TEMPERATURE PROFILES IN A FLOOR HEATED BROODER

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DECLARATION

STUDENT'S DECLARATION

This project is my original work and has not been presented for a degree in this or any other university.

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SUPERVISOR'S DECLARATION

We confirm that the above student carried out this research under our supervision as university supervisors.

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DEDICATION

I dedicate this to my family.

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ABSTRACT

Brooding is critical to the development of chicks in poultry farming. The main aim of brooding is to efficiently and economically provide a comfortable and healthy environment to chicks. Farmers provide chicks with the ideal temperature, ventilation, humidity and space requirements. In this study the focus is on provision of adequate heat in a model brooder by use of heated floors. The main advantage of heated floors lies in their ability to use low temperature heat which can be provided by solar energy. Most farmers in Kenya use charcoal for brooding. The use of heated floors for brooding is unknown. Therefore there exists a knowledge gap in the application of heated floors for brooding. Brooding using heated floors has several advantages; heating is done over the entire floor area resulting in better distribution of heat; there is reduced fire risk compared to charcoal, kerosene and gas brooders; heated floors do not take any space in the brooder unlike charcoal brooders; and the use of heated floor systems facilitates the use of automated temperature control.

This study was done to generate temperature profiles for a model heated floor. Analysis of the temperature profiles was used to determine the impact of; water heating temperature, ambient temperature, wood shavings and covering the top of the brooder. Of particular interest was the temperature of the floor and wood shavings and the temperature at 50mm height (typical height of a day old chick). It was demonstrated that the required brooding temperatures can be attained by adjusting the water temperature, thickness of wood shavings and extent of covering using empty sisal bags.

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ABBREVIATIONS

cfm	-	cubic feet per minute
IFHDS	-	In floor heat distribution and storage system
LPG	-	Liquid Petroleum Gas
PEX	-	Cross linked polyethylene
PVC	-	Polyvinylchloride
T-amb	-	Ambient temperature
T-wi	-	Temperature of water at pipe inlet
T-wo	-	Temperature of water at pipe outlet
T-wood	-	Temperature at the surface of the wood shavings
T (50mm)	-	Temperature of air 50mm above the floor or wood shavings

Chapter 1

INTRODUCTION

1.0 Background

Brooding in poultry farming refers to the care of chicks in the first four to six weeks of their life. This involves supply of adequate food, water as well as keeping the environmental conditions at certain values. This means keeping, temperature and humidity, ventilation, light at levels comfortable for the chicks.

Chicks before four weeks old cannot effectively regulate their body temperature unlike adult birds and hence artificial heating is required to maintain this temperature [1]. The temperature in the brooder enclosure should be between 30^{o}C and 35^{o}C for the first week, 28^{o}C and 30^{o}C for the second week, 25^{o}C and 28^{o}C for the third week and 20^{o}C and 25^{o}C for the fourth week [2], [3]. The temperature and humidity levels as required are important for proper chick growth. If the chick's body temperature is not maintained at the required level, the chicks will have poor growth, feed conversion and increased susceptibility to disease [1] In general chick enclosures should be kept at a temperature starting at about 34^{o}C and reduced gradually as the chicks grow up to 20^{o}C after four weeks. The first week is the most important stage. Brooder heating has been found to be the biggest single energy item in broiler farming [4].

The optimum relative humidity in a brooder has been found to be between 50 and 70% [1]. Low relative humidity is associated with dusty conditions within the brooder. Dusty conditions result in respiratory infections while high humidity results in increased ammonia production. Ammonia production occurs due to the microbiological breakdown of fecal matter in the litter (wood shavings) [1]. Also, high relative humidity is known to promote the growth of harmful microbial organisms. Ammonia gas has a negative impact on bird health and performance. It impairs the immune system and increases respiratory diseases in the chicks therefore reducing the growth rate. Poor growth rate during the brooding period cannot be recovered.

Adequate ventilation is necessary in order to remove ammonia, Hydrogen Sulphide, dust and odours. Ventilation also affects the relative humidity. Brooders should therefore be well ventilated. However excess ventilation has the disadvantage of resulting in heat loss and results in increased energy requirements.

In large sophisticated farms, the above conditions are easily achieved by air conditioning. The chick houses are air conditioned using fans and heaters. However, in most small scale farms in Kenya, there are no facilities for air conditioning and therefore farmers use other brooding methods. In most cases the farmers aim to maintain only the required temperature. However, the methods employed do not create the strict conditions required throughout the brooding period. The temperature in these brooders vary from one area of the brooder to another, it also fluctuates. This results in high mortality of the chicks and also poor growth. It is therefore important that alternative methods should be developed to maintain the temperature in the brooder at the right level with minimal variation and fluctuation.

In this project, an attempt is made to design and construct a floor heated brooder that could be used to provide the required temperatures and make it easier to maintain the ideal conditions for brooding. Further, floor heating can employ solar energy and also utilize hybrid systems that combine biomass, biogas, diesel, solar, LPG and natural gas.

The advantage of floor heating is that uniform temperatures can be maintained within the brooder. The brooder floor can also be kept dry – minimizing the wet conditions and heating can also be automated. The high heat capacity of the floor enables the temperature to be maintained for a long time without the heat source compared to other methods. It is in these respects that this type of heating procedure may benefit the brooding process in terms of adequate temperature conditions and overall cost reduction.

1.1 Problem statement

A preliminary survey for this project in a select number of commercial farms around Nairobi showed that charcoal brooding was practiced by nearly all commercial farmers. It was found to be ineffective in maintaining the required temperature conditions. It was difficult to manage and also released carbon monoxide in the brooders. This resulted in high mortality and poor chick growth. It is important that this method of brooding should be either improved or changed. This project aims to create an alternative method of heating the brooder. However, for this alternative method to be employed it is important to know if the required temperatures can be achieved. Thereafter the characteristics of the system should be understood.

1.2 Objective of the study

The overall objective of the study was to determine the temperature profiles in a floor heated brooder. In particular the objectives were:

i. To determine the impact of water inlet temperature on the brooder temperature.
ii. To determine the impact of wood shavings on the temperature in the brooder.
iii. To determine the impact of covering the top of the brooder using sisal bags.
iv. To determine the impact of ambient temperature on the brooder temperature
v. To determine the effect of the floor heat capacity on temperature in the brooder during heating and cooling.

1.3 Justification

Brooding using heated floors has many advantages over other methods of brooding. Provision of evenly distributed heat promotes growth of the chicks. The chicks can therefore achieve the required weight at market age. This improves the commercial viability of the poultry farm. Floor heating results in drier litter material reducing the production of ammonia by microorganisms. This reduces the incidence of respiratory diseases and other opportunistic diseases caused by impairment of the chick's immune system. Reduced incidence of diseases can result in improved mortality of the flock. Brooding using heated floors facilitates the use of solar energy for heating because heated floors use water at temperatures that can be attained using solar collectors. This can therefore reduce the dependence on charcoal for brooding. The use of heated floor results in better utilization of space in the brooder. In systems using charcoal for heating, the stoves take up space in the brooder. The use of a heated floor facilitates automation of the brooding operation. In large commercial systems this will result in lower labour costs and therefore higher profitability.

Chapter 2

LITERATURE REVIEW

2.0 Introduction

This chapter reviews chicks brooding requirements, the different methods of chick brooding and also examines selected floor heating applications.

2.1 Chick brooding

2.1.1 Chick brooding requirements

There are strict environmental conditions that need to be kept in commercial chick brooding. As stated in Chapter One, temperatures must be within 20^oC and 35^oC. According to van Eekeren [2] recommended brooding temperatures are 30^oC to 34^oC in the first week, 25^oC to 30^oC in the second week, 25^oC to 28^oC in the third week and 20^oC to 25^oC in the fourth week. According to Wageningen et.al [5] brooding temperatures should be 30^oC to 32^oC in the first week, 28^oC to 30^oC in the second week, 25^oC to 28^oC in the third week and 22^oC to 25^oC in the fourth week. STOAS human resources development worldwide [3] proposed brooding temperatures of 30^oC to 34^oC in the first week, 25^oC to 30^oC in the second week 25^oC to 28^oC in the third week and 20^oC to 25^oC in the fourth week. B. Fairchild [1] recommended brooding temperatures of 31^oC on the first day, 30^oC on the third day, 29^oC on the seventh day, 28^oC on the 14^{th} day and 25^oC on the 21^{st} day for radiant brooders. These conditions may easily be met using air conditioners. However, in the absence of electricity and capital to maintain the air conditioners other methods are likely to be applied which may not attain the temperatures; rendering the brooder to be either too hot, too cold or fluctuating.

High brooder temperatures cause heat stress in birds. Unlike mammals birds have no sweat glands and can only resort to panting to reduce the effects of heat stress. This is more so with chicks which cannot regulate their body temperature, in fact a chicks thermoregulatory system does not fully develop until about two weeks of age [6]. High brooder temperatures also cause chicks to increase water intake at the expense of food consumption. This has a negative effect on their growth.

Chicks subjected to low temperatures have impaired immune and digestive systems. Low temperatures can result in death due to opportunistic infection and overcrowding. In low temperatures the young chicks tend to crowd together, this may result in the smaller chicks getting smothered by the larger chicks [3]. Provision of adequate heat is essential during the brooding whereas a chick can go without food for the first three days of its life, it cannot survive without adequate heat [7].

In cold countries wood shavings are spread on the floor to assist in insulating the ground to maintain the brooder temperature [8]. Wood shavings are also necessary for absorbing excess moisture from chick droppings and spilt drinking water. They also dilute faecal material thus reducing contact between the chicks and manure. Wood shavings also cushion the birds from the hard floor.

Another important brooding condition is the relative humidity. According to Fairchild [1] relative humidity should be maintained at 50 to 70 percent throughout the growing period. Relative humidity below 50 percent causes dusty conditions which results in respiratory diseases. Relative humidity above 70 percent encourages microbial growth in the litter. Ammonia is generated from the chick droppings due to microbial growth in wet environments. High ammonia levels result in poor growth and increased respiratory disease [6].

Ventilation is very important to the health of chicks during the brooding. Proper ventilation reduces the build-up of ammonia, moisture and other gases such as Hydrogen Sulphide. Poor ventilation resulting in high relative humidity promotes production and buildup of ammonia. High ammonia levels cause impairment of the immune system and respiratory diseases. According to Czarick [6] ammonia levels above 60ppm cause a decline in performance of layers. Broilers are more sensitive to ammonia and can be harmed by less than 25ppm of ammonia. Broilers affected by ammonia never reach physical maturity. Short periods of high ammonia levels lead to decreased weight, increased feed conversion and increased respiratory disease. Ammonia levels should be kept below 30ppm at all times and preferably below 20ppm. A minimum ventilation rate of 0.1cfm per bird is recommended. As the birds grow the ventilation rate should be increased by the age of the birds in weeks multiplied by 0.1cfm per bird. High ventilation rates result in removal of heat from the brooder. As fresh air is added at a lower temperature more energy is required to heat the air in the brooder. Poor ventilation allows buildup of Hydrogen Sulphide (H_2S). Hydrogen Sulphide is formed when the protein in the birds manure is broken down. It is a very dangerous gas with a very offensive smell. It is fatal to both chicks and human beings even in low concentrations. It is recommended to eliminate it completely using proper ventilation [9]. Carbon dioxide is exhaled by the birds. It should not exceed 2500ppm [9] Carbon monoxide is formed as a result of incomplete combustion from charcoal stoves. This occurs when charcoal is used for brooding. It is an odourless and very dangerous gas. It should be completely eliminated through proper ventilation.

Space requirement for brooding chicks from one day old to 4 weeks old is $0.044m^2$/bird [10]. Space required varies depending on the type of floor. The recommended spacing varies from 0.04 to $0.065m^2$/bird for litter and wire systems and 0.036 to $0.065m^2$/bird for all litter systems[3].

Lighting is also important during brooding. Chick activity is greater in brighter light. The light should be bright enough to enable the chick to locate feed and water. The light intensity should be at maximum on the first day. This should be reduced gradually after 7 to 10 days.

2.1.2 Local brooding methods

A number of heating methods are employed in brooding within commercial farming in Kenya. These include charcoal, kerosene, electricity and LPG. The most widely used source of heat is charcoal through specially made stoves. There is limited published information that describes this heating method adequately. However a few studies have reported information concerning charcoal heating.

Mulugeta [11] carried out an experiment to determine the amount of charcoal required for brooding. In order to determine the amount of charcoal required for chick brooding the heat generation capacity of the brooder and survival rate of the chicks were evaluated. The performance of pot charcoal brooders using 500, 750 and 1,000gms of charcoal were evaluated. The survival rate of chicks using the pot charcoal brooders was compared to that of an electrical brooder and one batch in which no heat was provided. The temperature in the brooders and the survival rate of the birds were monitored for 15 days. The survival rate for all the pot charcoal brooders was almost equal. Each had 4 to 5 deaths out of 34. Due to power interruptions the electrical brooder had a 50% survival rate. The batch for which no heat was provided recorded a 100% death rate. The findings of the study showed that an equal survival rate was achieved using 500gms and 1000gms. Even though the number of chicks that can be brooded per unit mass of charcoal was not established, the study demonstrated that using more than the required amount of charcoal does not increase the performance of the brooder.

From the study it was established that the temperature in the brooder when using charcoal brooders varies greatly. Table 2.1 shows the temperature at three distances from the pot brooder. It shows that the temperature in the brooder varies depending on the distance from the stove and time after lighting the stove. The maximum temperature is achieved 5 to 10 minutes after lighting the brooder. It then decreases and is at a minimum 5 minutes before addition of more charcoal. At a distance of 125cm from the pot brooder the temperature varied by 10^oC from the start to end of charcoal burning.

Table 2.1 Temperature measured from pot charcoal brooder

Amount of charcoal in brooder	5 to 10 minutes after burning of charcoal started			40 to 45 minutes after burning of charcoal started			5 minutes before adding charcoal for the next round		
	25cm	75cm	125cm	25cm	75cm	125cm	25cm	75cm	125cm
500gms	41.3^oC	33.7^oC	30.0^oC	39.3^oC	32.3^oC	29.7^oC	28.0^oC	24.3^oC	20.3^oC
750gms	44.3^oC	37.0^oC	31.0^oC	42.3^oC	35.0^oC	30.0^oC	31.7^oC	24.0^oC	21.3^oC
1000gms	50.0^oC	42.7^oC	32.0^oC	49.0^oC	40.3^oC	31.0^oC	36.7^oC	28.7^oC	23.7^oC

Source: [11] Mulugeta Ayalew

In a study by Awudu [12] a perforated pot charcoal heater was used to brood chicks over a period of one week. The performance of the “Awudu” heater was compared to that of LPG, Kerosene and an electric bulb heater. 0.5kg of charcoal was placed in the pot heater and temperature measurements taken at a distance of 20 cm from the heater. The measurements were taken at 3, 6 and 10 cm height. It was found that 0.5kg of charcoal could be used to sustain a minimum average temperature of 37^oC over a period of 12 hours during the day and 35^oC for a similar interval at night. It was found to be as effective as the LPG, Kerosene and electric heaters. The main advantage was cost as the “Awudu” heater was 5, 10 and 15 times cheaper than LPG, Kerosene and electric heating.

The typical Kenyan charcoal stove consists of two main chambers the lower part the stove and the upper part the chimney. The lower part of the charcoal stove has an air inlet near the base where the ash collects. The air inlet protrudes into the stove and acts as a safety feature as it prevents hot ash and charcoal from falling out of the brooder and onto the chicks. Charcoal is placed on a perforated plate in the stove chamber. The perforations allow air to flow from the air inlet through the charcoal and out through the chimney. The chimney helps in creating a draft. The main advantage of these charcoal stoves is the low cost of brooding. The charcoal stove costs kshs 2,000 (US$ 23) and a bag of charcoal costs less than kshs 1,000 (US$ 11.5). The main disadvantage of charcoal brooding is the difficulty of heat regulation and pollution due to production of Carbon dioxide and Carbon monoxide. Heat transfer from the charcoal brooder is by convection and radiation. Heat transfer by convection occurs above the chicks making it less efficient and effective as a source of heat for the chicks.

The use of charcoal for brooding increases the demand for wood fuel which promotes cutting of trees. Charcoal production has a significant impact in Kenya due to the low forest cover of only 121,700 hectares [13]. This forest cover is well below the internationally recommended cover of 10%.

Electric brooders: Infrared bulbs are used to brood small lots of chicks typically less than 200 chicks. One 250 Watt lamp is recommended per lot of 50 to 75 chicks [14]. 100W or 150W bulbs may also be used in warm weather or when the chicks are older [15]. The lamp is placed at a distance of 30 to 40cm above the brooder floor. It provides light and heat which is used to warm the brooder. In areas where electricity is available but not consistent a back-up source of energy for heating is required. Lack of a constant supply of electricity can result in a high mortality rate. In the study by Mulugeta Ayalew [11] 50% death rate was recorded due to inconsistent electricity supply for brooding using electric heaters. The temperature and relative humidity when using the electrical system was not discussed in the study. Due to the position of the bulb above the chicks most of the heat produced heats the air above the chicks making it less efficient and effective. Figure 2.1 shows brooding using infra-red lamps.

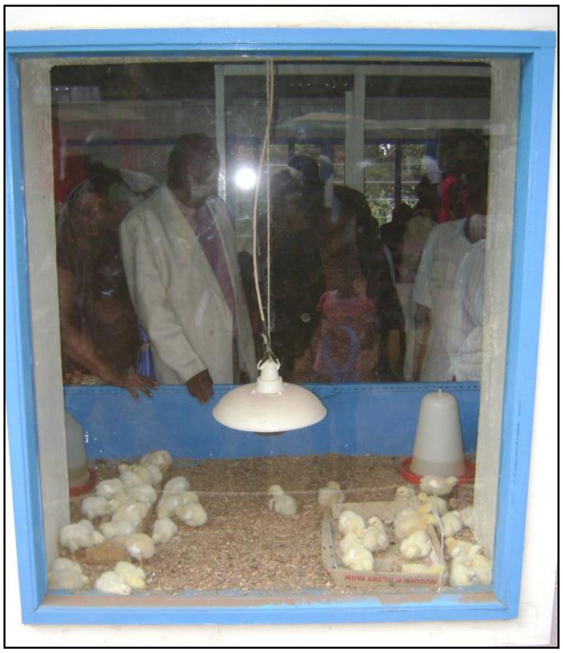

Figure 2.1 Brooding using infra-red lamps

Kerosene brooders: In this method of brooding Hurricane lamps are used to brood chicks. This method of brooding is common in places with no electricity. The Hurricane lamps provide both heat and light. Hurricane lamps are readily available and affordable. The retail price of a hurricane lamp is kshs500 (6USD). However the running costs are high due to the cost of kerosene and the consumption rate of the lamps. A litre of kerosene costs kshs 86 per liter (1 USD) and the average consumption rate of kerosene using hurricane lamps is 0.02 litres per hour [16], [17]. Combustion of Kerosene releases soot and gases that are harmful to the health of both man and poultry [18]. In the event of stock outs of fuel the farmer may have to use a different method of brooding.

Gas brooder: Some commercial farmers use gas brooders. Kenchic Limited the largest day old chick supplier in Kenya uses Liquid Petroleum Gas (LPG) in their gas brooders. Gas brooders can be used anywhere because LPG gas is available in all major towns. They have the advantage of producing humid heat which encourages feathering [10]. However the main disadvantage is the increased risk of fire due to the naked flame. The risk of fire is increased by the use of combustible floor materials such as wood chips. The initial investment cost of gas brooders is higher than that of charcoal and Kerosene brooders. Kenya imports LPG and the prices tend to increase every year. However, use of biogas could be attempted.

Radiant tube brooders: Radiant tube brooders make use of Propane or Natural Gas fired heaters in the shape of long tubular pipes hung near the ceiling of the chicken house. The radiant tube consists of a fire box connected to a metal tube of 12 to 15m length. The burners in the fire box draw in combustion air from outside of the brooder. The heated air is then pushed through the tube. The temperature in the firebox reaches up to 530^{o}C and the temperature at the end of the tube reaches between 175^{o}C to 200^{o}C [19]. Metallic reflectors are placed above the tubes to protect the roof and to reflect most heat to the ground. The main advantage of radiant tube heaters is their ability to heat a large percentage of the brooder quicker than other systems [20].

Solar energy brooding: Solar brooders use of the Sun's energy to provide heat to the chicks. Solar systems may be passive or active. Active solar systems use fans or pumps to transfer heat from a solar collector to the brooder while passive systems do not utilize any mechanical system for heating. Nwanya and Ike [21] carried out study using a small scale solar brooder with a capacity for 28 chicks. The brooder measured 1.42m length by 0.92m width and 0.52m height. It had a solar collector of 1.38m length by 0.47m width. The solar collector was placed on the roof of the brooder. The brooder also had a solar heat storage system using water as the storage medium. With the ambient temperature varying between 18.6^{o}C and 32.8^{o}C the brooder was maintained at temperatures of between 24^{o}C and 33^{o}C over a period of 5 weeks.

In a study by Okonkwo and Akubuo [22] the performance of a Trombe wall poultry house was investigated. The poultry house consisted of a Trombe wall and a brooding room of 6.6m^2. The Trombe wall was used as a solar collector and solar energy store. During the period of investigation the ambient temperature varied between 18^{o}C and 37^{o}C, the Trombe wall temperature varied between 22^{o}C and 60^{o}C and the brooding house temperature varied between

28^{o}C and 35^{o}C. Tests were done using live chicks for a period of 5 weeks per batch over a five year period. The mortality rate was 3% compared to 5% and 10% achieved by kerosene and electric brooding systems.

2.2 Floor heating

Under floor heating can be traced back as early as the Roman period. The Romans relied on a system of flues and ducts in walls and under the floor to circulate hot air from fires [23].There are two types of under floor heating systems electric heated systems and fluid heated systems. Under floor heating systems that use a fluid flowing through pipes are referred to as "hydronic systems". The pipes are cast in a concrete floor slab or they may be placed under some form of floor covering. The pipes are made of polyethylene, copper or steel. Most hydronic systems utilize water as the heat transfer fluid. Depending on the location pure water or a mix of water and anti-freeze may be used. Figure 2.2 shows a typical hydronic floor. In this study a hydronic system with copper pipes cast in concrete was used to test the performance of a model heated floor.

