age and different incubation temperatures on chick length (cm), chick weight (g) and residual yolk (g) of day old Hybro G+ broilers

Age	Temp	Chick Length	Chick Weight	Residual Yolk
27	37.2ºC	*	*	*
	37.4ºC	*	*	*
	37.5ºC	18.92	34.10	3.001
30	37.2ºC	19.19	37.90	4.100
	37.4ºC	*	*	*
	37.5ºC	*	*	*
31	37.2ºC	19.44	36.90	3.800
	37.4ºC	19.40	37.90	3.600
	37.5ºC	*	*	*
32	37.2ºC	19.58	38.40	4.800
	37.4ºC	*	*	*
	37.5ºC	*	*	*
33	37.2ºC	19.38	38.50	3.800
	37.4ºC	19.50	36.80	3.400
	37.5ºC	*	*	*
34	37.2ºC	*	*	*
	37.4ºC	19.30	36.70	3.200
	37.5ºC	*	*	*
35	37.2ºC	*	*	*
	37.4ºC	19.67	35.20	2.800
	37.5ºC	*	*	*
36	37.2ºC	*	*	*
	37.4ºC	19.84	38.70	4.600
	37.5ºC	*	*	*
37	37.2ºC	*	*	*
	37.4ºC	19.73	38.30	3.600
	37.5ºC	*	*	*
38	37.2ºC	*	*	*
	37.4ºC	*	*	*
	37.5ºC	19.75	38.10	3.111
39	37.2ºC	*	*	*
	37.4ºC	*	*	*
	37.5ºC	19.68	39.30	3.600
s.e.d	Average	0.17	0.95	0.59
	Maximum	0.18	0.99	0.62
	Minimum	0.13	0.70	0.46
LSD		0.34	1.90	1.18
AVG s.e.d		0.029	0.905	0.346

(*) Missing data; LSD: Least Significant Difference; AVG SED: average Standard Error of the Difference

Human interference and changes in incubator temperature brought about the introduction of younger eggs is kept to a minimum in single stage incubators, as eggs are placed in the incubator and the incubator is closed for the 18 days of the incubation process. On the contrary, when using multistage incubators, the embryos are of various ages and therefore, different stages of development with different temperature profiles. In addition,

there is continuous interference, such as that created by the setting patterns (setting and transfer at least twice a week) and consequent opening and closing of the incubators, which can create a significant disruption to the incubation process contributing to more variable environmental conditions. A second reason for the observed results could be attributed to the fact that the egg bank at the commercial hatchery, when this experiment was conducted, was so low that there was no other option than using eggs produced by a large number of breeding flocks, with ages ranging from 27 to 39 weeks. If age of the flocks producing the hatching eggs for this trial were more similar for each specific treatment, the results might have been different. However, it could be argued that the temperature range chosen for this experiment was too narrow. Unfortunately when working with commercial operations of the scale of this commercial hatchery the use of extreme treatments that could negatively impact the entire operation is not possible. Although the different treatments could be considered too close to each other to grant a significant effect, if incubation temperatures were reduced further (below 37.0ºC) there was a significant risk of severely affecting the new eggs placed in the machines, resulting in a very slow start and consequently result on delayed or wide spread of hatch. On the other hand, temperatures much higher than 37.5ºC would have produced the effects widely reported in the literature and significantly reduced chick quality.

2.4.2 Broiler Trial

The results of the performance trial are presented in Table 2.3. There were no significant differences in any of the parameters measured due to different incubation temperatures to 42 days of age. In particular, results to 7 days of age, which are considered of relevance when evaluating chick quality, were not affected. Mortality was in general low and showed no significant difference due to incubation temperature. Joseph et al. (2006) reported that incubation temperatures of 36.6 and 39.5ºC resulted both in low body weight and performance of broiler chickens to 3 weeks. After this age, there were no differences in performance due to incubation temperatures. It is likely that broilers were able to compensate from 3 weeks onwards. The performance of broilers on the control treatment – incubation temperature of 37.8ºC was in agreement with the results of the trial performed in this study.

Table 2.3 The effects of different incubation temperatures on body weight (g), daily food intake (g/bird day), cumulative food intake (food / bird), weekly mortality (%) and cumulative mortality (%) of Hybro G+ broilers to 42 days of age.