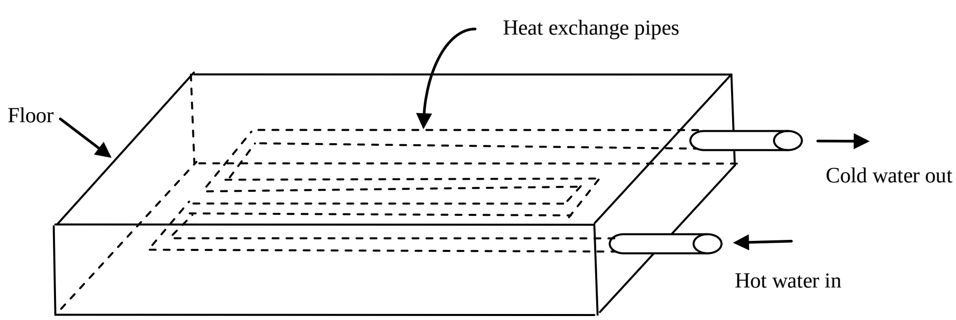

Figure 2.2 Hydronic floor

Under floor heating is recommended for heating brooders because it has several advantages over the conventional heating systems. Under floor heating systems have better heat distribution because the heat transfer fluid is circulated over the entire floor. Heat supply is therefore even. Under floor heating can be done using solar energy which can be used to provide heated water at up to 70^{o}C, this can therefore reduce the demand for fossil fuel and charcoal. The pipe work in hydronic systems is hidden therefore all floor space is used by the chicks [24]. Charcoal, kerosene and gas brooders take up space in the brooder. The use of low temperature heat and hidden pipes reduces fire risk compared to charcoal and gas brooders that use naked flames. Charcoal brooding uses naked flames which can easily cause fire if pieces of charcoal fall onto the floor material. Compared to radiator systems under floor heating is quiet [25]. The operating and maintenance costs of under floor systems are lower than those of charcoal or fossil fuel powered systems. The operation of under floor systems can be fully automated. A fully automated system requires fewer people which results in lower costs. In an automated system temperature control is better. The brooder area can be zoned by the use of independent thermostats. Heating can therefore be provided to the entire floor or to individual sections of the brooder. This allows for gradual expansion of the area used for brooding as the chicks grow. The use of heated floors results in warm dry floors which inhibit the growth of dust mites. Due to under floor heating there is likely to be less dampness and condensation in the brooder. There are no draughts in under floor heating systems unlike heating using radiators and fans.

The key design parameters in the design of an under floor heated system are: pipe size, spacing, layout, position in the slab, thermal conductivity of the pipe and the insulation of the slab. There are two main patterns used for laying pipes in heated floors, the helical coil method and the parallel runs method [24]. In the helical coil method the pipe is laid on the outer sides of the slab. It is then coiled towards the centre of the slab in loops of decreasing diameter. From the centre of the slab the pipe is then coiled in the reverse direction. Figure 2.3 shows the helical coil pattern. When water is circulated the pattern allows for alternate loops of hot and cold runs [24]. In this study the helical pattern was selected because it gives a more even distribution of heat.

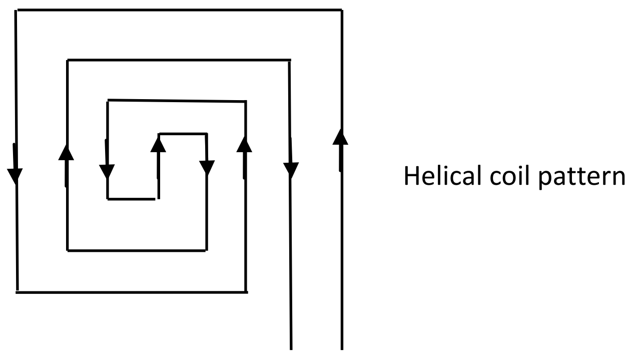

Figure 2.3 Helical coil pattern

The second pattern used for laying pipes in heated floors is the parallel runs method. In this method the first length of pipe is laid parallel to the one side of the slab. The subsequent runs are laid parallel to one another until the whole floor is covered. Figure 2.4 shows the parallel runs method.

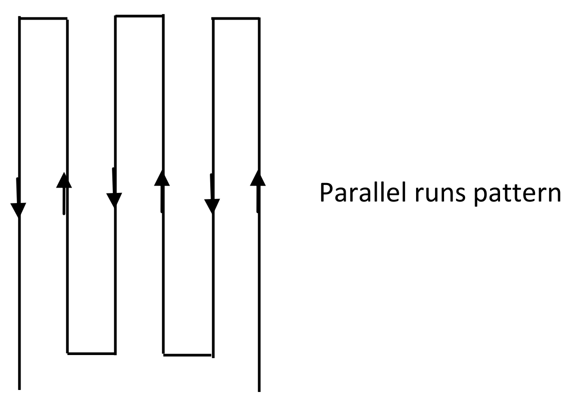

Figure 2.4 Parallel runs pattern

The pipes used in a heated floor can be made of copper, galvanized iron, PVC or PEX. When selecting a material to use for the pipe, the designer needs to consider the cost impact of the material used, the useful life of the pipe and the effect of the pipe material on the performance of the heated floor. Copper pipes have the highest thermal conductivity but are more expensive than Galvanised iron and PEX pipes. PEX pipes are more robust and less likely to get damaged during placement of the concrete. The pipes have an oxygen barrier layer on the outside to exclude air from the water circulation system. The pipes are flexible enough to have them laid in coils with gently rounded bends. The pipes can therefore be laid without joints or connection fittings [24].

A study was carried by Jin et.al [26] on the impact of pipe material type and thickness on thermal performance of a heated floor. They concluded that thermal resistance of a pipe had an impact on performance only if the thermal conductivity of the pipe was low. In the current study the pipe used in the model was made of copper. Copper is a good conductor of heat, it has a thermal conductivity of 386W/mK [27] therefore it is not expected to impact the performance of the floor.

When designing a heated floor the designer must consider the thickness and thermal resistance of the floor cover material. If the thermal resistance of the floor cover material is high then the thermal performance of the floor will be poor. In a study by Sattari and Farhanieh [28] on the impact of floor cover and pipes design on the thermal performance of a heated floor. It was concluded that the thickness and type of floor cover had a greater impact on the performance of a heated floors than the pipe size and material.

Weitzmann et.al [29] investigated a two dimensional simulation model of heat losses and temperature of a heated slab in a building. The model focused on heat loss through the floor construction and foundation. Heat loss through the foundation was found to have a large impact on the energy consumption of the building. The floor should be well lagged to avoid excessive heat loss through the foundation.

As water is circulated in a heated floor the temperature at the pipe level increases. The increased temperature induces an upward and downward heat flux. The upward heat flux is the useful fraction of the total heat supplied. The downward heat flux represents the heat loss fraction of the total heat supplied. The ratio between the upward heat flux and the total supply flux is known as the insulation efficiency [30]. The insulation efficiency depends on the thermal resistance of the floor covering material and the underlying insulation.

Xing et.al [31] built a radiant floor cooling system from an existing floor heating system. A numerical model for the radiant floor cooling system was built using the finite volume method.

The results of numerical modeling and measurement showed that water velocity did not have a significant effect on the performance of the system.

Hasan et.al [32] demonstrated that water at supply and return temperatures of 45^{o}C and 35^{o}C were able to maintain rooms in a house at comfortable room temperatures. Z.P. Song et.al [33] found that the initial temperature of the water had the greatest influence on the performance of the heated floor.

Solar energy has been used to provide heat for under floor heating systems. Alkhalaileh et.al [34] studied the use of solar ponds to provide heat for space heating. In their study they demonstrated that a solar pond floor heating system could meet most of the heating requirement. Badran and Hamdan [35] compared an under-floor heating system using solar collectors with an under-floor heating system utilizing a solar pond. The solar collector system was found to be 7% more efficient than the solar pond system. The solar collector also had lower operation and maintenance costs.

Kurtay et.al. [36] used solar energy to heat an office in Ankara. Their study was carried out under winter conditions with an ambient temperature of -12^{o}C. They used flat plate solar collectors which were fixed on the roof of the office. The floor area of the office was 23m^{2}. 140meters of plastic water pipes of 16mm outer diameter and 2mm thick were laid on the floor. A 3cm thick layer of concrete was poured onto the pipes. Laminate floor material was used as the finishing layer. Under the pipes a 3cm thick layer made of polystyrene was used as insulation. They found that 15% of the energy needs in winter could be provided by solar energy. The house was maintained at an average temperature of 16^{o}C.

In a study by Kocher, et.al [37] a simple in floor heat distribution and storage system (IFHDS) was designed. The system was heated using air from solar collectors. The air was passed through passageways in a concrete mass. In this system heat was transferred from the air to the concrete by convection. It was then transferred to the surface of the thermal mass by conduction and to the air by convection and radiation. They developed a two dimensional finite difference model to simulate the performance of the system. They found that lower floor temperatures resulted in a more efficient system. When using a solar heated floor the user should aim to use the minimum acceptable temperature. They found that IFHDS systems with less thermal storage mass were more efficient. When designing the floor the selected thickness of the thermal storage mass should be the minimum necessary to meet the floor surface temperature fluctuation limits. Keeping the floor surface temperature fluctuation within reasonable limits allows for a higher average floor surface temperature thereby optimizing the efficiency of the IFHDS.

Chapter 3

CONSTRUCTION OF A FLOOR HEATED BROODER AND EXPERIMENTATION

3.0 Introduction

Local chick brooding normally involves isolating a small area within a large chick house (that houses all birds) by means of three-ply to house the chicks. Within this enclosure heat, food and water are provided. As stated in Chapters 1 and 2, the heating is usually by charcoal stoves. The isolating three-ply is about two feet high and open to the rest of the housing. In this arrangement, no insulation is provided on the walls of the three-ply and the exhaust from the stoves is vented within the enclosure. This method wastes heat, it has excessive ventilation requirements and the heating is not uniform.

In this chapter the construction of a small scale brooder is explained with some variation from the normal practice. First, the heating will be through the floor using warm water and secondly, the three-ply will be insulated. The top of the brooder will in the first stage be left open as is the usual practice, and then covered to varying degrees.

Also described here are the various tests to determine temperature and its variation within the constructed brooder when heated with water at various temperatures. The water temperatures were kept at hotness typical of that produced by thermal solar heaters.

The brooder construction was done in two sections, first the floor and then the walls. The floor construction was based on typical heated floor designs from the literature review.

3.1 Brooder Fabrication

3.1.1 Construction of the brooder floor

The floor construction followed the typical procedure used in house floor construction. The size of the small scale brooder floor was chosen to be 1m by 1m. This was considered appropriate because many sizes of floors are determined by the square area and hence this can easily be scaled upwards. The floor materials i.e. cement, sand and ballast were mixed in the ratio 1:2:4.

A model heated floor brooder was fabricated. The brooder consisted of a slab, a water tank and heater and the brooder walls. The heated floor system was then assembled.

During construction of the floor a copper tube of 3/8 inch (9.5mm) diameter was bent into a helical pattern and cast into the slab. Copper was used because it has a high thermal conductivity which facilitated better heat exchange. A spacing of 0.08m between the runs was chosen to facilitate fast and even heating of the slab. Figure 3.1 shows the copper tube attached to wire mesh and placed on the concrete mix during fabrication. In addition to reinforcing the concrete the wire mesh improves the distribution of heat in the slab.

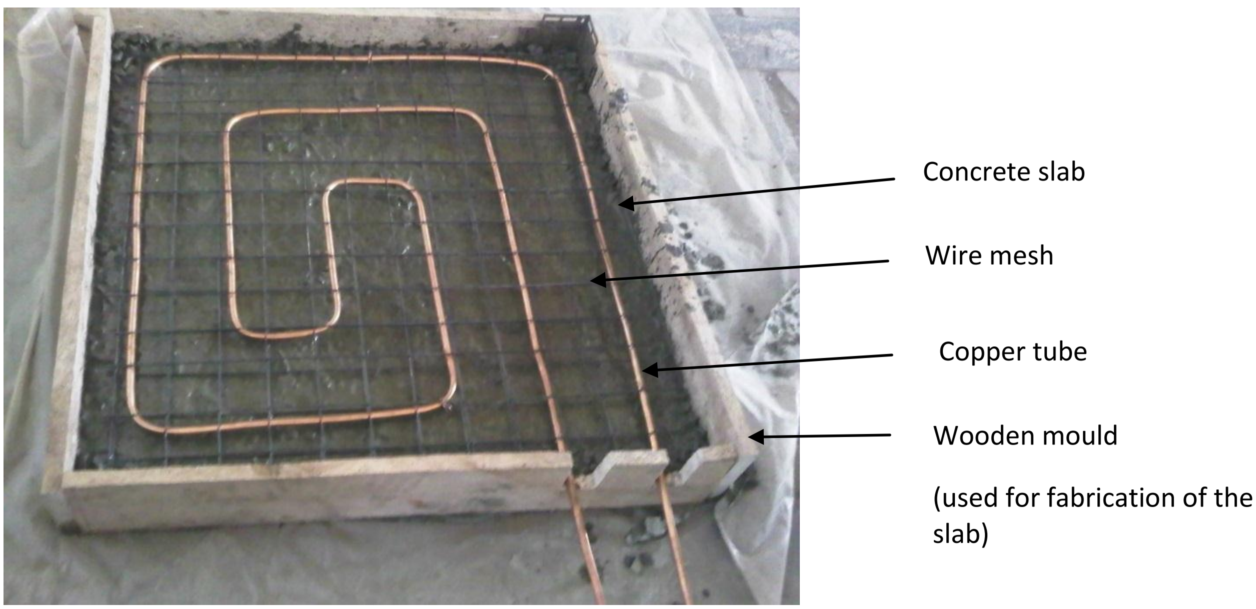

Figure 3.1 Copper tubing placed on concrete during fabrication of floor

Figure 3.2 shows the concrete slab after addition of concrete around and over the copper pipe. The slab was left to cure for three weeks. Thereafter, Polyethylene insulation was cut and affixed to the slab on all sides and at the bottom leaving only the top surface exposed. The polyethylene insulation used was 0.05m thick and had a silver foil on one side. The polyethylene used had a thermal conductivity of 0.0293W/m^{o}K. A one inch layer of screed was added to the surface of the slab. The materials used were cement and sand mixed in the ratio 1:4. It was then left to cure for three weeks. Figure 3.3 shows the floor and insulation

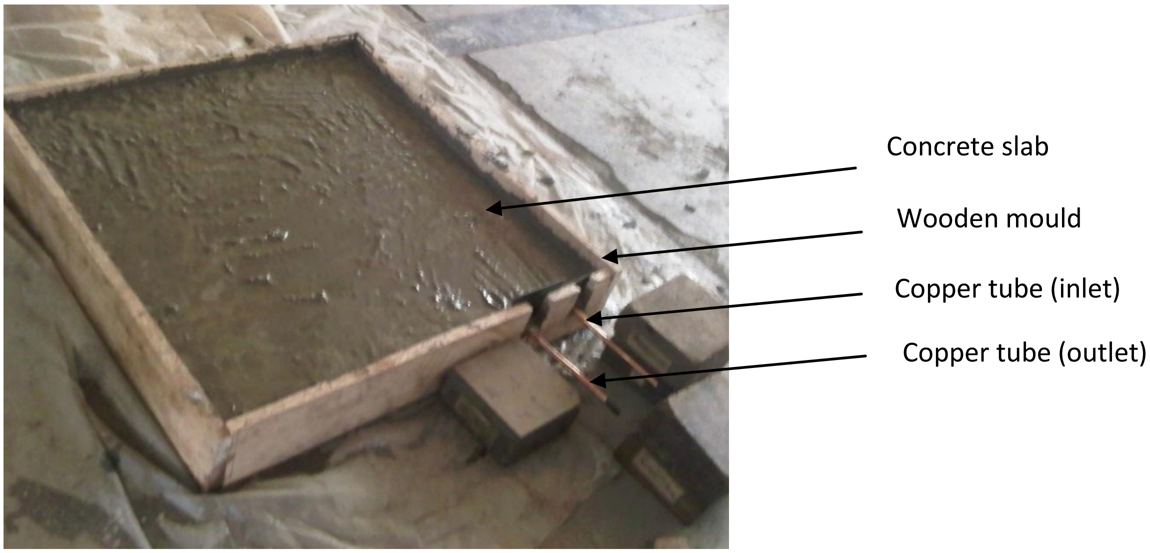

Figure 3.2 Cast slab with inlaid copper tubing before curing

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Figure 3.3 Photograph of brooder floor

Figure 3.4 shows the cross section of the heated floor. The total thickness of the slab was 0.15m and the copper tube was 0.05m below the surface of the floor

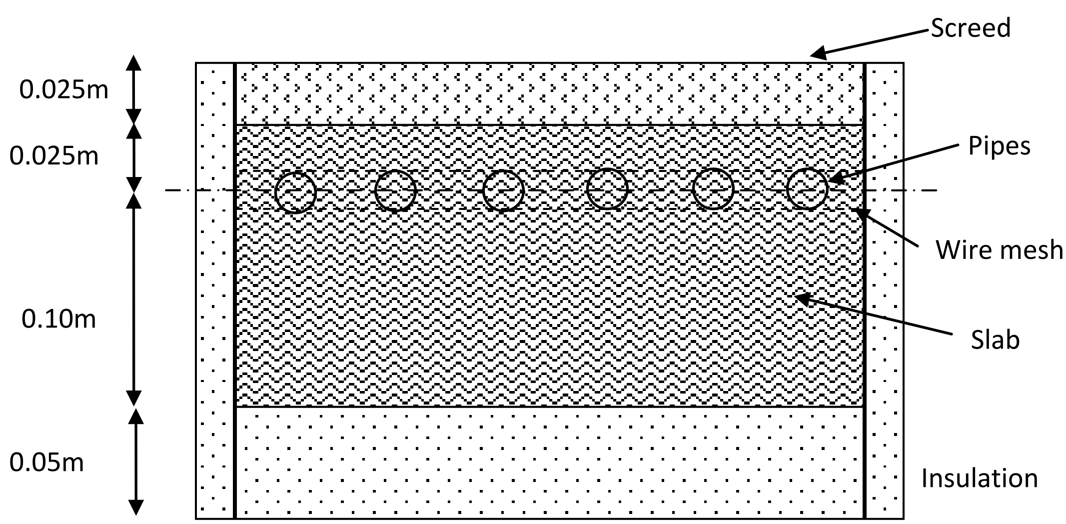

Figure 3.4 Cross section of brooder floor

3.1.2 Hot water system

A plastic water tank of 70 litres capacity was used for hot water storage. An electric heating element and a thermostat were affixed to the tank. Inlet and outlet pipes were fixed on the opposite side of the tank. The tank was then covered using Styrofoam of one inch thickness to reduce loss of heat from the tank. Figure 3.5 shows the water tank. The pump used was a 0.37 kW pump with a maximum flow rate of 40litres/minute and a maximum head of 38meters. A system of valves connected to the pump was used to control the flow rate of water into the slab. Figure 3.6 shows the pump and valves set up.

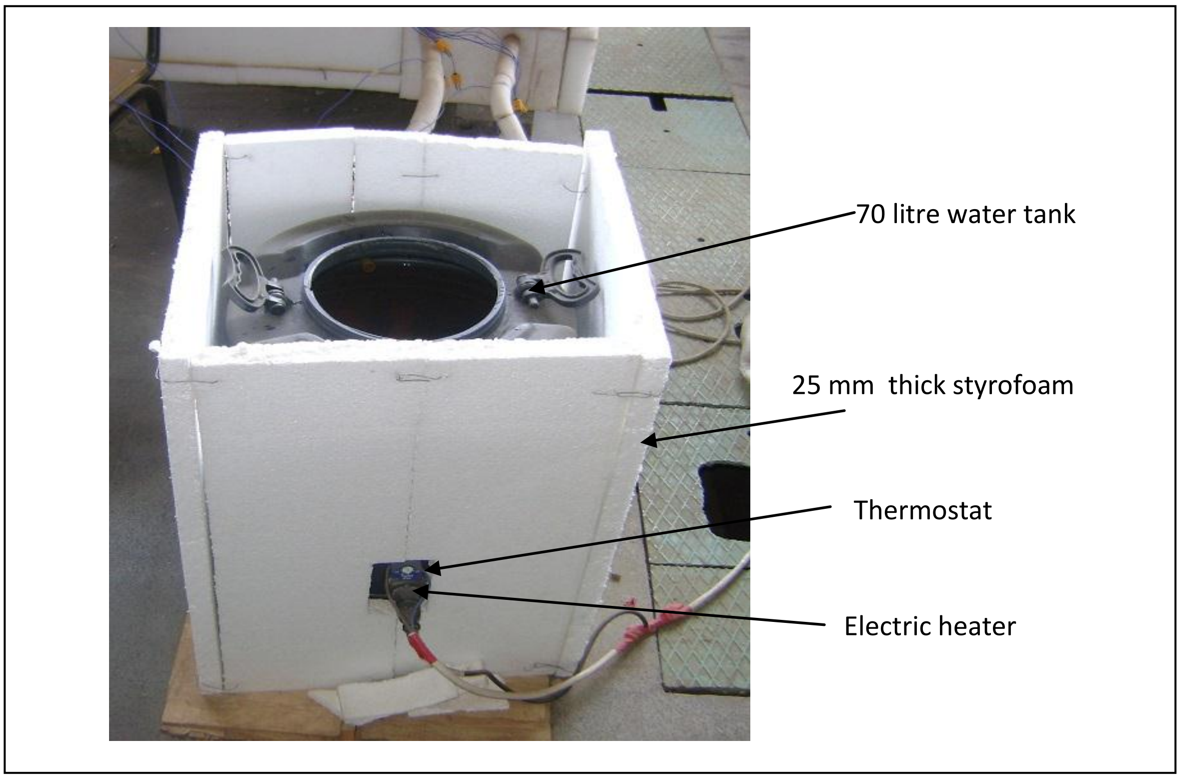

Figure 3.5 Hot water system: water tank with heating element and thermostat

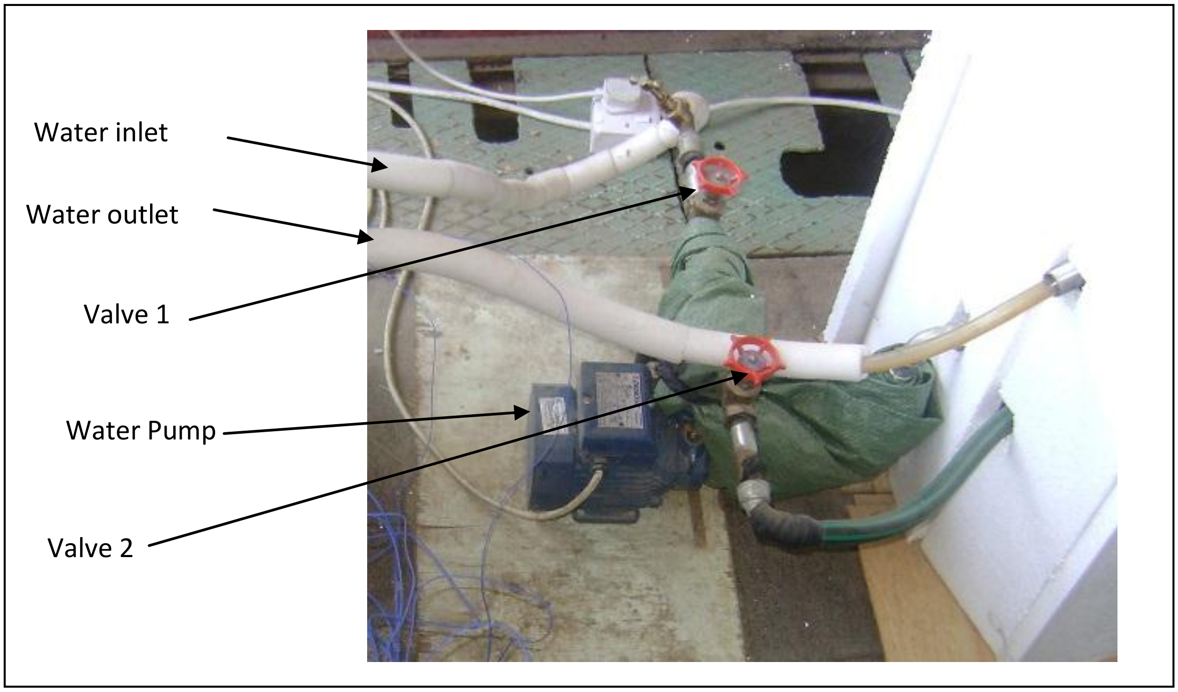

Figure 3.6 Hot water system: pump and valves

3.1.3 Fabrication of the brooder walls

The brooder walls were fabricated using three-ply. Three-ply of 1 meter length and 0.6 meter high were joined together to form the brooder walls. On the outside of the three-ply a 25.4mm thick layer of Styrofoam was attached. Styrofoam was used to reduce heat loss through the sides of the brooder. Figure 3.7 shows the brooder walls.

Figure 3.7 Brooder walls – three ply and styrofoam

A schematic of the layout of the brooder and the heating system is shown in Figure 3.8.

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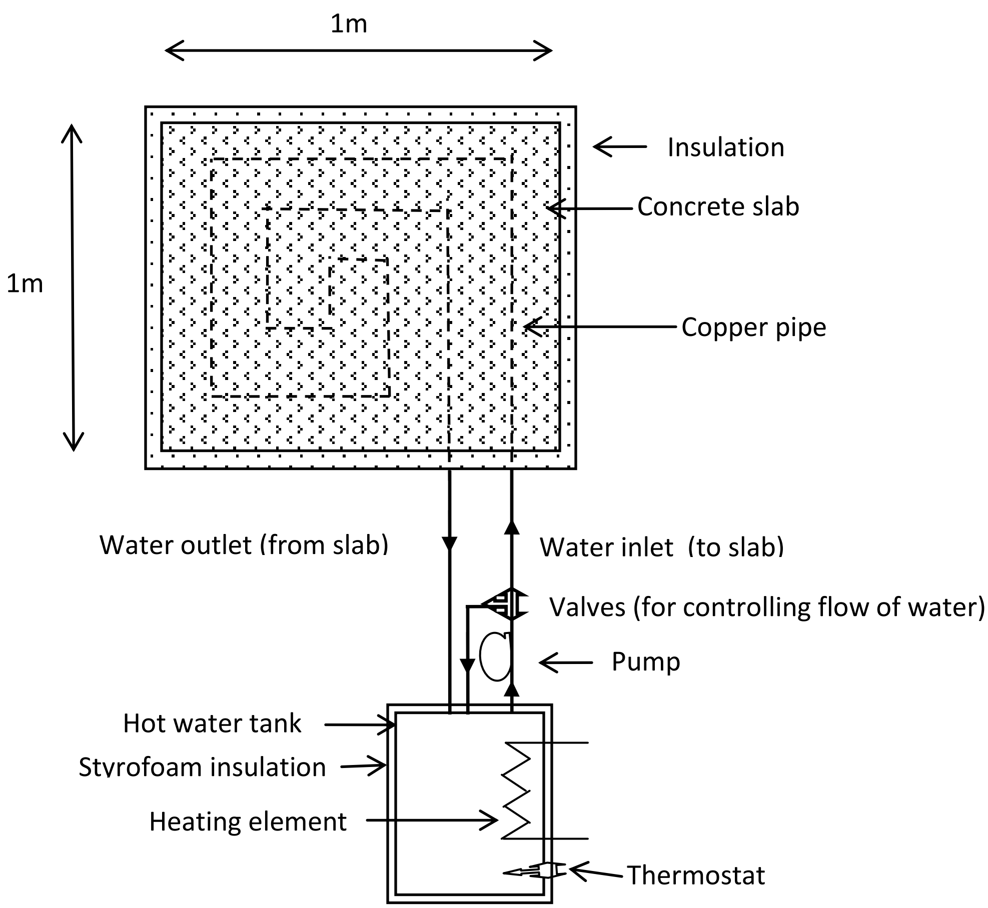

Figure 3.8 Schematic layout of the heated floor brooder

The costs of the brooder were; brooder floor kshs 8,000 (USD 90), brooder guard kshs 1,800 (USD 20), heating system kshs 9,300 (USD 103) giving a total cost of kshs 19,100 (USD 212). The costs were high due to the high costs of the copper tube and polyethylene used to insulate the floor. These costs can be greatly reduced by use of alternative materials such as cross linked polyethylene tubing instead of copper tubing and styrofoam instead of polyethylene to insulate the floor. It's also expected that for larger floor areas larger purchases will result in lower material costs due to economies of scale.

3.2 Tests carried out on the heated floor brooder

Tests were carried out to determine the temperature profiles of the floor heated brooder. In the first series of tests (set-up one) the floor of the brooder was not covered with any bedding material (wood shavings). The top of the brooder was also left open as is the practice in charcoal brooding. In the second series of tests (set-up two) the brooder floor was covered using wood shavings. Due to the insulating qualities of wood shavings only one inch of wood shavings was used instead of four inches which is the common practice. In the third series of tests (set-up three) the brooder with wood shavings was covered to varying degrees using empty sisal bags. Sisal bags were chosen because they are not air tight. In the fourth series of tests the temperature rise of brooder was measured and finally the rate of cooling of the brooder was determined.

At the start of all the experiments the pump was primed and the temperature of water was set using the thermostat. The flow rate of water used for all the experiments was 0.05litres/second, this was set using the valves shown in Figure 3.6 and Figure 3.8. Temperature measurements were done using a digital temperature recorder. Figure 3.9 is a photo of the digital temperature recorder used. The digital thermometer used could record up to twelve temperature readings simultaneously. The temperature sensors used were type K thermocouples. To measure the slab surface temperature the sensors were affixed to the surface of the slab and held in place using masking tape. To measure the temperature above the surface of the slab or wood shavings the temperature sensors was held in place using plastic tubes drilled with holes at one inch intervals. This is shown in Figure 3.10 and Figure 3.11. The temperature sensors were named T1 to T12, temperature sensors T1 to T9 were used to measure the temperature in the brooder. Temperature sensors T10 and T11 were used to measure the water inlet and outlet temperatures. Temperature sensor T12 was used to measure the ambient temperature.

Figure 3.9 Digital thermometer and logger

3.2.1 Set-up 1: The Brooder

This test was done to determine the effect of floor heating on the brooder temperature. The temperature of the brooder was determined at the surface of the floor and at 50mm height. The temperature at the surface of the floor is important because the chicks will sense the floor temperature at their feet. The temperature at 50mm height is important because it is the height of day old chicks. The floor was heated using water at temperatures between 66^{o}C and 36^{o}C. The aim of this experiment was to establish the relationship between water input temperature and the brooder temperature.

To determine the temperature profiles the floor surface was divided into four parts. At the centre of each a temperature sensor was attached. Figure 3.10 shows the points of attachment of the four sensors named T1, T2, T3 and T4. Above each of these points thermocouplesT5 to T8 were suspended at a height of 50mm above the slab. Temperature sensors T5, T6, T7, and T8 were suspended directly above T1, T2, T3 and T4 respectively. Temperature sensor T9 was suspended at a height of 50mm above the floor at the center of the floor. Figure 3.11 shows the sensors held in place at a height of 5cm above the slab. Temperature sensors T10 and T11 were fixed to the water inlet and water outlet pipes. Temperature sensor T12 was suspended outside of the brooder to measure the ambient temperature.

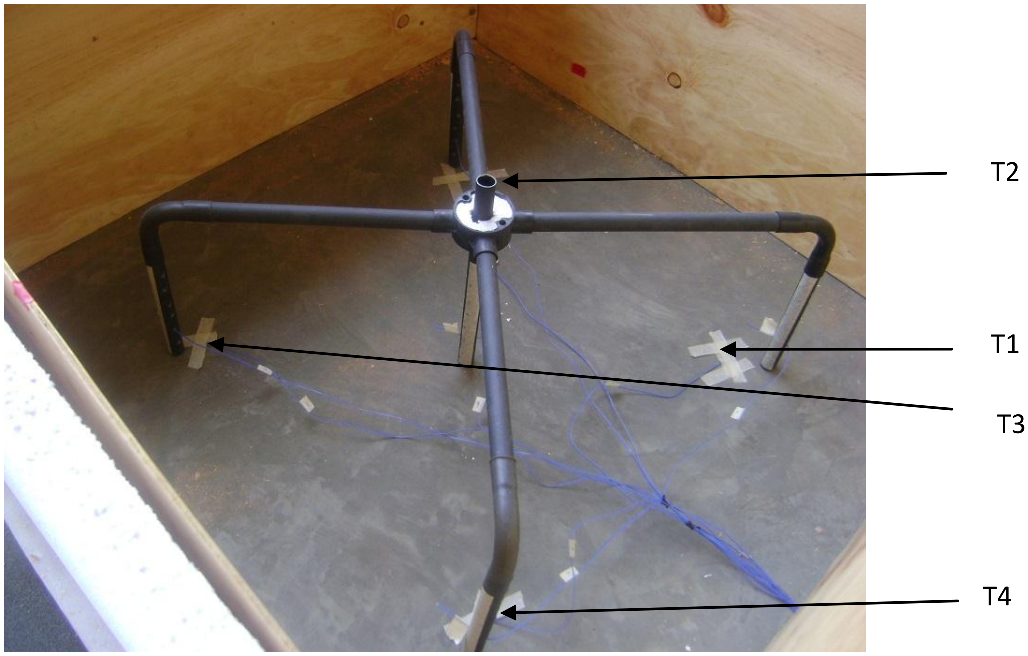

Figure 3.10 Point of attachment of temperature sensors on the floor

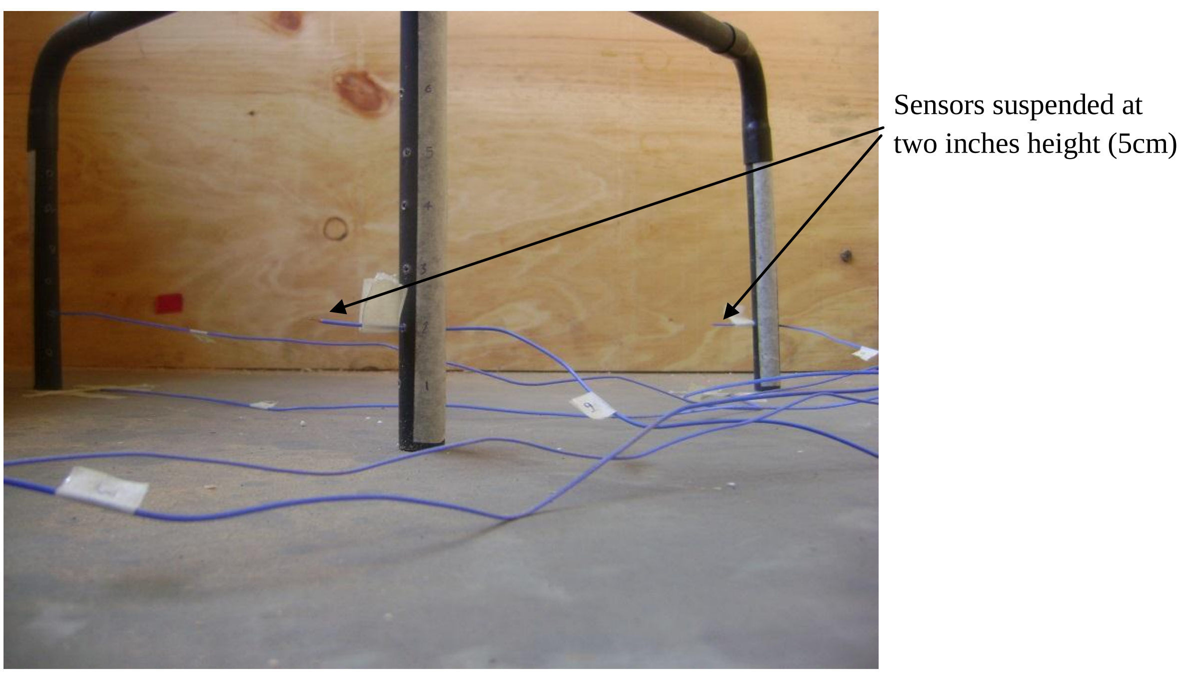

Figure 3.11 Temperature sensors suspended at chick height, two inches (50mm) above the floor

The slab was heated using water at temperatures of 66^{o}C, 53^{o}C, 47^{o}C and 36^{o}C. At each of these temperature settings temperature readings from each of the twelve sensors were recorded using the data logger. Temperature readings were taken over a period of twenty four hours. The average slab surface temperature was determined from sensors T1, T2, T3 and T4. The temperature at chick height was the average of T5, T6, T7, T8 and T9.

Hourly readings of temperature versus time were plotted. The chart showed the floor surface temperature, temperature at 50mm height and the ambient temperature as measured during the experiment.

3.2.2 Set up 2: Brooder with 25.4mm (one inch) wood shavings

This test was done to determine effect wood shavings have on the temperature of the brooder when heated using water at temperatures between 66^{o}C and 36^{o}C. As stated in chapter two, wood shavings are used to absorb chicken droppings and to insulate the floor. In this case however the useful property is only the absorption of water and droppings and to provide a soft surface which prevents injury to the chick's feet. The insulating effect should be minimized hence only one inch of wood shavings was used instead of four inches.

The four temperature sensors on the slab surface were kept in the same position as the previous experiment. The slab was then covered using a one inch layer of wood shavings. Temperature sensors T5, T6, T7 and T8 were placed directly above T1, T2, T3 and T4 respectively. They were placed an inch above the slab surface at the same level as the surface of the wood shavings. Sensor 9 was fixed 5 cm above the surface of the wood chips at the centre of the brooder. Sensors 10 and 11 were used to record the water inlet temperature and water outlet temperatures. Sensor 12 was used to record the ambient temperature. Figure 3.12 shows the position of the sensors T6 and T9.

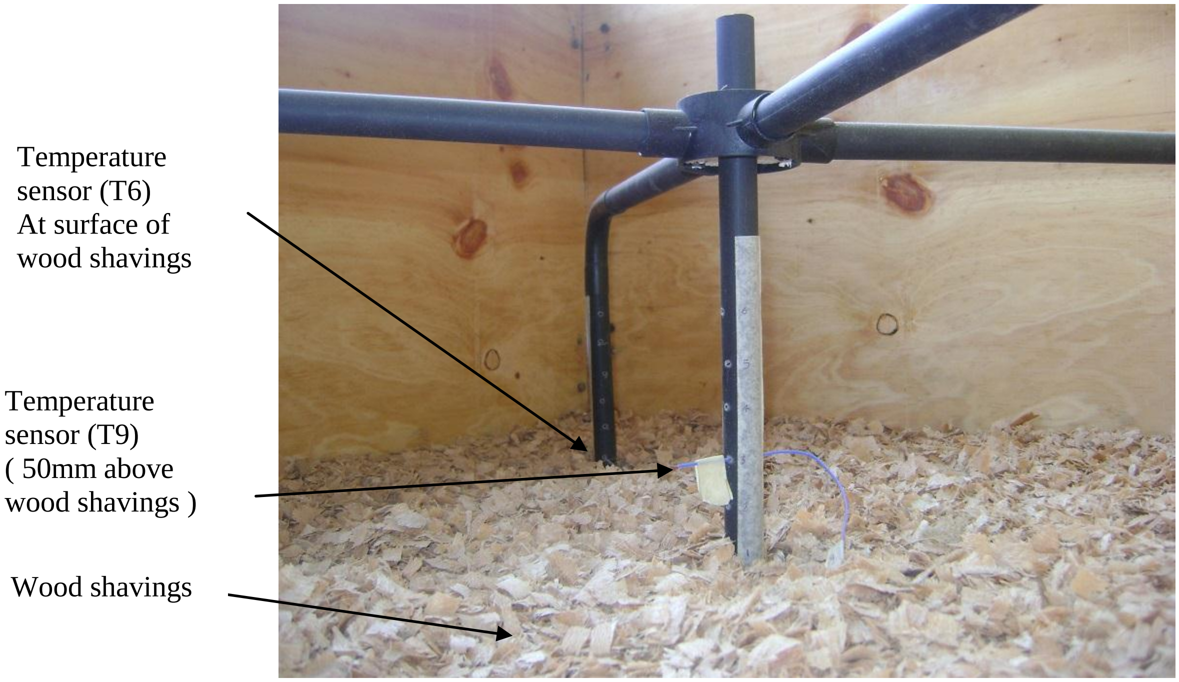

Figure 3.12 Temperature sensors suspended at chick height, two inches (50mm) above wood shavings

The slab was heated using water at 66^{o}C, 53^{o}C, 42^{o}C and 36^{o}C. At each of these temperature settings temperature readings from all the sensors were recorded using the data logger. Temperature readings were taken over a period of twenty four hours. The slab surface temperature was determined as the average of the sensors T1, T2, T3 and T4. The temperature at the surface of the wood shavings was determined by averaging the temperature readings from sensors T5, T6, T7 and T8. The temperature at chick height was measured using sensor T9.

Hourly temperature readings showing the floor surface temperature, temperature at the surface of the wood shavings, temperature 50mm above the wood shavings and ambient temperature were plotted against time.

3.2.3 Brooder set up 3: Brooder covered using sisal bags

This test was done to determine effect covering had on the temperature inside the brooder. The experiment set up used was the same as brooder set-up two the only difference was the empty sisal bags used to cover the top of the brooder. The brooder was heated using water at 61^{o}C and a flow rate of 0.05litres/s. Four tests were carried out first the brooder top fully open this was used as the base case, second the brooder top covered using sisal bags with 10% of the top open, third the brooder top covered leaving only 5% of the top open and fourth the brooder top fully covered using the sisal bags. Figure 3.13 shows the brooder covered using empty sisal bags with 10% opening. Temperature readings were taken from 4:00pm in the evening to 10:00am the next morning.

The hourly temperature readings were then plotted on graphs of temperature versus time. The data was analysed further and graphs showing the temperature at the surface of the wood chips and temperature at chick height at different ambient temperatures were generated.

Figure 3.13 Brooder covered using sisal sacks with a 10 centimeter spacing (10% opening)

3.2.4 Heating of the brooder

Before chicks are placed in a brooder it should be heated to between 32°C and 34°C. It is therefore important to know how long it takes to heat the brooder to the required temperature. This experiment was done to determine how long it took to heat the brooder. Using set-up three the brooder was covered leaving only 5% of the top open. The brooder was then heated using water at 49°C.

3.2.5 Cooling of the brooder

One of the advantages of using a heated floor brooder is the application of solar energy to heat the brooder. However solar energy has the disadvantage of being available only during the day. It is therefore important to know how long the floor can retain heat when no heating is taking place. The amount of energy stored is a function of the mass and specific heat capacity of the floor. This experiment was done to find out how long the brooder took to cool and the rate of cooling. Using set-up three with the brooder covered leaving only 5% of the top open the brooder was heated until it attained a steady temperature of 56°C. The pump was then switched off at 4:00pm and readings taken until 10:00am the next morning.

Chapter 4

RESULTS AND DISCUSSIONS

4.0 Introduction

In this chapter the results of the experiments outlined in Chapter Three are presented. In the first experimental set up, termed set-up one the brooder (Fig. 3.10) was heated using water set at four different temperatures. The purpose was to determine the temperatures attainable in the brooder. In set-up two, the brooder floor was covered by one inch wood shavings and the temperature measurements as in setup-1 were repeated. As wood shavings are normally used in chick brooding, they are likely to have an effect on the temperatures within the brooder. Set-up three involved covering the brooder to different degrees to mitigate the effect of ambient conditions. The resulting temperature levels were measured and comparison made. The heating and cooling rates depended on the floor heat capacity. Heating and cooling curves were generated from measurements taken when the floor was heated and when the floor was left to cool after heating. In all set ups a constant water flow rate of 0.05l/s was used.

For each experiment set up graphs were generated showing how the floor temperature and the temperature at 50mm height varied with time and ambient temperature.