Body weight						
Temperature	7	14	21	28	35	42
37.2ºC	170	442	920	1363	2068	2472
37.4ºC	175	453	924	1345	2074	2485
37.5ºC	171	442	905	1311	2027	2434
s.e.d.	4.0	9.8	14.9	58.4	24.1	34.7
LSD	8.2	20.0	30.4	118.7	49.0	70.7
Daily food intake						
Temperature	7	14	21	28	35	42
37.2ºC	28.3	54.8	103.9	144.5	172.7	170.0
37.4ºC	29.2	53.9	104.0	144.0	171.8	166.8
37.5ºC	29.1	53.2	102.7	144.2	166.9	167.7
s.e.d.	0.84	1.05	1.69	1.97	2.06	3.28
LSD	1.72	2.13	3.44	4.00	4.19	6.67
Cumulative food intake						
Temperature	7	14	21	28	35	42
37.2ºC	198	384	132	1012	1209	1190
37.4ºC	205	377	137	1008	1203	1168
37.5ºC	204	372	133	1010	1168	1174
s.e.d.	5.91	7.32	4.00	13.75	14.43	22.96
LSD	12.02	14.89	8.13	27.98	29.36	46.72
Mortality						
Temperature	MT 7	MT 14	MT 21	MT 28	MT 35	MT 42
37.2ºC	0.67	1.17	0.50	1.25	2.25	7.92
37.4ºC	0.25	0.50	0.25	1.25	2.08	6.75
37.5ºC	0.75	0.75	1.83	1.17	1.17	6.67
s.e.d.	0.537	0.598	0.590	0.667	0.945	1.314
LSD	1.093	1.218	1.200	1.358	1.923	2.673
Cumulative Mortality						
Temperature	7	14	21	28	35	42
37.2ºC	0.67	1.83	2.25	3.33	5.58	13.17
37.4ºC	0.25	0.75	1.00	2.17	4.00	10.67
37.5ºC	0.75	1.42	3.17	4.33	5.42	11.75
s.e.d.	0.54	0.72	0.84	0.98	1.39	1.91
LSD	1.09	1.47	1.70	1.99	2.82	3.88

s.e.d.: Standard Error of the Difference; LSD: Least Significant difference.

The results observed in this performance trial are in agreement with the results of the incubation trial where embryos subjected to a range of incubation temperatures between 37.2 and 37.5ºC showed no difference in chick quality and further performance.

CHAPTER 3
GENERAL CONCLUSIONS

Incubating eggs at different incubation temperatures namely 37.2, 37.4 and 37.5ºC did not result in differences in terms of chick quality and subsequent broiler performance. These results were unexpected, as it was suggested by the literature and different experts visiting the hatchery that such small variations will significantly affect chick quality. The effects of dramatic changes in incubation temperature have been widely reported, and this experiment was planned to test if variations within normal commercial incubation conditions would have an effect on chick quality. It is therefore concluded that chick quality is more affected by a combination of a range of factors. These factors are related to the different variables that can affect the efficiency of multi-stage incubators as those used in this trial. Embryo temperatures were maintained within the expected ranges; however, it is possible that due to the conventional management of this type of incubators there was an overlapping in incubation temperatures amongst the treatments.

In addition, the difficulties in gathering fertile eggs of similar breeder ages added a factor that, although expected to have an effect in the quality of the hatchlings, may have resulted in an additional confounding effect. In spite of precautions taken to suppress the confounding effect of breeder age, further research is required to confirm these results.

The trend observed in many countries around the world, where large poultry companies are changing from multi-stage to single-stage incubators, in particular for the incubation of high-yield broilers, might not reach developing countries in the near future. Replacing the current type of incubators is an extremely expensive exercise; therefore, studying incubation conditions that will result in improved chick quality is well worth it. The trials performed for this thesis confirm that incubation temperature within 37.2 and 37.5ºC do not negatively affected the quality of day-old chicks or their subsequent performance to 42 days of age under commercial rearing conditions.

REFERENCES

Alsop, F.M., 1919. The effect of abnormal temperatures upon the developing nervous system in the chick embryos. Anatomical Record. 15, 307-331.

Ande, T.B. & Wilson, H.R., 1981. Hatchability of chicken embryos exposed to acute high temperature stress at various ages. Poultry Science. 60, 1561-1566.

Barrot, H.G., 1937. Effect of temperature, humidity and other factors on hatch of hen's eggs and on energy metabolism of chick embryos. US Dept. Agr. Tech. Bull. 553, 1-45.

Byerly, T.C., 1938. Effect of different incubation temperatures on mortality of chick embryos. Poultry Science. 17, 200-205.

Decuypere, E., 1984. Incubation temperature in relation to postnatal performance in chickens. Archiv fűr Experimentelle Veterinärmedizin. 38, 439-449.

Decuypere, E. & Michels, H., 1992. Incubation temperature as a management tool: a review. World's Poultry Science Journal. 48, 28-38.