4.1 Set-up 1: The Brooder

Hot water set at 66^{o}C was passed through the brooder floor as explained in Section 3.2.1 and temperatures 1 to 12 were recorded at intervals of 1 second by a data logger for a period of 18 hours. The recordings were made after the floor had attained steady temperature. Thermocouples T1 – T4 measured the floor temperature. The floor temperatures as recorded are shown in Figure 4.1. It was observed that the floor temperature was not even. There were temperature differences between the four sensors, indeed the largest temperature difference was 3.2^{o}C. Some thermocouples were closer to the pipes which could result in higher temperature readings.

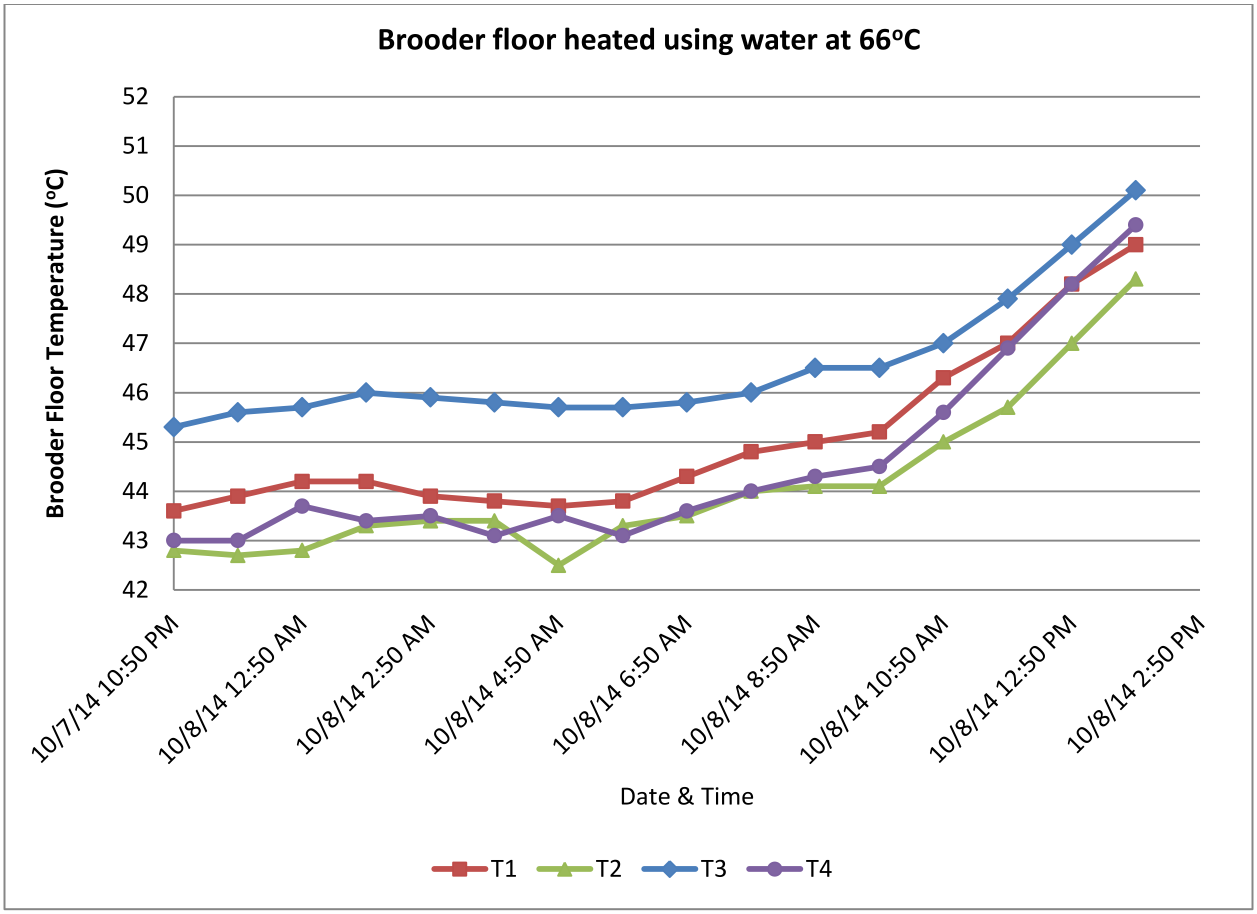

Figure 4.1 Floor temperature when heated using water at 66°C

Figure 4.2 shows the position of the thermocouples on the surface of the floor. Also indicated are the average day and night temperatures as measured by thermocouples. For this study the temperatures were averaged to obtain a one floor temperature. Uneven heating is more pronounced in parallel arrangements.

The average floor temperature was found to be 47.9°C during the day (10.00am and 4.00pm) and 44.2°C during the night (4.00pm and 10:00am). These floor temperatures were higher than the recommended brooding temperature. To reduce the temperature a floor covering material such as chicken wire or slats may be used for the chicks to step on.

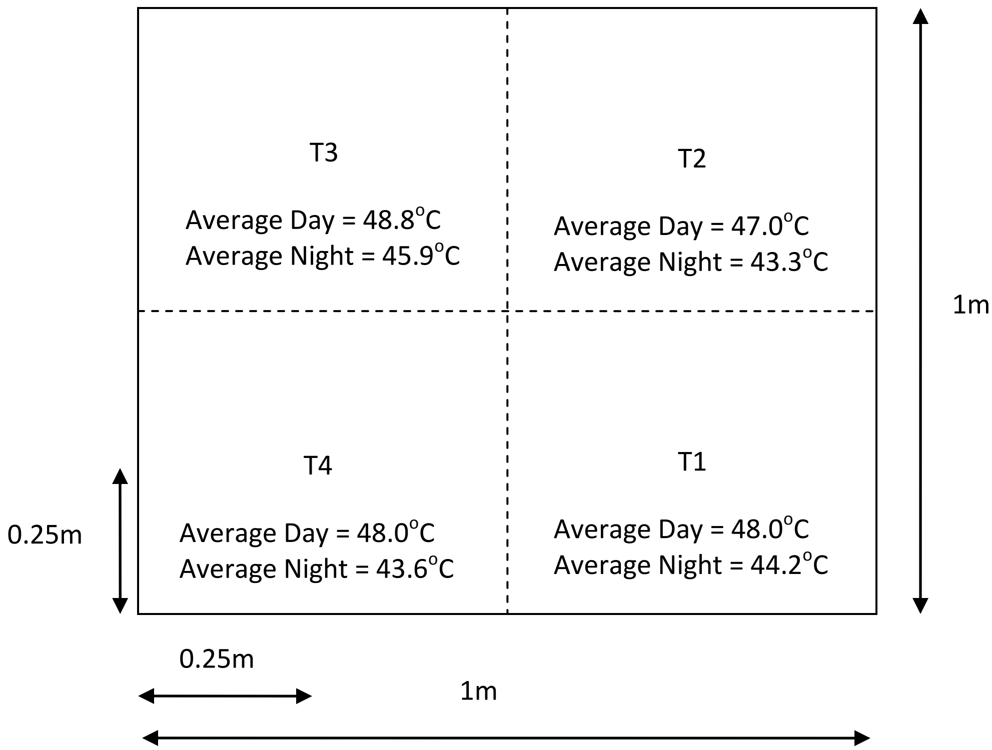

Figure 4.2 Position of thermocouples T1 to T4 on the floor surface

The temperature of air, 50mm above the floor was recorded using thermocouples vertically above T1 to T4, these were referred to as T5 to T8 respectively. Thermocouple T9 measured the temperature at the center of the brooder. Figure 4.3 shows the temperatures as recorded. During the day (10.00am and 4.00pm) the average temperature was found to be 29.2^{o}C, during the night (4.00pm and 10:00am) the temperature was 24.4^{o}C. The day and night temperatures were lower than the required temperatures for brooding. The temperature at the floor surface was too high for brooding whereas the temperature at 50mm height was too low. In order to reduce the temperature at the chicks feet slats may be placed on the floor. These will allow heat to pass through. To experience a higher temperature at the chicks body the chicks may lie down to warm especially at night.

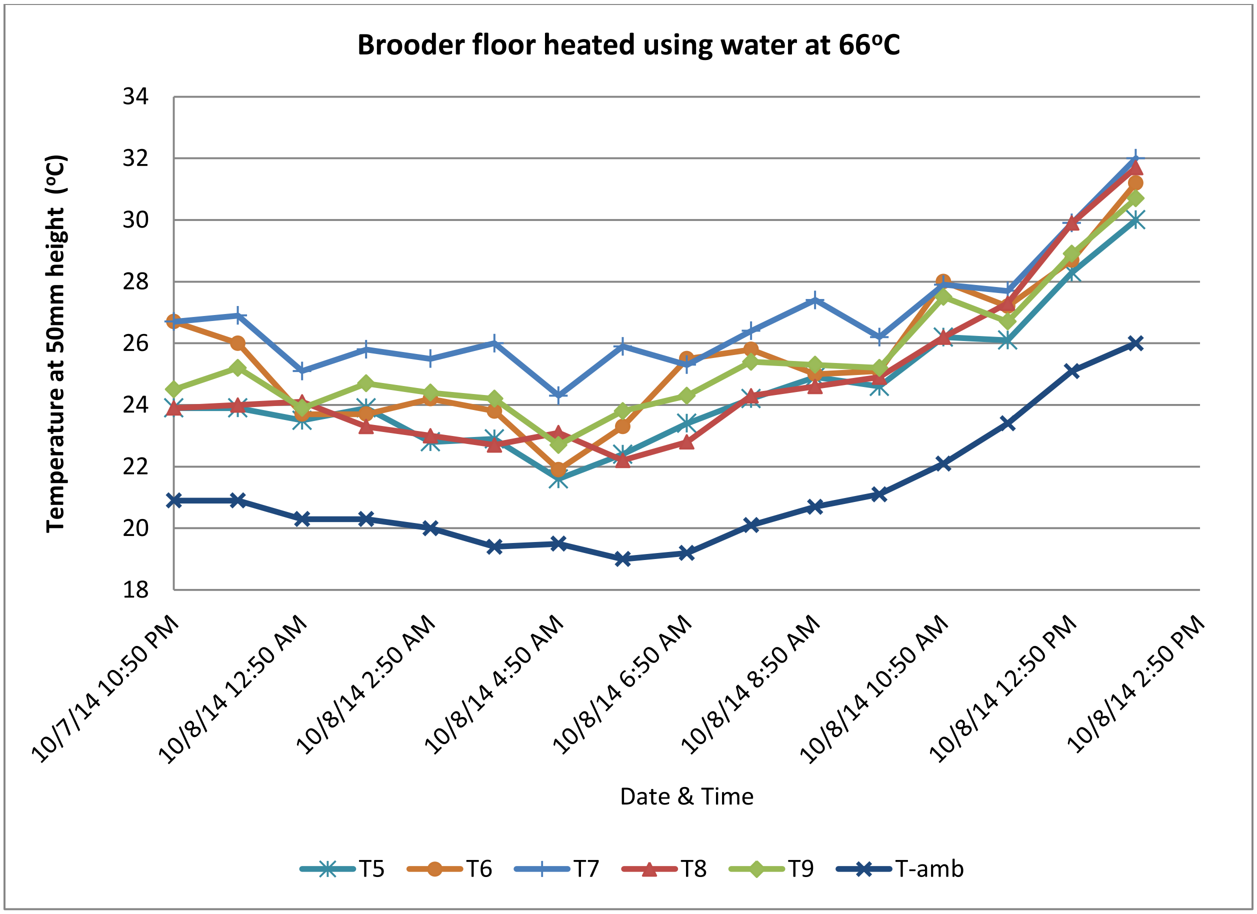

Figure 4.3 Temperature at 50mm height when heated using water at 66°C

Thermocouples T10 and T11 measured the brooder water inlet and outlet temperatures respectively. Heat loss from the slab was low this resulted in a small average temperature drop of 1.2°C.

T12 measured the ambient temperature of the room it changed from an average of 24.7°C during the day to an average of 20.1°C during the night. As shown in Figure 4.4 the temperatures of the floor and the temperature at 50mm height closely followed the variation of the ambient temperature.

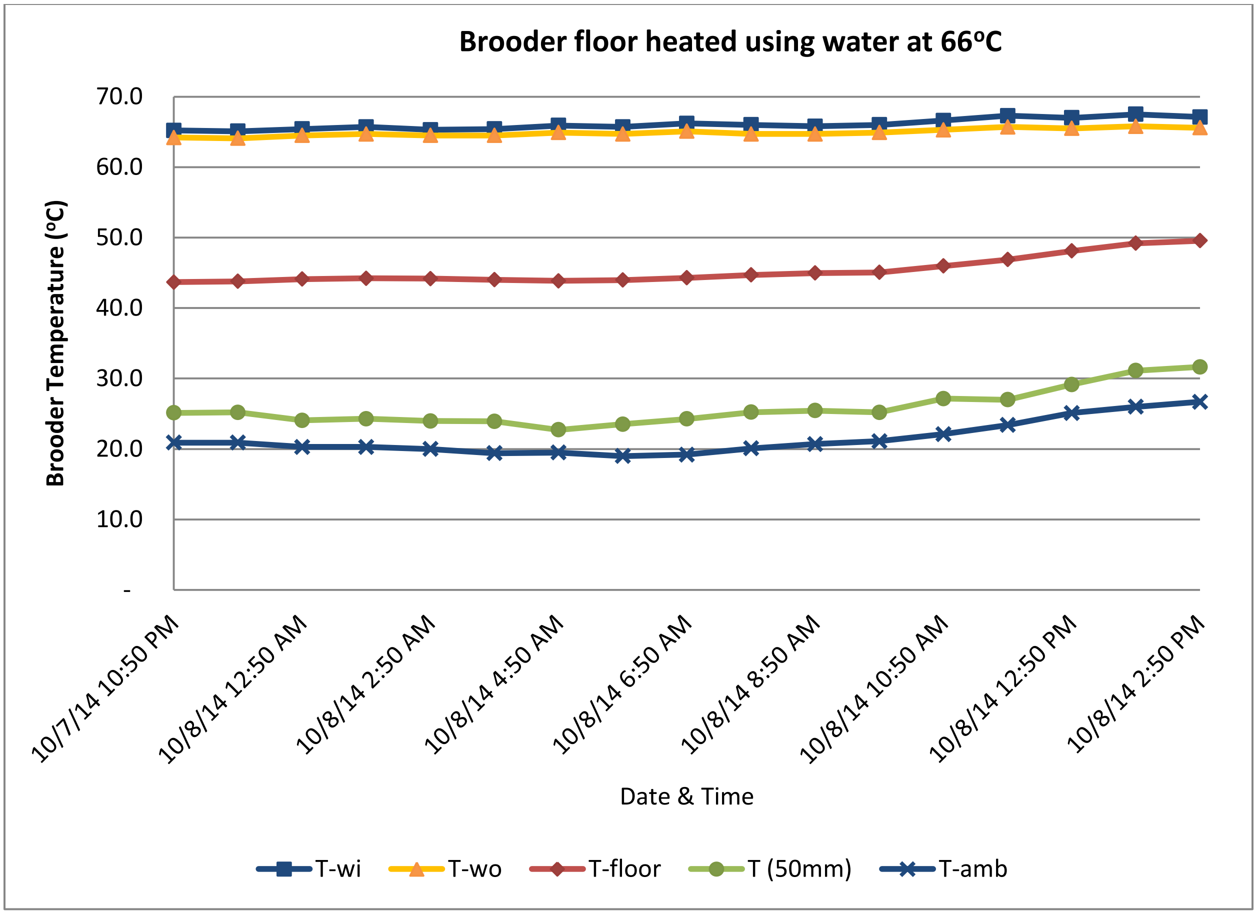

Figure 4.4 Temperature profiles in brooder heated using water at 66°C

The floor temperatures discussed above 47.9°C during the day and 44.2°C during the night were higher than the recommended brooding temperatures of 32°C to 34°C. For this reason the water inlet temperature was reduced gradually in order to determine the water temperature that would result in the required floor temperature.

The water temperature was reduced to 53°C and the experiment repeated. Figure 4.5 shows the temperatures achieved in the brooder when heated using water at 53°C.

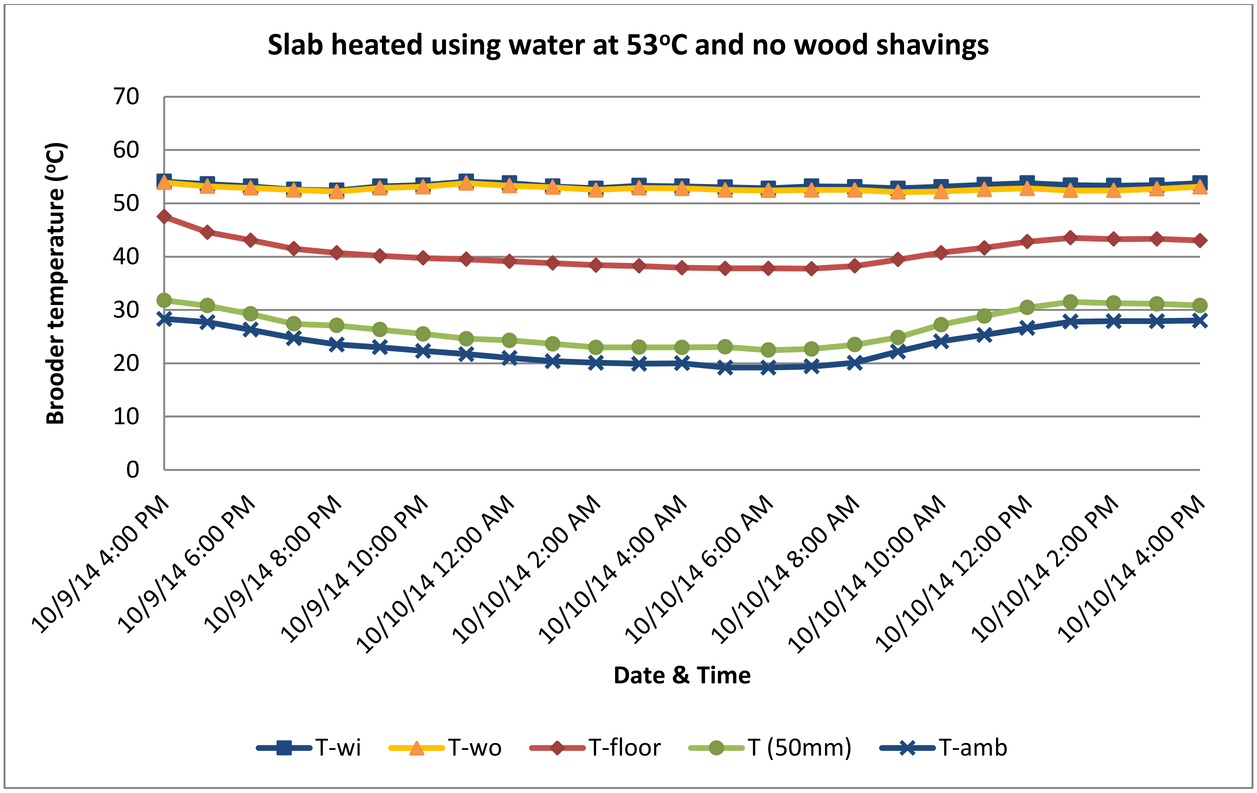

Figure 4.5 Temperature profiles in brooder heated using water at 53°C

The average floor temperature decreased from 47.9°C during the day and 44.2°C during the night to 42.6°C during the day and 40.0°C during the night. This showed that the water inlet temperature had a significant influence on the floor surface temperature. These temperatures were still higher than the recommended brooding temperature.

The average temperature at 50mm height was 30.0°C during the day and 25.3°C during the night. This was higher than 29.2°C during the day and 24.4°C at night achieved in the previous experiment. The higher temperature at 50mm height was due to the higher ambient temperature. The average ambient temperature in the previous experiment was 24.7°C during the day and 20.1°C during the night compared to 26.8°C during the day and 22.2°C in this experiment. In the current experiment the temperature at 50mm height was greatly impacted by the ambient temperature, water inlet temperature had a lessor effect on the temperature.

The temperature of the heating water was reduced to 42^{o}C. Temperature readings were recorded and are shown in Figure 4.6. The average floor temperature was found to be 37.9^{o}C during the day and 33.4^{o}C during the night compared to 42.6^{o}C during the day and 40.0^{o}C during the night. This further confirmed that the floor temperature was mainly determined by the water inlet temperature.

The temperature at 50mm height was 30.3^{o}C during the day and 24.5^{o}C during the night. This was close to 30.2^{o}C during the day and 25.3^{o}C during the night achieved when the brooder was heated using water at 53^{o}C. The ambient temperatures were close 26.8^{o}C during the day and 22.2^{o}C at night for 53^{o}C heating water and 28.1^{o}C and 22.6^{o}C for heating water of 42^{o}C. This further confirmed that water inlet temperature has little impact on the temperature at 50mm height.

Whereas the day floor temperature of 37.9^{o}C was 3^{o}C higher than the maximum recommended temperature the night floor temperature of 33.4^{o}C was suitable for brooding day old chicks without further modification. By regulating the flow of water the required brooding temperature could be attained during the day. However, the temperature at 50mm height was lower than the required temperature.

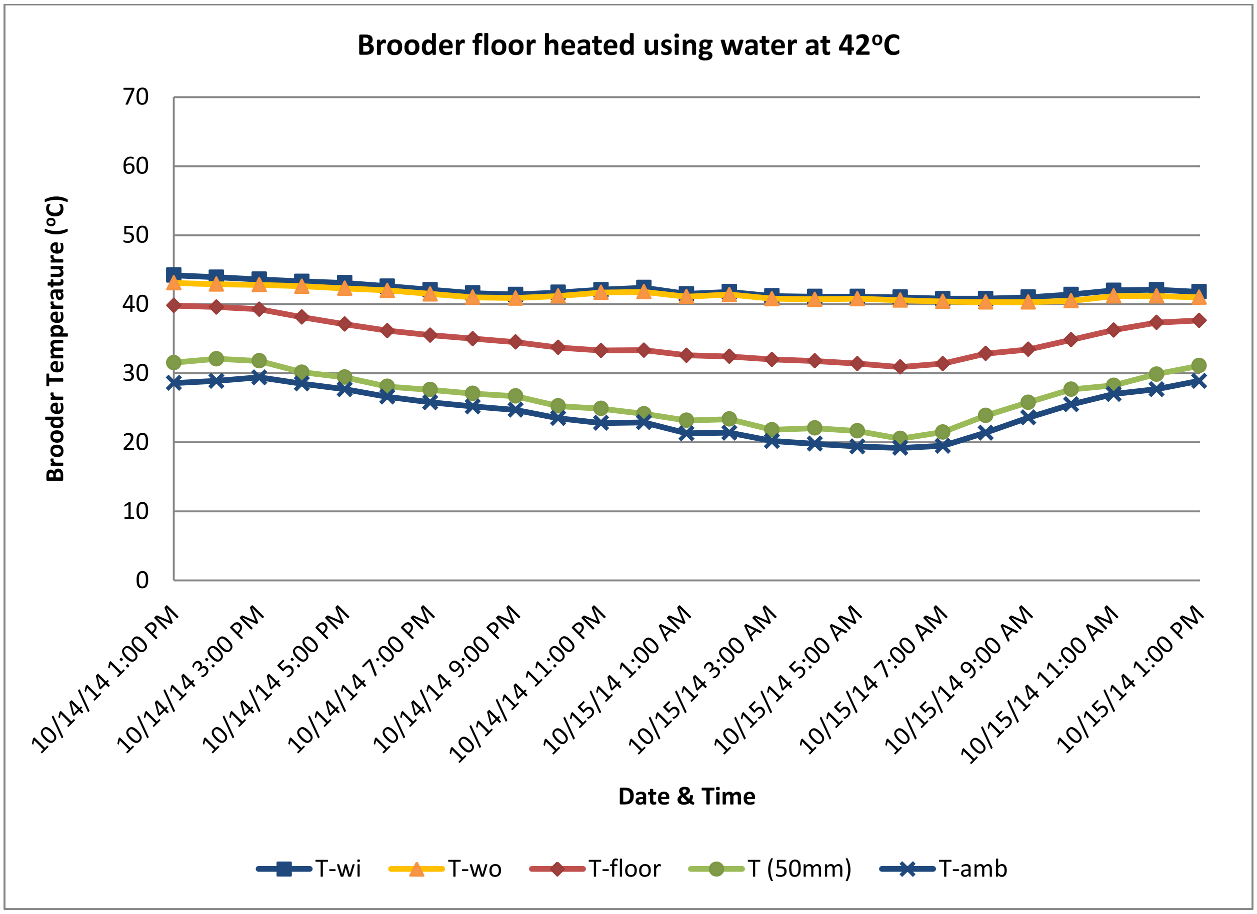

Figure 4.6 Temperature profiles in brooder heated using water at 42^{o}C

The water temperature was reduced further to 36°C and temperature measurements taken again. The temperatures attained are shown in Figure 4.7.

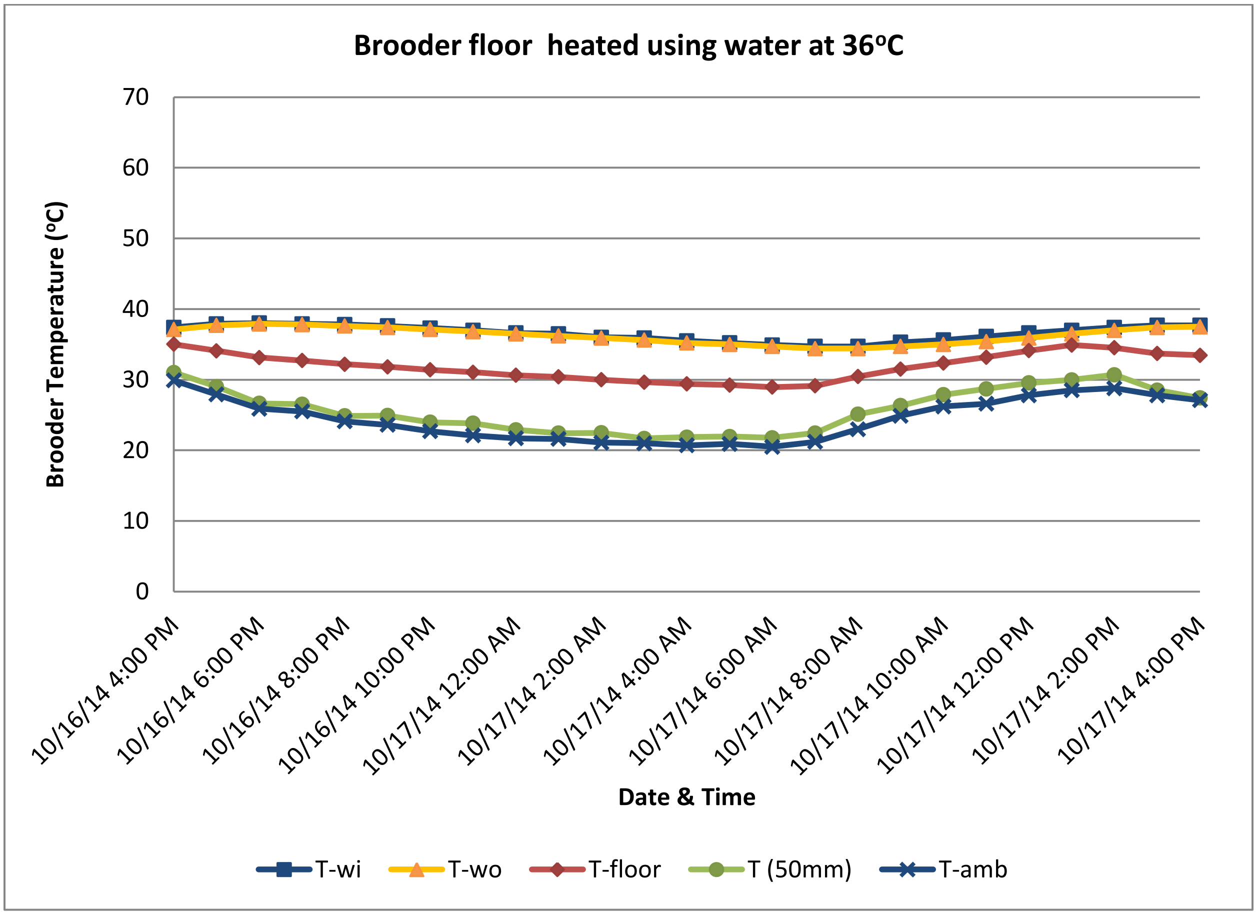

Figure 4.7 Temperature profiles in brooder heated using water at 36°C

The floor temperature decreased from 37.9°C during the day and 33.4°C during the night when heated using water at 42°C to 33.7°C during the day and 30.9°C during the night when heated using water at 36°C. Whereas the daytime temperatures were high enough for brooding day old chicks the night temperatures were not high enough.

In this experiment the average floor temperature was found to be 29.0°C during the day and 24.0°C during the night compared to 30.3°C during the day and 24.5°C during the night when heated using 42°C water.

It was observed that the brooder floor temperature was a function of ambient temperature and water inlet temperature. In order to illustrate the impact of ambient temperature and water inlet temperature on the brooder floor temperature, graphs showing floor temperature attained at each ambient temperature were plotted. This was done for each of the water inlet temperatures of 36^{o}C, 42^{o}C, 53^{o}C and 63^{o}C. The result of the analysis is shown in Figure 4.8. From the graphs equations were derived defining the relationship between brooder floor surface temperature and ambient temperature for each water inlet temperature. It was observed that as ambient temperature increased the brooder floor temperature increased. A one degree rise in ambient temperature resulted in a 0.63 to 0.77 degree rise in the brooder floor temperature. From the chart it was evident that as inlet water temperature increased the brooder floor temperature increased. A one degree increase in water inlet temperature resulted in a 0.5 to 0.55 degree increase in floor temperature.

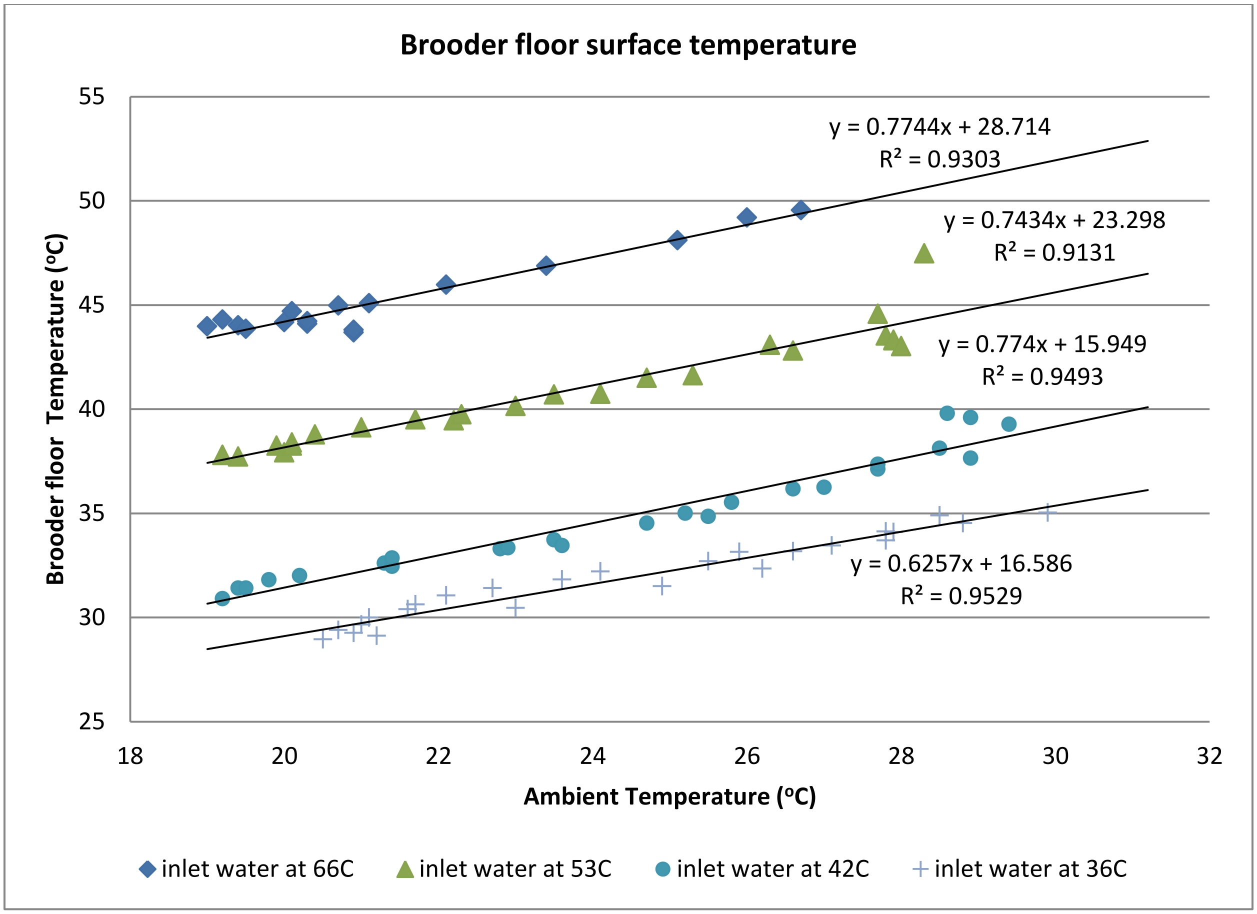

Figure 4.8 Summary of temperature profiles at floor surface

The other useful parameter measured was temperature at 50mm height. In order to show the impact of ambient temperature and water inlet temperature on the temperature at 50mm height graphs showing temperature achieved at each ambient temperature were generated. Like in the previous chart this was done for water inlet temperatures of 36^{o}C, 42^{o}C 53^{o}C and 63^{o}C. The results of the analysis were plotted in Figure 4.9. From the graph it was noted that higher ambient temperature resulted in higher temperature at 50mm height. A rise of 1^{o}C in ambient temperature resulted in 1.01 and 1.07 increase in temperature. Higher inlet water temperature resulted in higher temperature at 50mm height above the floor surface. A change of 1^{o}C in water inlet temperature resulted in a marginal increase of 0.1 to 0.12 degrees.

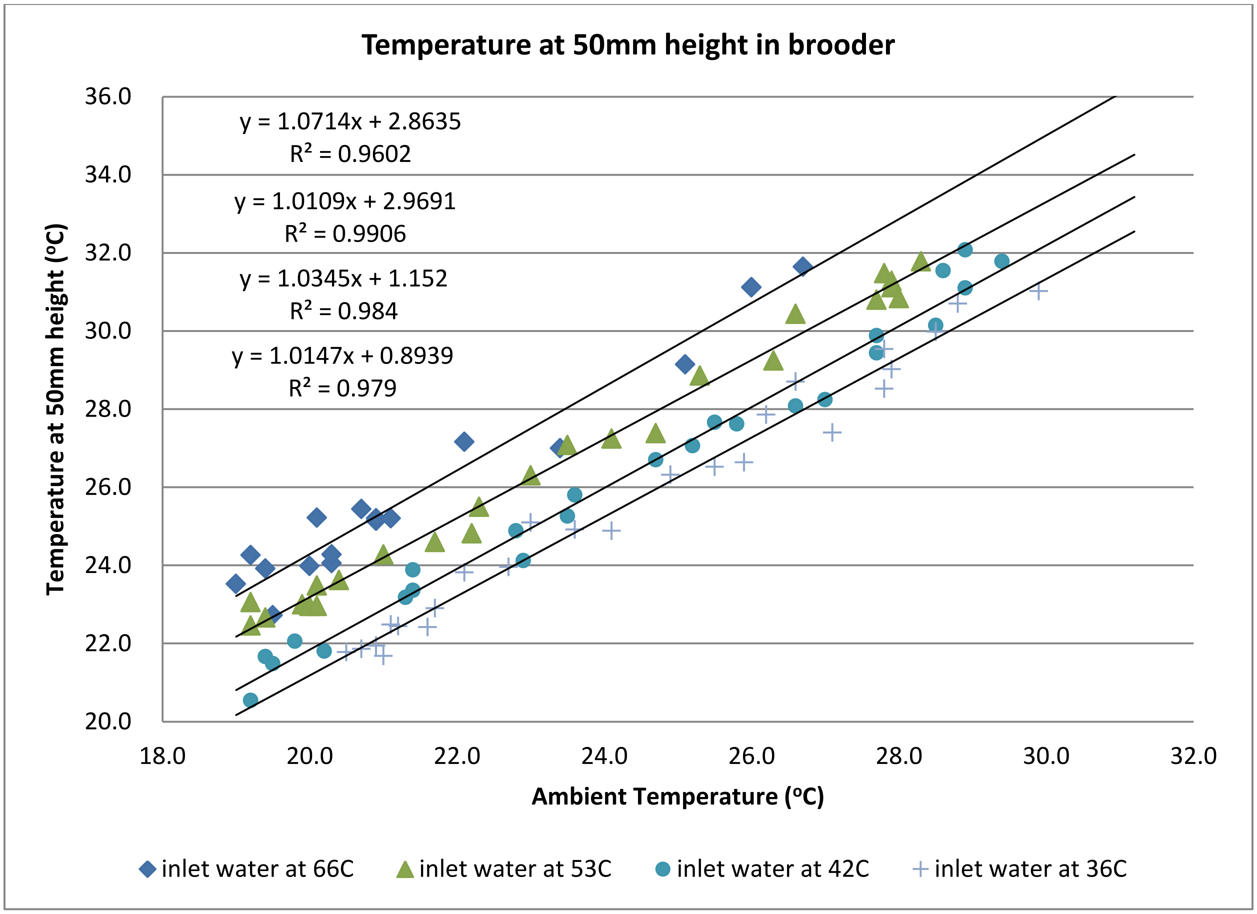

Figure 4.9 Summary of temperature profiles at 50mm height

4.2 Set up 2: Brooder with 25.4mm (one inch) wood shavings

In this section the same experiment set up used in set up 1 was used, however one inch of wood shavings were placed on the floor. Wood shavings serve three functions in brooders; first they are used to absorb water and droppings in the brooder, second they provide a soft surface which prevents injury to the feet of the young birds and third they insulate the floors. In this case however heat is provided from the floor therefore the insulating effect of the wood shavings was minimized by reducing the thickness of wood shavings from the commonly used four inches to one inch. The same temperature settings used in brooder set up 1 were used in the tests.

Hot water at 66^{o}C was passed through the brooder floor as explained in Section 3.2.2 and twelve temperature readings were taken using a data logger for a period of 24 hours. Thermocouples T1 to T4 measured the temperature at the surface of the floor. Thermocouples T5 to T8 measured the temperature at the surface of the wood shavings. Thermocouple T9 measured the temperature in the centre of the brooder at 50mm height above the surface of the wood shavings.

The temperatures recorded at the surface of the wood shavings are shown in Figure 4.10. The temperatures recorded at the sensors were not uniform therefore an average value was obtained to represent the wood surface temperature. The average temperature at the wood shavings surface was 32.1^{o}C during the day and 27.1^{o}C at night. The day temperature of the wood shavings was high enough for brooding. To achieve a higher temperature the thickness of the wood shavings may be reduced. The night temperature was not high enough for brooding day old chicks. Wood shavings are good insulators therefore the thickness of the wood shavings should be reduced to achieve the desired brooding temperature.

The average temperature at 50mm height was 25.2^{o}C during the day and 20.3^{o}C at night compared to 29.2^{o}C during the day and 24.4^{o}C at night in set-up 1. The temperatures in set-up 2 were lower due to the insulating effect of the wood shavings.

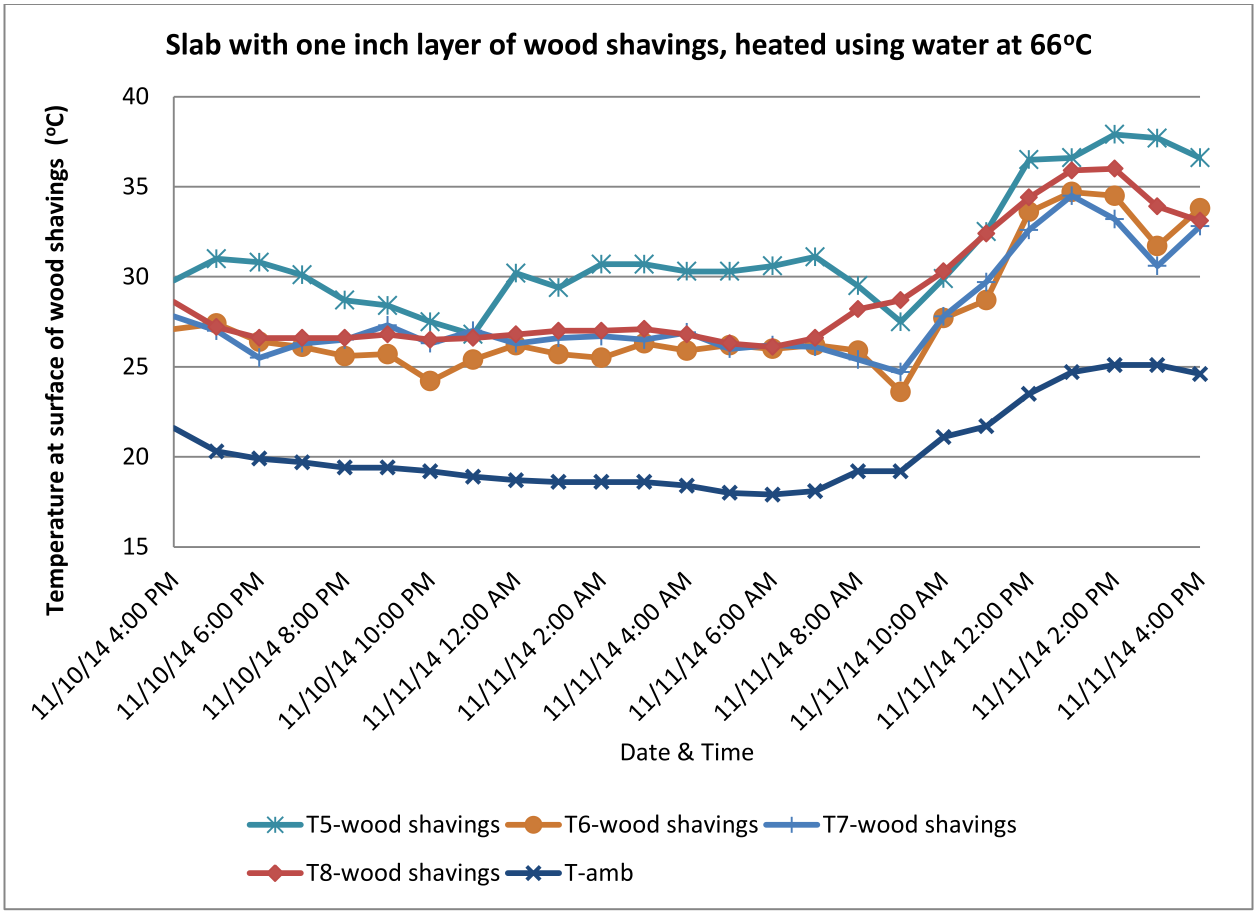

Figure 4.10 Temperature at wood shavings surface and ambient temperature when heated using water at 66°C

The floor surface temperatures were recorded and the results shown in Figure 4.11. The average floor temperature in set-up 2 was 57.5°C during the day and 56.5°C at night compared to 47.9°C during the day and 44.2°C at night. Whereas ambient temperature had an impact on the floor temperature in set up 1 it had no effect in set-up 2. Therefore the average floor temperature in set up 2 was much higher than set up 1.