Decuypere, E., Tona, K., Bruggeman, V. & Bamelis, F., 2001. The day-old chick: a crucial hinge between breeders and broilers. World's Poultry Science Journal. 57, 127-138.

Deeming, D.C., Rowlett, K. & Simkiss, K. 1987. Physical influences on embryo development. Journal of Experimental Zoology Supplement, 1: 341—345.

Deeming, D.C. 1989. Characteristics of unturned eggs: critical period, retarded embryonic growth, and poor albumen utilization. British Poultry Science. 30: 239-249.

Deeming, D.C., 2000. Are you overheating your eggs without realising it? World Poultry December 2000. pp. 14-15.

Deeming, D.C., 2000. What is chick quality? World Poultry December 2000. pp. 34-35.

Geers, R., Michels, H., Nackaerts, F., & Konings, F., 1983. Metabolism and growth of chickens before and after hatch in relation to incubation temperatures. Poultry Science. 62,1869-1875.

Genstat. 2005. 8.1 Edition. Lawes Agricultural Lawes.

Harman, M.T., 1922. Heat as a factor producing abnormalities in the chick. Trans. Kans. Acad. Sci. 31, 66-76.

Hill, D., 2002. Chick length uniformity profiles as a field measurement of chick quality. Hatchery International Practice; vol 16 no 24. Hulet, R. M., Meijerhof, R. 2001. Multi- or single-stage incubation for high-meat yielding broiler strains? Poultry Science 80: 1041

Joseph, N. S., Lourens, A. and Moran Jr., E. T. 2006. The Effects of Suboptimal Eggshell Temperature During Incubation on Broiler Chick Quality, Live Performance, and Further Processing Yield. Poultry Science, 85: 932- 938

Kaltofen, R.S. 1961. The effect of fertility rate and frequency of turning on embryonic mortality during artificial incubation. Animal Breeding Abstracts, 29: 106- 107.

Kortuem, L. 2004. Single-stage vs. multi-stage. Hatch talk, Jamesway Incubator Company. Dec. p.1

Lourens, S., 2003. Residual yolk and egg weight loss during incubation under controlled eggshell temperatures. Avian and Poultry Biology Reviews 14: 209-211.Incubation and fertility research group meeting, WPSA Working Group 6 (reproduction), University of Lincoln, UK, 4-5 September 2003.

Lourens, A., Molenaar, R., van der Brand, H., Heetkamp, M.J.W., Meijerhof, R. and Kemp, B. 2006. Effect of egg size on heat production and the transition of energy from egg to hatchling. Poultry Science, 85: 770-776.

Lundy, H., 1969. A review of the effects of temperature, humidity, turning and gaseous environment in the incubator on the hatchability of the hen's egg. In: The fertility and Hatchability of the Hen's Egg (Eds Carter, T.C. and Freeman, B.M.), Oliver and Boyd, Edinburgh. pp. 143-176.

Meijerhof, R., 2003. Problem solving in the commercial broiler sector. Avian and Poultry Biology Reviews 14: 212-214.Incubation and fertility research group meeting, WPSA Working Group 6 (reproduction), University of Lincoln, UK, 4-5 September 2003.

Meijerhof, R., 2005. Defining & measuring quality in day olds. International Hatchery Practice; vol 19 no 7, 31.

Michels, H., Geers, R. & Muambi, S., 1974. The effect of incubation temperature on pre- and post-hatching development in chickens. British Poultry Science. 15, 517-523.

Romanoff, A.L., 1935. Influence of incubation temperature on the hatchability of eggs, postnatal growth and survival of turkeys. Journal of Agricultural Science. 25, 318-325.

Romanoff, A.L., 1936. Effects of different temperatures in the incubator on the prenatal and postnatal development of the chick. Poultry Science. 15, 311-315.

Taylor, G., 2000. High-yield breeds require special incubation. World Poultry December 2000. pp. 28-29.

Taylor, G. & Havran, T., 2000. Matching setting systems to hatchery needs. World Poultry December 2000. pp. 11-13.

Thompson, J.B., Wilson, H.R. & Voitle, R.A., 1976. Influence of high temperature stress of 16-day embryos on subsequent hatchability. Poultry Science. 55, 892-894.

Wilson, H.R., 1991. Physiological requirements of the developing embryo: temperature and turning. In: Avian Incubation (Tullett, S.G., Ed.), Butterworth-Heinemann, London, pp. 145-156. Wilson, H.R. & Wilmering, R.F. 1988. Hatchability as affected by egg turning in high density plastic egg flats during the last half of incubation. Poultry Science, 67: 685—688.