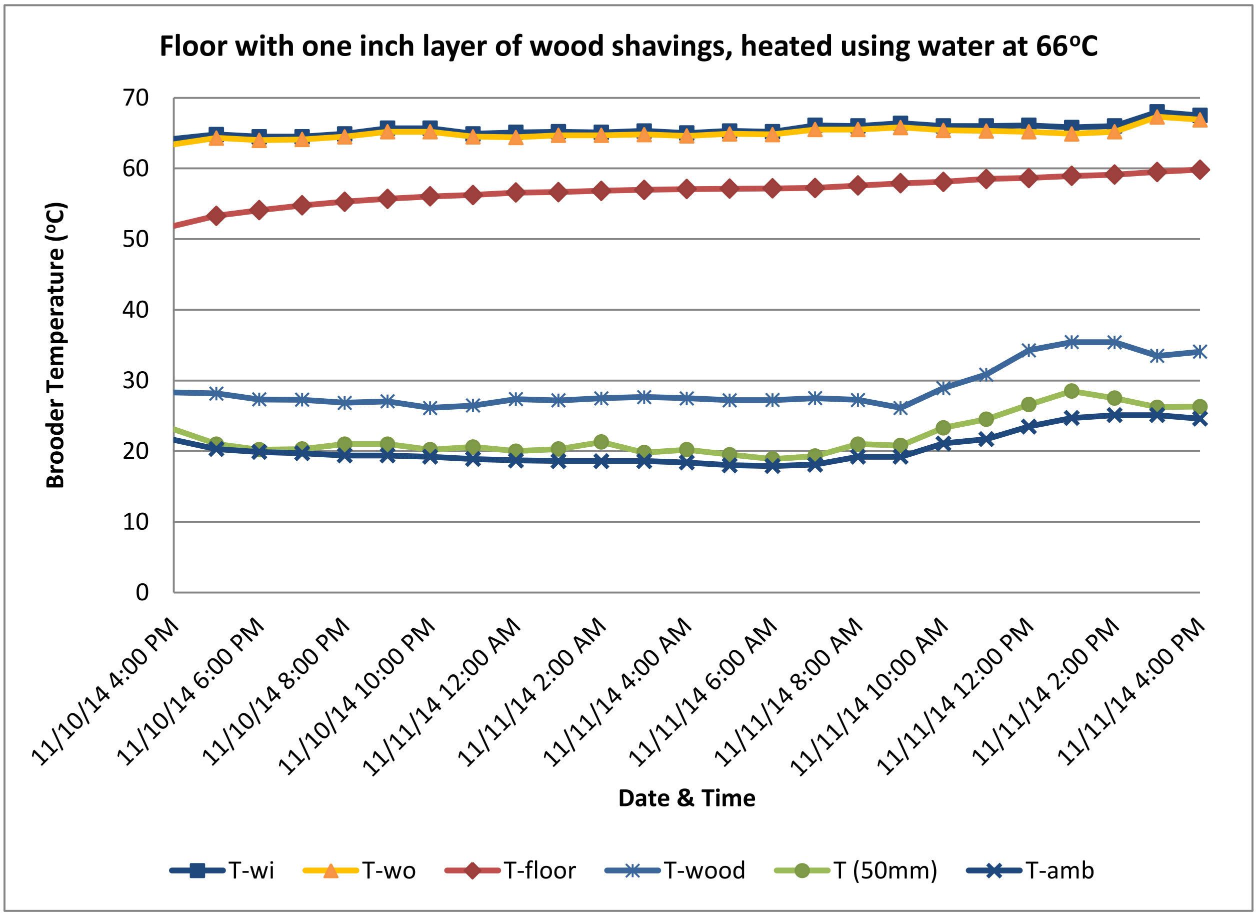

Figure 4.11 Temperature profiles for brooder with wood shavings, heated using water at 66^{o}C

In the second test the water temperature was lowered to 53^{o}. Temperature measurements were taken and the results presented in Figure 4.12.

The temperature at the surface of the wood shavings was 32.3^{o}C during the day and 28.2^{o}C at night compared to 32.1^{o}C (day) and 27.1^{o}C (night) when water at 66^{o}C was used for heating.

The floor surface temperature was 48.2^{o}C both day and night compared to 42.6^{o}C (day) and 40.0^{o}C (night) in set up one for the same water temperature. The floor surface temperature remained unchanged due to the insulating effect of the wood shavings in set up 2. The temperature varied in set up one due to the effect of the ambient temperature.

At 50mm height the temperature was 28.0°C during the day and 23.7°C at night. In set up one it was 30.2°C during the day and 25.3°C at night. The temperature in set up 2 was lower due to the insulating effect of the wood shavings.

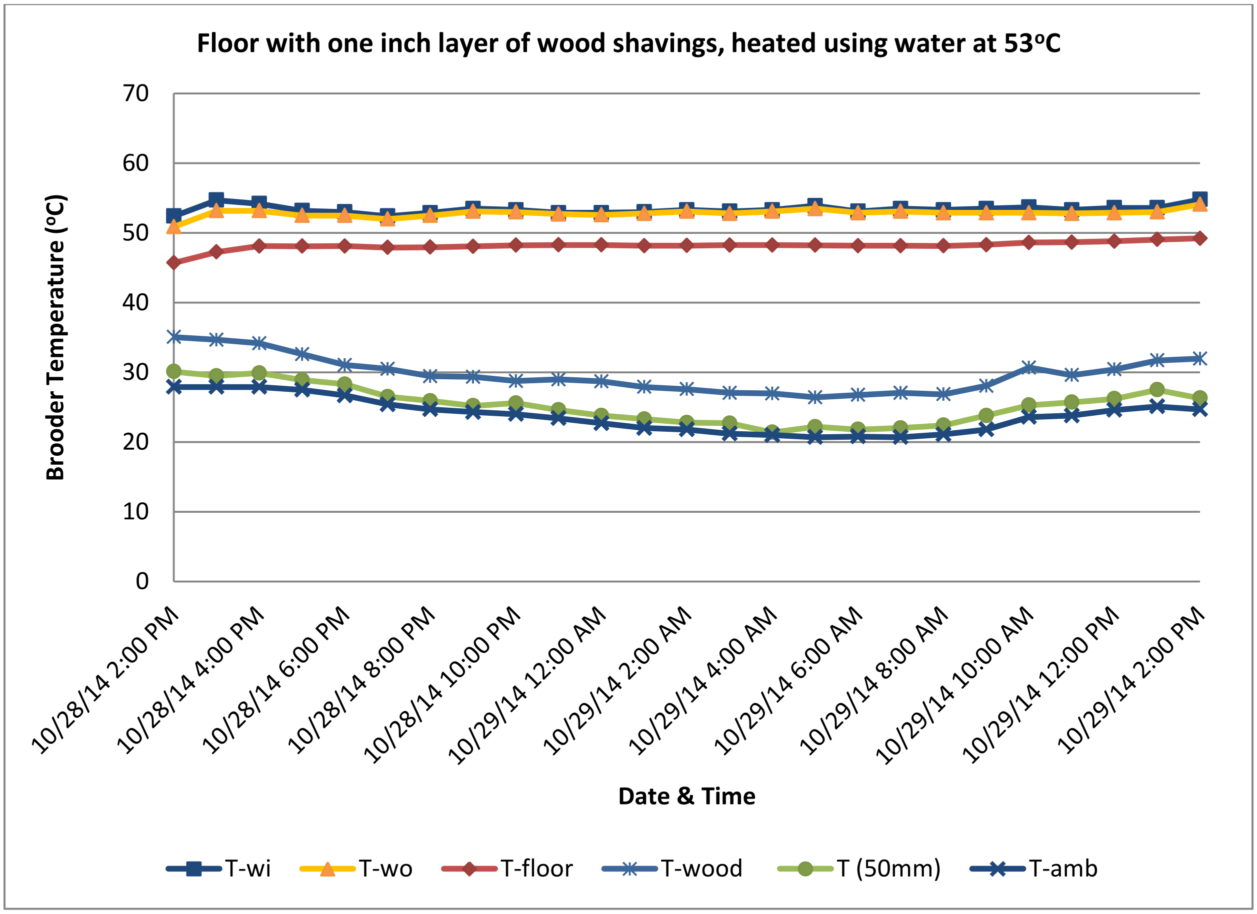

Figure 4.12 Temperature profiles for brooder with wood shavings, heated using water at 53°C

In the third test the water temperature was lowered to 42°C and the experiment repeated. Figure 4.13 shows the brooder temperatures achieved. The average temperature at the wood shavings was found to be 30.7°C during the day and 24.8°C at night compared to 32.3°C (day) and 28.2°C in the previous test.

The air temperature at 50mm height was lower than that in set up one. The temperatures attained were 26.3°C day and 21.2°C at night compared to 30.3°C and 24.5°C in set up one.

The floor temperature was 38.9°C during the day and 38.3°C at night compared to 37.9°C and 33.4°C for set up one respectively.

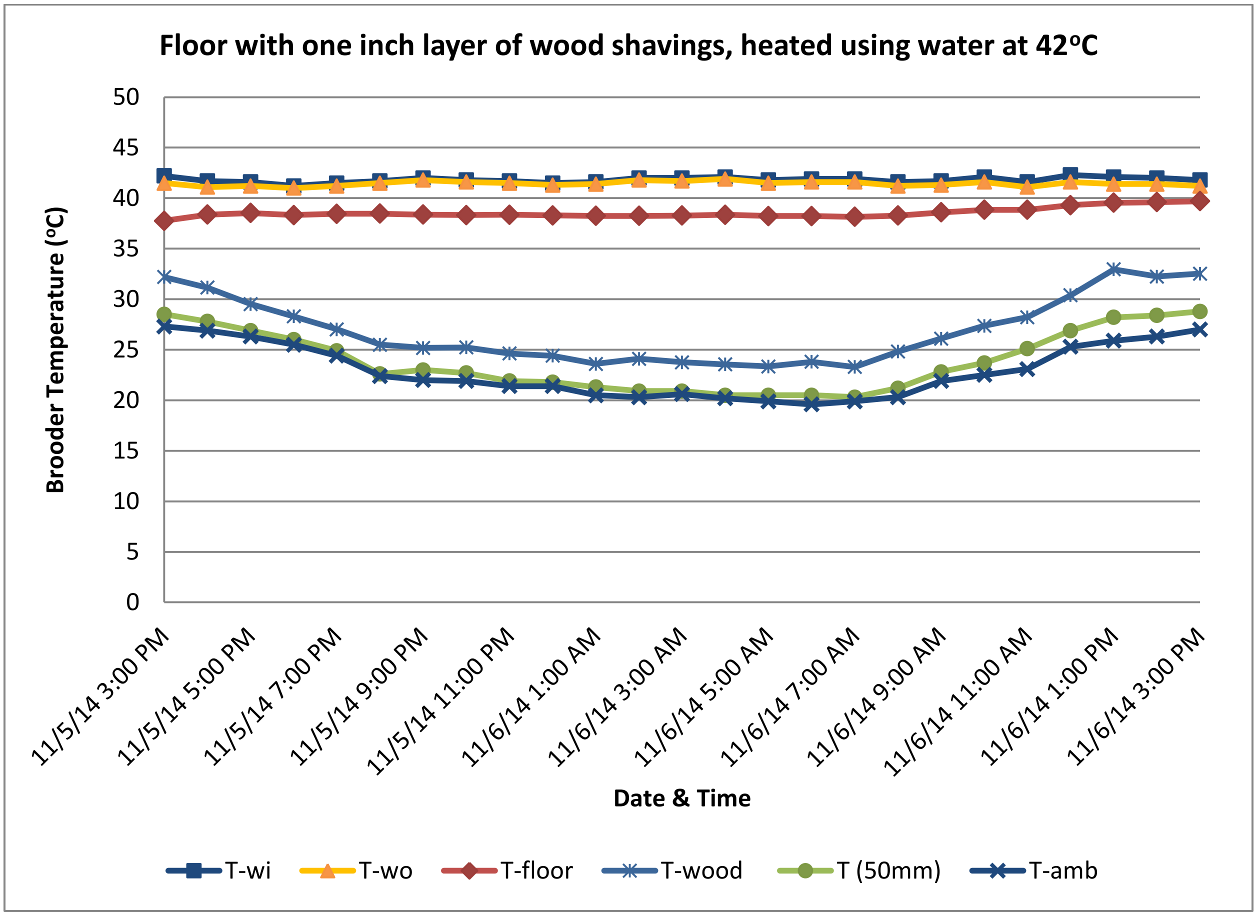

Figure 4.13 Temperature profiles for brooder with wood shavings, heated using water at 42°C

In the fourth test the water temperature was set to 36°C. Temperature readings were taken and the results shown in Figure 4.14. The floor temperature was 32.4°C during the day and 33.2°C at night compared to the results of set up one 33.7°C (day) and 30.9°C (night). Ambient temperature had a greater impact on the temperature in set up one than set up two.

The temperature at the surface of the wood shavings was 29.0°C (day) and 23.4°C (night) compared to 30.7°C (day) and 24.8°C (night) in the previous test. At 50mm height the temperature was 26.3°C during the day and 21.2°C at night compared to 29.0°C and 24.0°C in set up one.

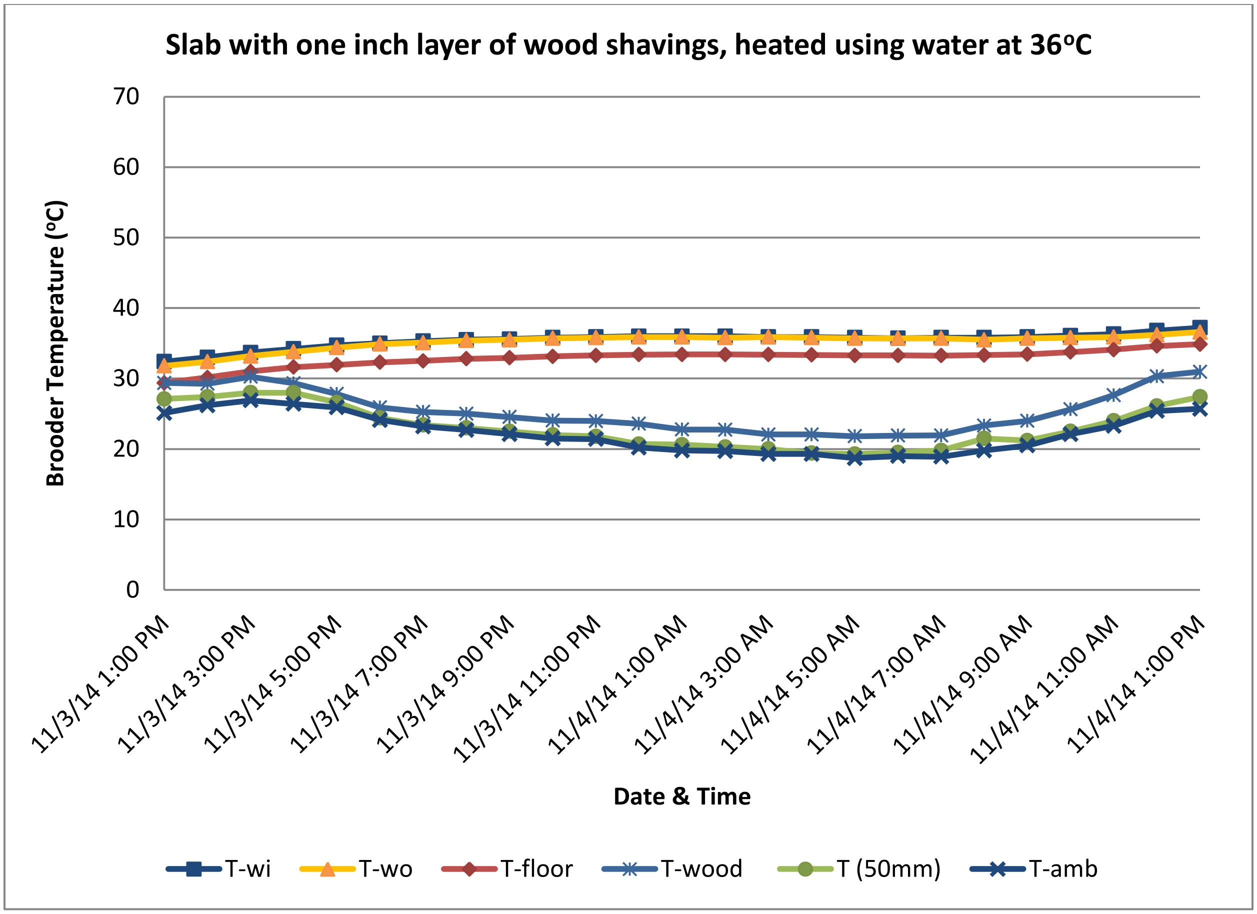

Figure 4.14 Temperature profiles for brooder with wood shavings, heated using water at 36°C

From the experiments carried out in set-up one and set-up two graphs were plotted showing the brooder floor temperature attained when the brooder was heated using water at 42°C. The results are shown in Figure 4.15. It was observed that in set-up one the floor temperature was affected by the ambient temperature, whereas in set-up two ambient temperature had little or no effect on the brooder floor surface temperature. The R^2 value showing the correlation between ambient temperature and floor temperature was very low. In set-up two due to the insulating effect of the wood shavings there was poor correlation between the ambient temperature and brooder floor temperature. In set-up one there was a strong correlation between the ambient temperature and floor temperature. A one degree rise in ambient temperature resulted in a 0.78 degree rise in floor temperature.

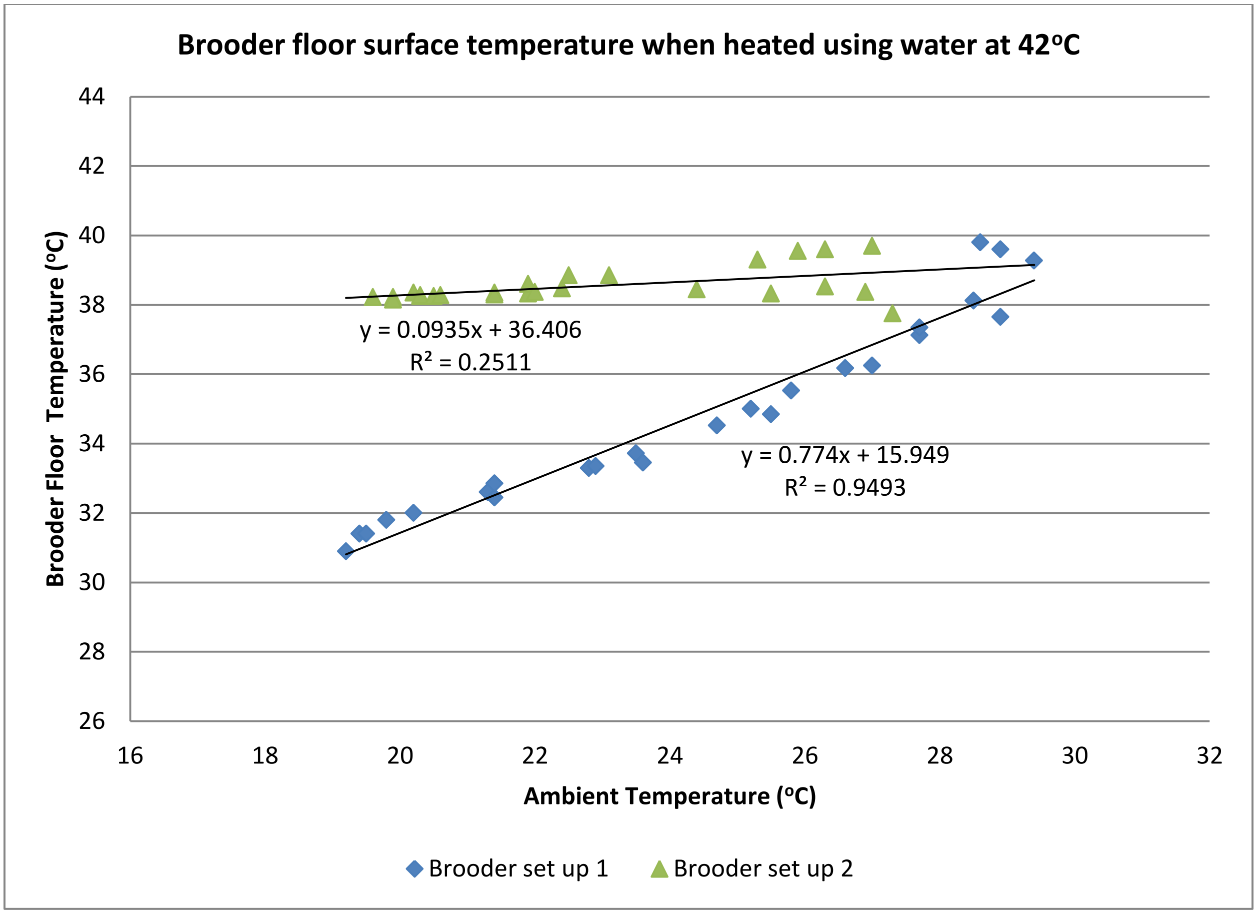

Figure 4.15 Comparison of the brooder floor surface temperature in set-up 1 and 2

A comparison was made of the temperatures at 50mm height above the floor for set-up one and 50mm height above the wood shavings for set-up two. Graphs showing the temperatures when the brooder was heated using water at 42^{o}C were plotted and are shown in Figure 4.16. The graphs showed the relationship between ambient temperature and temperature at 50mm height in both set-ups. From the chart it was observed that higher ambient temperature resulted in higher temperature at 50mm height in both set-ups. The gradients of the graphs for both set-ups were almost the same which showed that the change in temperature at 50mm height was almost the same. In set-up one a one degree rise in ambient temperature resulted in a 1.1 degree rise in temperature at 50mm height compared to 1.0 in set-up two.

It was also observed that the temperatures in set-up two were higher than those in set-up 1. In set-up two the temperature at 50mm height was 21.8°C compared to 20.6°C in set up one at 20°C ambient. The temperatures in set-up two were 0.4°C to1.3°C higher than set-up one with the largest difference at the lower temperatures.

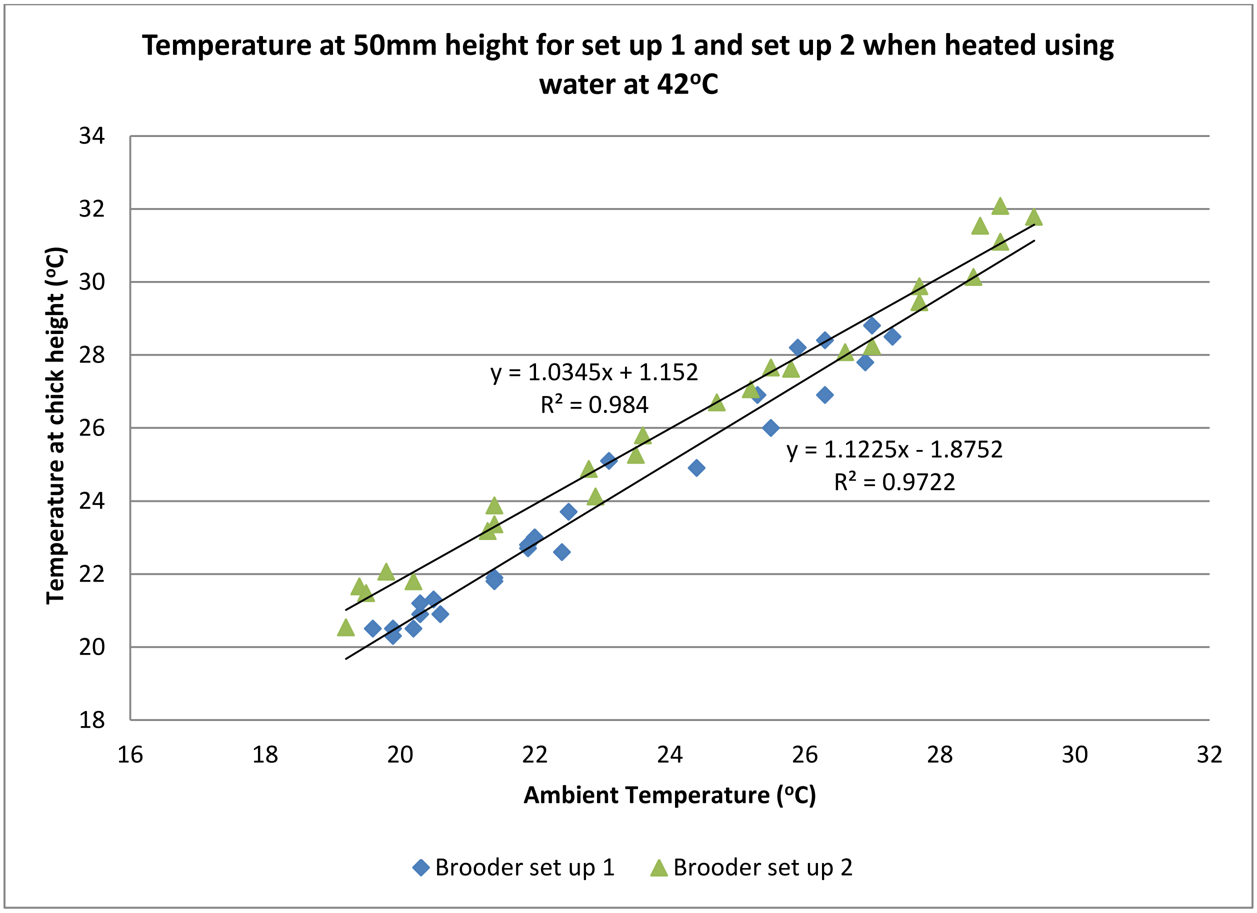

Figure 4.16 Comparison of the brooder temperature at 50mm height in set up 1 and 2

The temperature at wood shavings surface was determined by the water inlet temperature and the ambient temperature. The impact of water temperature was marginal, a 1°C increase in water inlet temperature resulted in a 0.18°C to 0.23°C rise in wood shavings temperature. The impact of ambient temperature was large a 1°C rise in ambient temperature produced a 1°C to 1.2°C rise in wood shavings temperature. The results are shown in Figure 4.17

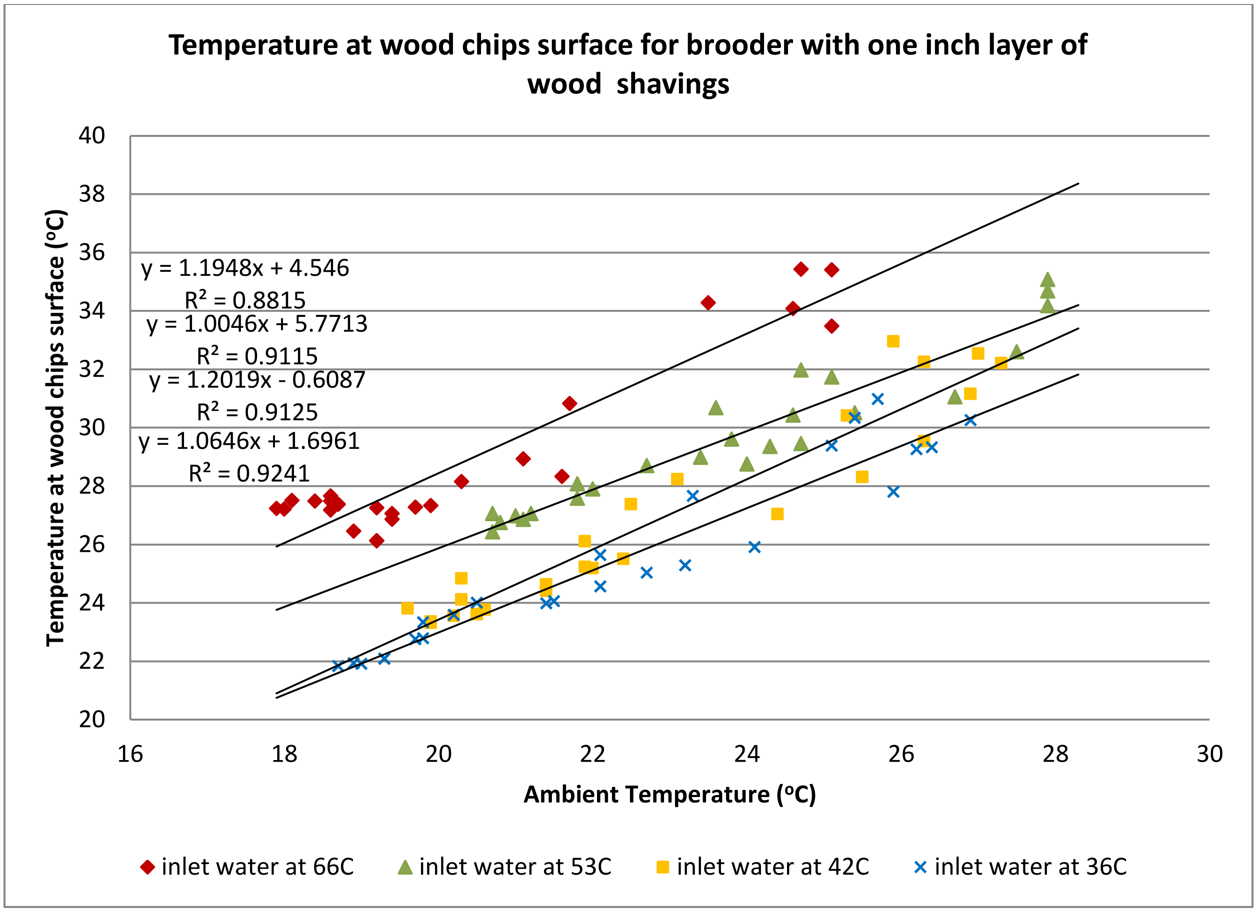

Figure 4.17 Summary of temperature profiles at surface of wood shavings

4.3 Brooder set up 3: Brooder covered using empty sisal bags

In the previous experiments carried out using set up 1 and set up 2 the temperature at 50mm height was greatly affected by the ambient temperature. In order to attain higher temperatures inside the brooder the top of the brooder was covered. Sisal bags were chosen because they were not air tight. The rest of the experiment set up remained the same as that in set up 2. The flow rate of water was maintained at 0.05litres/second and the temperature was set to 61^{o}C. Four scenarios were considered fully open top (base case), 10% of the top open, 5% of the top open and fully covered using sisal bags. The detailed methodology used is outlined in detail in section 3.2.3 and the temperature measurement points are shown in Figure 3.12. All experiments were carried out between 4:00pm and 10:00am in the morning. The results of the tests are presented and discussed below.

In the first test the brooder set up used was the same as that in set up two with the temperature of hot water set to 61^{o}C. The top of the brooder was not covered because the first test was used as the base case. The average floor temperature was 53.5^{o}C. The average temperature at the wood shavings was found to be 30.1^{o}C while the temperature of air 50mm above the floor was 24.8^{o}C. During the experiment the average ambient temperature was 22^{o}C. It was noted that the temperatures at the wood shavings and 50mm height were lower than the recommended brooding temperatures.

In the second test the same set up was maintained except for the top which was covered using empty sisal bags. A space equivalent to 10% of the top surface area was left uncovered. Figure 3.13 shows how the top of the brooder was covered. Figure 4.18 shows the results of the test. The average temperature of the floor surface was 55.0^{o}C compared to 53.5^{o}C in the first test. The average temperature at the wood shavings was found to be 33.3^{o}C compared to 30.1^{o}C an increase of 2^{o}C. The temperature of air 50mm above the floor was found to be 29.9^{o}C compared to 24.8^{o}C and increase of 5^{o}C. The difference in average ambient temperature in the first and second test was less than 1^{o}C it was 22.9^{o}C in the second test compared to 22^{o}C in the previous test. The temperatures of thermocouples at the surface of the wood shavings and 50mm height above the wood shavings still followed the variation of the ambient temperature.

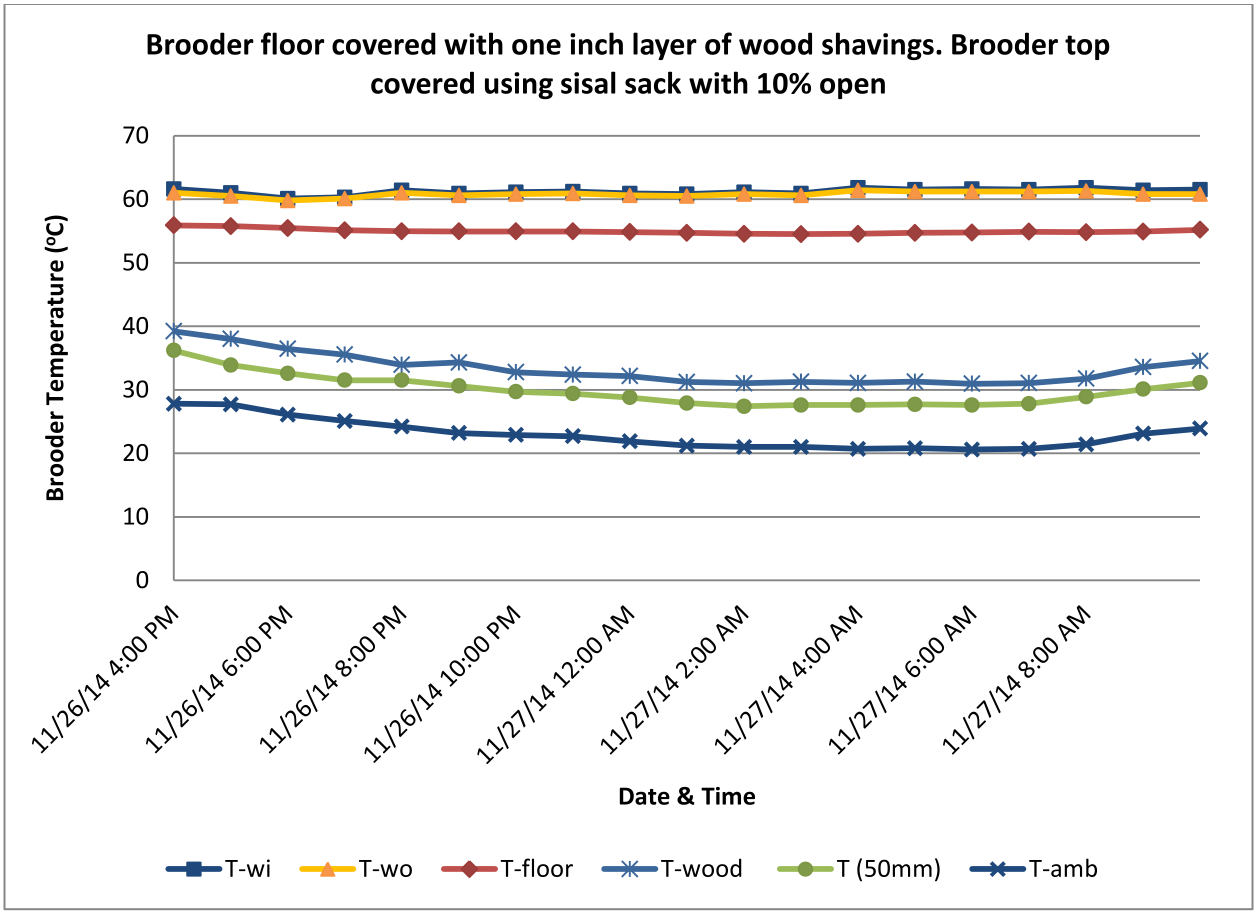

Figure 4.18 Temperature profiles for brooder with wood shavings, top covered with 10% open and heated using water at 61^{o}C

The average temperature at wood shavings seemed high enough for brooding however the temperature at 50mm height seemed lower than the required brooding temperature.

In order to further ascertain the impact of covering on the temperature inside the brooder the top of the brooder was further covered leaving an opening of only 5% of the surface area.

In the third test the top of the brooder was covered further and only a space of 5% of the top surface area was left uncovered. Temperature readings were taken and are shown in Figure 4.19.

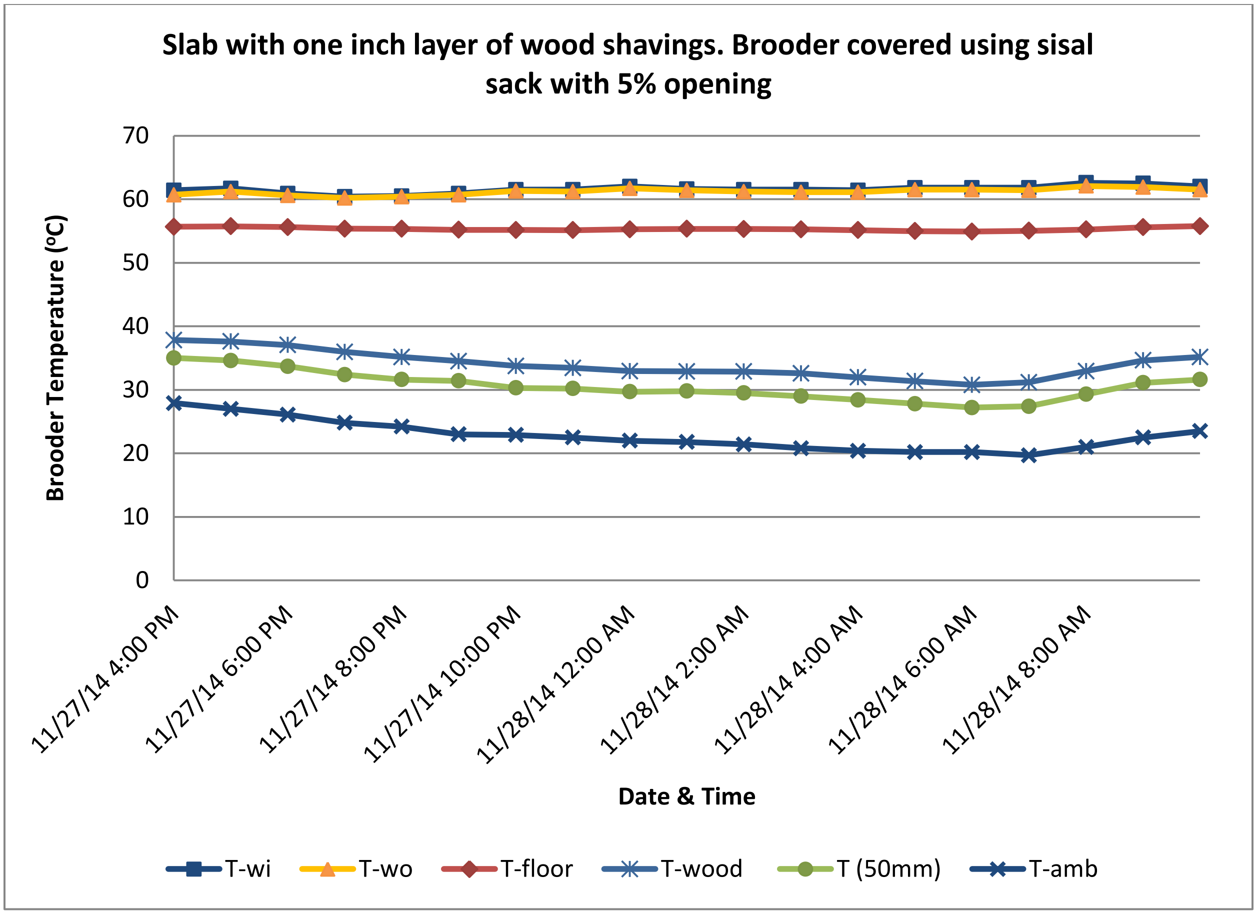

Figure 4.19 Temperature profiles for brooder with wood shavings, top covered with 5% open and heated using water at 61°C

The average temperature of the floor surface was 55.3°C this was close to the previous test value of 55.0°C. The average temperature at the surface of the wood shavings was 33.9°C which was 0.6°C higher than the 33.3°C attained in the previous test. The previous test had an average temperature of 33.1°C. The temperature of air 50mm above the floor was 30.5°C this was also 0.6°C higher than 29.9°C achieved in the previous test. The average ambient temperature was 22.7°C compared to 22.9°C in the previous test a difference of only 0.2°C. As shown in Figure 4.19 the temperature at the surface of the wood shavings and 50mm height above the wood shavings still followed the variation of the ambient temperature.

The temperatures achieved at the wood shavings were high enough for brooding however the temperatures at 50mm height were two to four degrees lower than the recommended brooding temperatures.

In the fourth test the same set up was maintained this time however the top was fully covered using sisal bags. Figure 4.20 shows the results of the test.

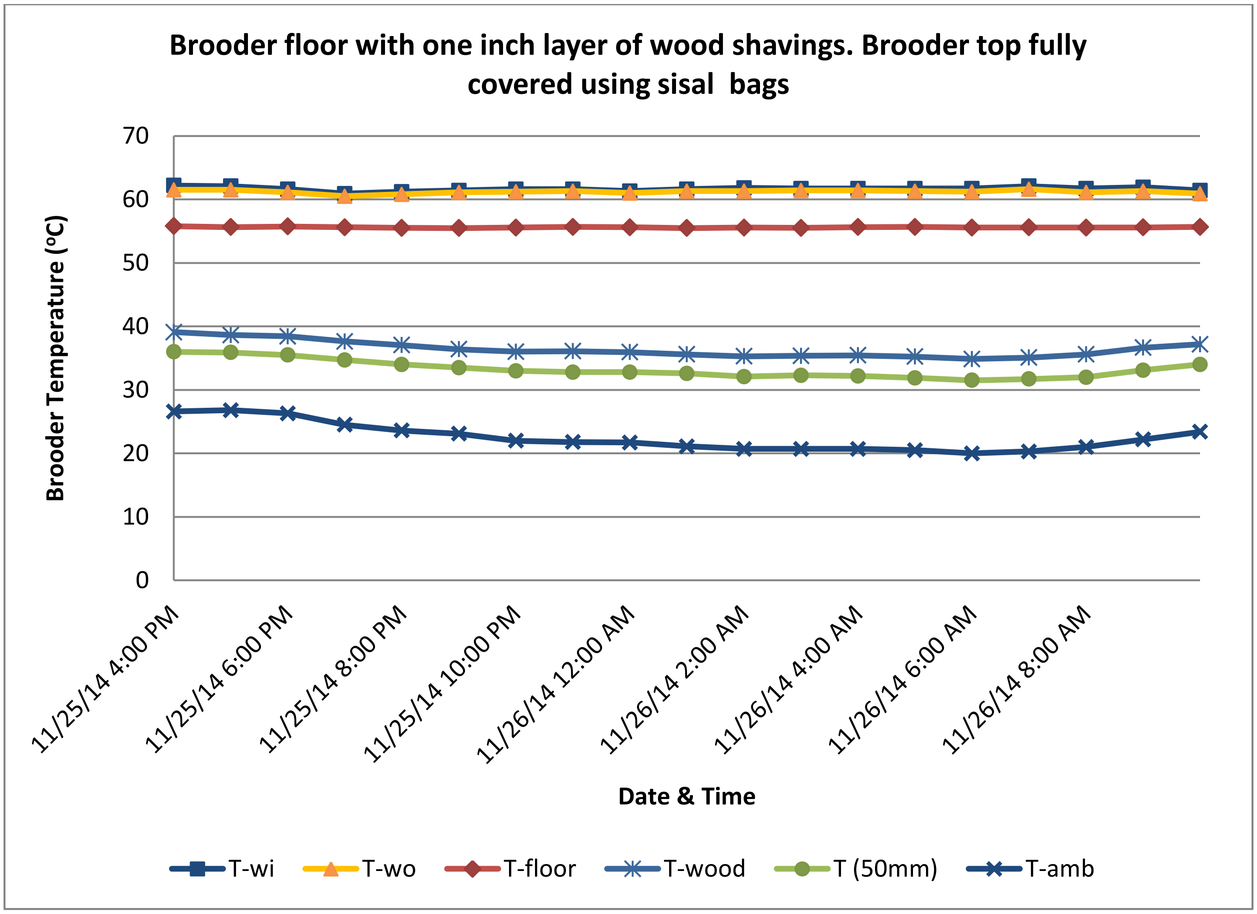

Figure 4.20 Temperature profiles for brooder with wood shavings, top fully covered and heated using water at 61°C

The average temperature of the floor surface was 55.6°C slightly higher than 55.3°C in the previous test. The average temperature at the wood shavings was found to be 36.4°C which was 2.5°C higher than 33.9°C from the previous test. The temperature of air 50mm height above the floor was found to be 33.2°C this was high enough for brooding day old chicks. It was 2.7°C higher than the 30.5°C attained in the previous test. The average ambient temperature was 22.5°C almost the same as the previous test value of 22.7°C.

Temperature at the surface of the wood shavings was dependent on the ambient temperature and the extent to which the top of the brooder was covered. A chart was generated showing how the temperature at the wood shavings varied with ambient temperature for each of the tests. Figure 4.21 shows the impact covering had on the temperature at the surface of the wood shavings. For every 1°C rise in ambient temperature, the temperature at the surface of the wood shavings increased by 0.6°C to 1.3°C. The impact was greatest at the lower temperatures.

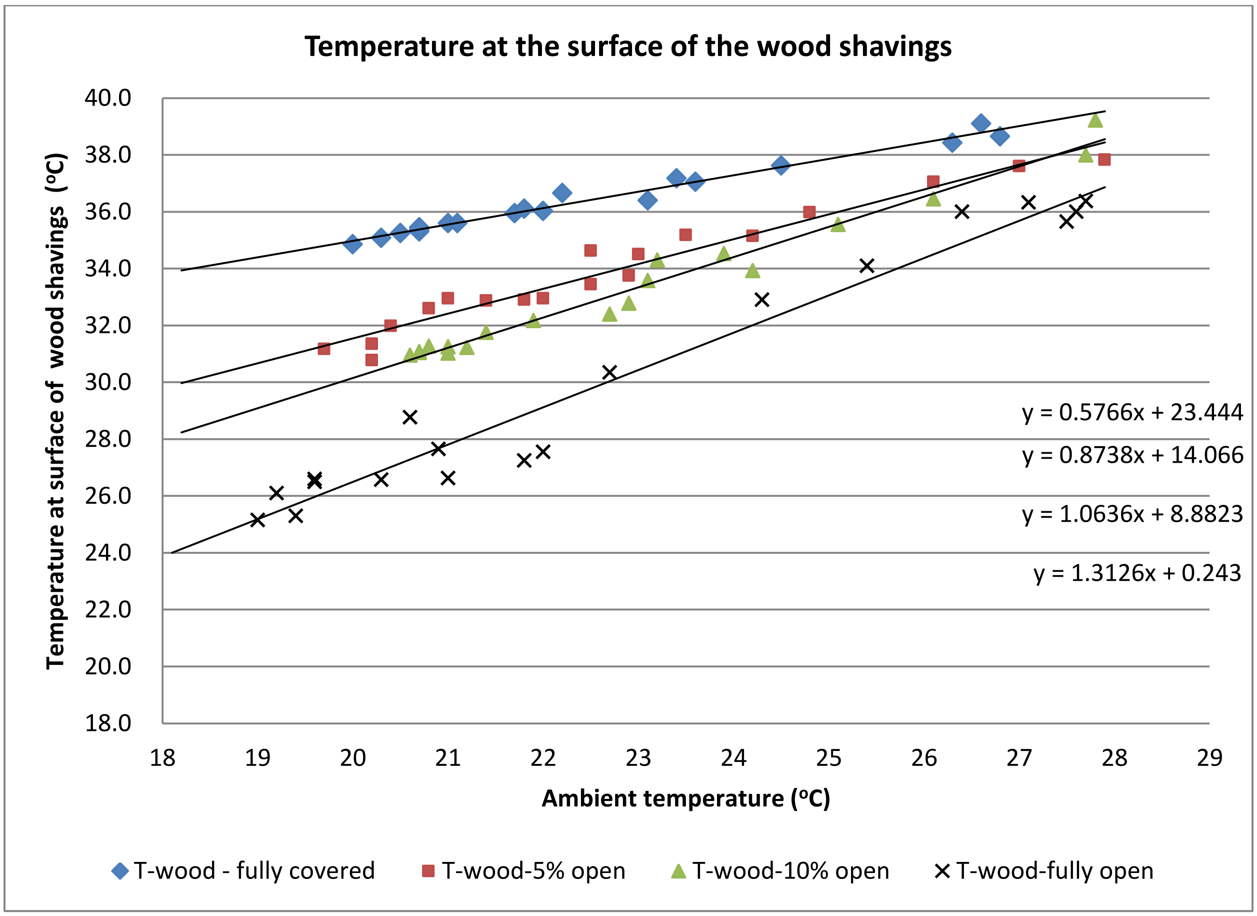

Figure 4.21 Impact of covering on the temperature at the surface of the wood shavings

The results of the tests showed that the temperatures at 50mm height were dependent on both the ambient temperature and the extent to which the brooder was covered at the top. A chart was plotted showing the relationship between temperature at 50mm height and ambient temperature for each of the scenarios considered (fully open top to fully covered top). The chart showing this relationship is Figure 4.22.

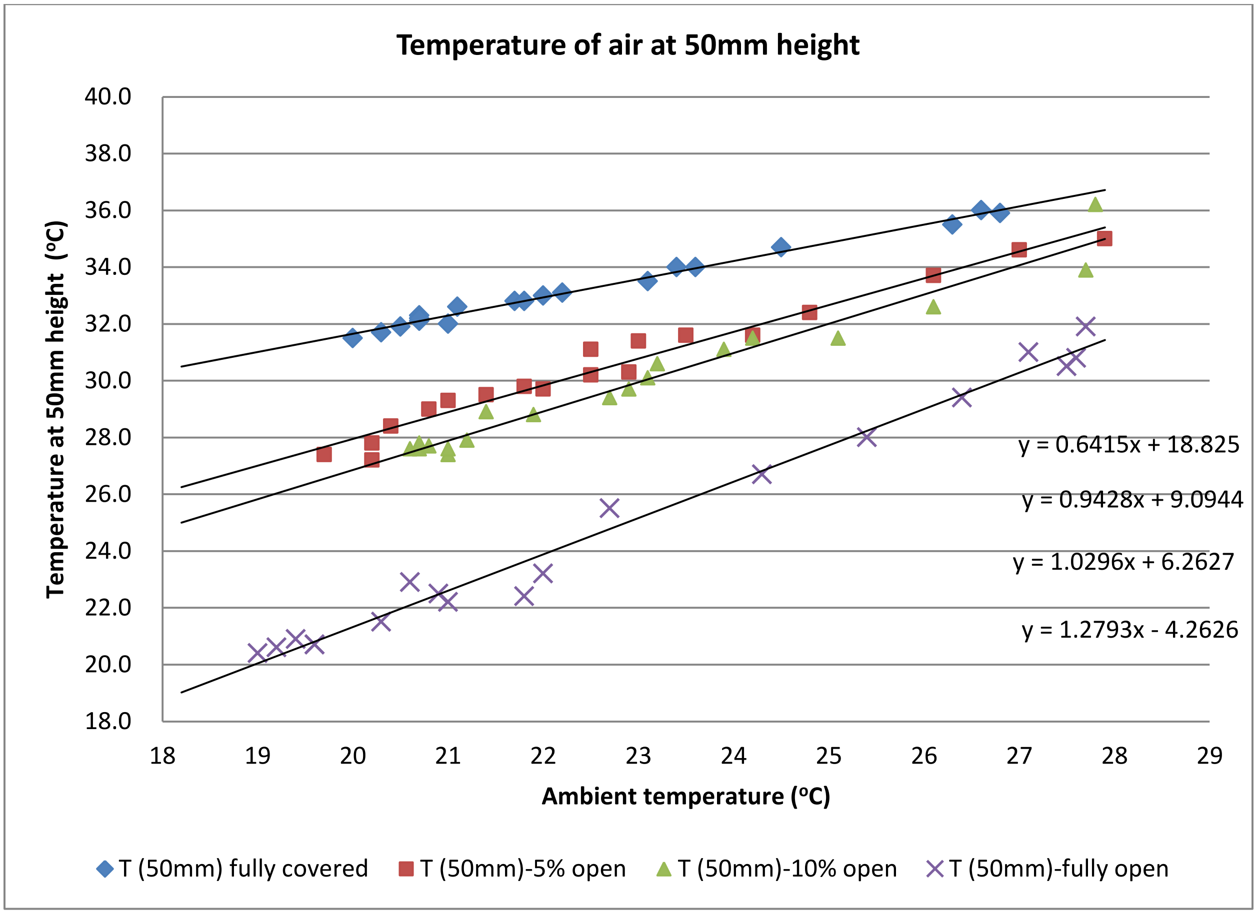

Figure 4.22 Impact of covering on the temperature at 50mm height

A 1^{o}C rise in ambient temperature resulted in a 0.6^{o}Cto 1.3^{o}C rise in the temperature at 50mm height. The largest impact was in the fully open case in which 1^{o}C rise in ambient temperature resulted in 1.28^{o}C rise in brooder temperature (50mm height). In the fully covered test a 1^{o}C rise in ambient temperature resulted in 0.64^{o}C rise in temperature at 50mm height.

A change in covering of the top from fully open to 10% open resulted in a temperature increase of 2.8^{o}C at wood shavings surface and 3.1^{o}C at 50mm height. Covering further to 5% open resulted in an increase of 1.0^{o}C at wood shavings and 3.2^{o}C at 50mm height. When the brooder top was fully covered the temperatures increased by a further 3.2^{o}C at the wood shavings and 5.0^{o}C at 50mm height. Between 5% open top and fully covered top the recommended brooding temperatures for day old chicks (32^{o}C to 35^{o}C) could be achieved.

4.4 Effect of floor heat capacity on heating and cooling

One of the advantages of using heated floors for brooding is the storage of heat by the floor. Concrete floors store heat energy due to their high heat capacity. Heat capacity affects the speed at which the floor heats up and cools. In order to understand the effect of the slab heat capacity on heating and cooling, heating and cooling curves were generated. These curves can be used to estimate the time required to heat the floor and the time taken to cool.

4.4.1 Heating

In order to understand how long it could take to heat the floor, the floor was heated and the temperature rise recorded. Brooder set up 3 was used with water at 49^{o}C. The top of the brooder was covered using the sisal bags with a 5% opening and readings were taken over a period of 12 hours.

It can be seen from Figure 4.23 the floor surface temperature rose rapidly at the start of heating and reduced as the temperature of the floor rose. The greatest temperature rise was at the start of heating, in the first one hour the temperature increased by 8.3^{o}C after four hours the temperature increased by 2^{o}C per hour and after ten hours the temperature rise was only 0.4^{o}C per hour. Steady temperature was achieved after twelve hours.

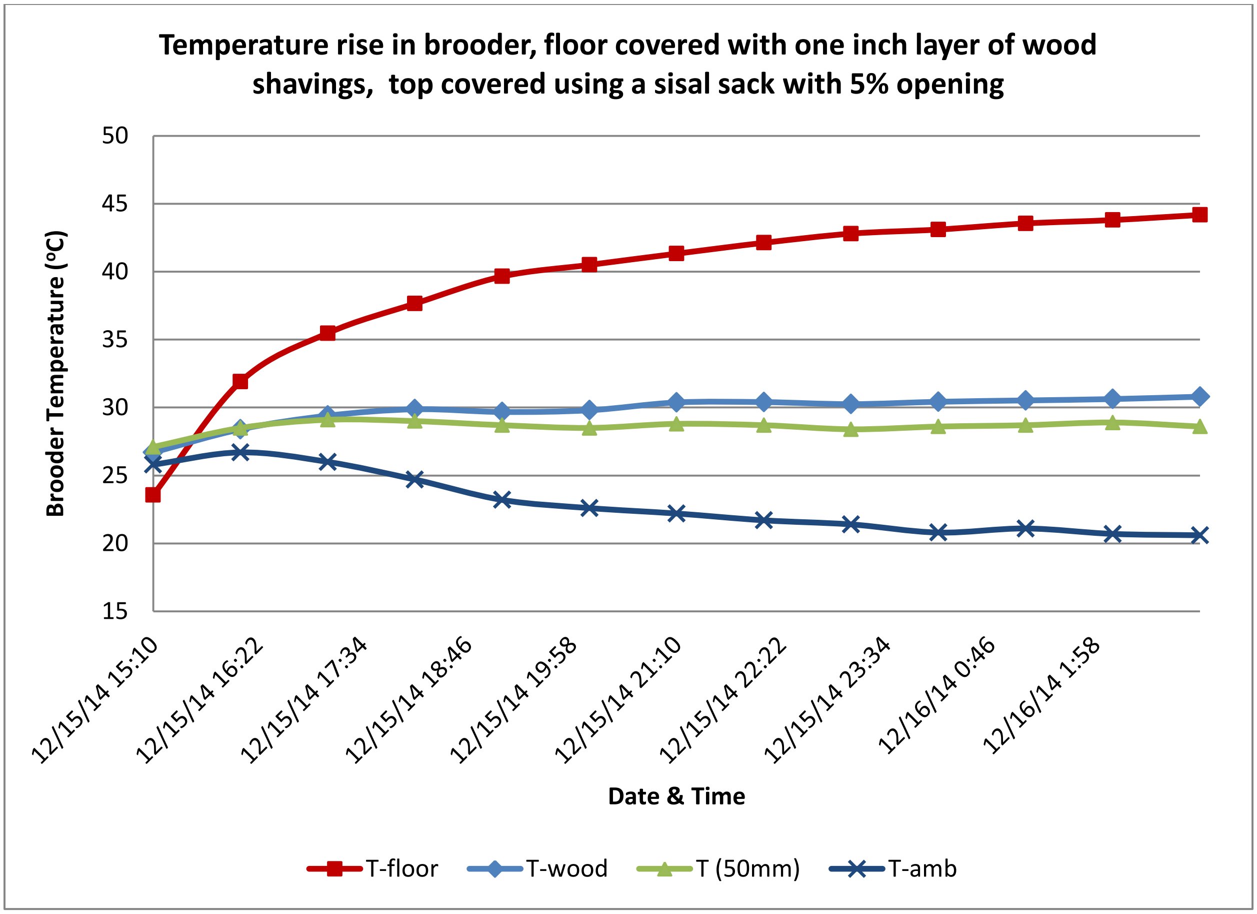

Figure 4.23 Floor heated using water at 49°C, one inch layer of wood shavings on the floor. Brooder covered with 5% opening.

The temperature of the wood shavings increased from 26°C to 30°C in six hours and further increased to 30.8°C after six more hours of heating. The temperature at chick height took about three hours to attain a steady temperature after twelve hours the temperature at chick height was 28.6°C.

4.4.2 Cooling

In solar powered systems solar energy is available during the day only. Therefore it is important to know how long the floor can maintain the brooder temperature in the evening or night when solar energy is not available. This was done by switching off the pump. The temperature in the brooder was determined by the temperature of the floor. The rate of cooling of the brooder was therefore determined by the rate at which floor cooled. The rate at which the brooder floor cooled was determined by the heat capacity of the slab. It is expected that the higher the heat capacity of the slab the slower the rate of cooling.

Using the same experimental set up the brooder floor was heated until a floor temperature of 56°C was attained the pump was then switched off at 4:00pm. Temperature readings were then taken till 10:00am the next morning. Figure 4.24 shows the results of the experiment.

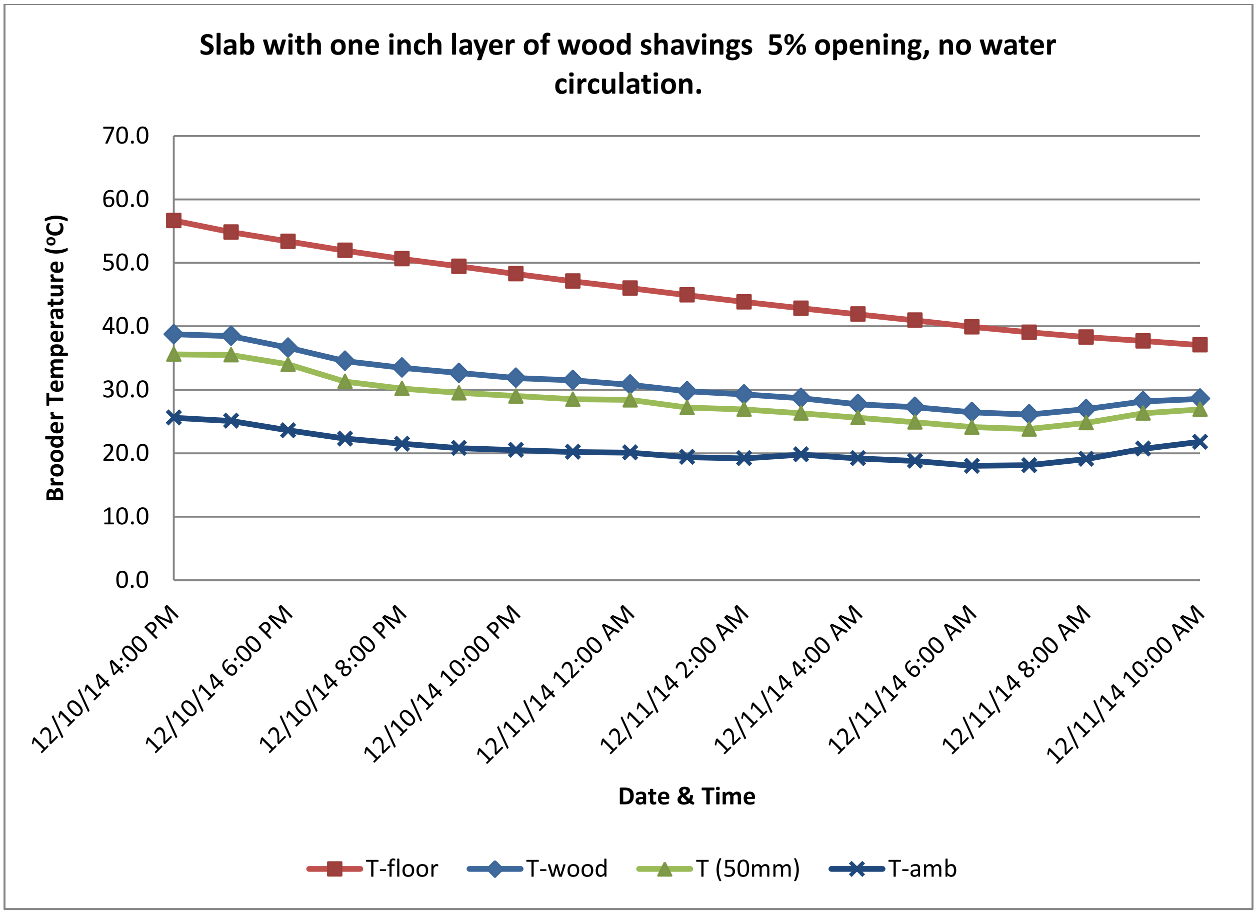

Figure 4.24 Cooling of floor with a one inch layer of wood shavings and 5% of the top open, no water circulation

The temperature of the slab reduced gradually from 56.7°C to 37.1°C a drop of 19.6°C in 18 hours. The gradual temperature drop in the brooder was due to the impact of the floors heat capacity. Ambient temperature had the greatest influence on the temperature at the surface of the wood shavings and temperature at chick height. The minimum temperature at chick height during the test period was 23.8^{o}C this occurred at 7:00a.m in the morning when the ambient temperature was 18.1^{o}C. The brooding conditions for the day old chicks (32^{o}C to 35^{o}C) could be met for four hours after switch off. By storing heated water in a well lagged tank. Heated water can be circulated and the temperature in the brooder maintained at the required temperature until morning.

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

In this chapter conclusions and recommendations of the study are presented.

5.1 Conclusions

A floor heated brooder was constructed and several tests carried out to determine the temperature profiles when the floor was heated using water. Three experimental set ups were considered; the first the brooder as constructed, the second with wood shavings on the floor and the third with the top covered to different degrees using empty sisal bags. Finally heating and cooling curves were generated. The significant findings of the study were:

1) Impact of water inlet temperature

   In set-up one it was determined that a one degree rise in water inlet temperature resulted in up to 0.55^{o}C rise in the floor surface temperature compared to set-up two which had a 0.8^{o}C rise. In set-up two a one degree increase in water inlet temperature resulted in a 0.18^{o}C to 0.23^{o}C rise in wood shavings temperature. The impact of water inlet temperature on air temperature at 50mm height was low. In set-up one water temperature had a marginal impact of 0.1^{o}C to 0.12^{o}C rise in brooder temperature per one degree rise in water inlet temperature. In set-up two the impact of water temperature was negligible.

2) Impact of wood shavings

   Due to the insulating effect of the wood shavings the floor temperature in set-up two was not affected by the ambient temperature. Therefore the average floor temperature when the floor was covered using wood shavings (set-up 2) was higher than the average floor temperature attained when the floor was bare (set-up 1). The average air temperatures at 50mm height were also higher in set-up two than set-up one. The temperatures were higher by 0.4^{o}C to 1.3^{o}C when heated using water at 42^{o}C.

3) Impact of covering

   Covering the brooder top using empty sisal bags increased the temperature inside the brooder by up to 7^{o}C at the wood shavings surface and 9^{o}C at 50mm height.

4) Impact of ambient temperature

   In set-up one it was established that a one degree change in ambient temperature resulted in a 0.65^{o}C to 0.77^{o}C increase in brooder floor temperature and a one degree rise in ambient temperature resulted in an equal rise in brooder air temperature (50mm height). The impact of ambient temperature on the wood shavings surface temperature was greater, a one degree rise in ambient temperature resulted in 1.0^{o}C to 1.2^{o}C rise in wood surface temperature. Likewise temperature at 50mm height was higher by up to 1.2^{o}C in set-up two.

5) Temperature rise in the brooder when heated using water was greatest at the start of heating, thereafter it reduced as the floor temperature increased. The floor took over 12 hours to attain a steady temperature.
6) The floor cooled down slower than it heated up. The floor was able to maintain sufficient heat for brooding for about four hours after heat addition was stopped.

In summary it was demonstrated by heating the brooder floor using water at 36^{o}C to 66^{o}C average floor temperatures of up to 44^{o}C (set-up one) and 57^{o}C (set-up two) could be attained. Whereas high floor surface temperatures were attained the average temperature at wood shavings varied between 23.4^{o}C and 27.1^{o}C (night) and the average temperature at 50mm height was only 24^{o}C (night). By covering the top of the brooder using empty sisal bags higher brooder temperatures were achieved. When water at 61^{o}C was used for heating the floor, average wood shaving temperatures of between 30.1^{o}C and 36.4^{o}C were achieved between the fully open and fully covered tests. The corresponding temperatures at 50mm height were 24.8^{o}C to 33.2^{o}C. It was therefore concluded that the required chick brooding temperatures could be achieved by altering water temperature or extent of covering the top using sisal bags.

5.2 Recommendations

To further increase knowledge and understanding of floor heated brooders the following recommendations are made.

1. An analysis of the temperature profiles for the brooder with no wood shavings (floor bedding material) and covered at the top using sisal bags.
2. Analysis of the temperature profiles when the brooder is heated overnight using water stored in an insulated storage tank.
3. The impact of covering on ventilation and humidity should be investigated.
4. An analysis of a system in which heat is provided using solar collectors.
5. Performance of a fully automated system in which heating and flow of heated water are controlled.

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