THE EFFECT OF THERMAL STRESS ON EGG PRODUCTION IN LAYER CHICKENS UNDER DEEP LITTER SYSTEM IN HOUSE HOLD SETTINGS IN KIBAALE, MID WESTERN UGANDA.

BY

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DECLARATION

I, Muntukwonka Pascal, hereby declare to the Graduate School of Kyambogo University that this thesis is my original work, unless otherwise stated. It has never been submitted to any institution for an academic award.

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APPROVAL

This thesis has been submitted to Kyambogo University Graduate School with the approval of University research supervisors

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DEDICATION

The author dedicates this piece of work to his beloved parents Mr. Bukombi Matthew (late) and Mrs. Biira Bukombi. He equally dedicates it to his brothers, sisters, wife and children.

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LIST OF ABBREVIATIONS AND ACRONYMS

A/C	:	Air Conditioner
AE	:	Avian Encephalomyelitis
AI	:	Avian Influenza
ANOVA	:	Analysis Of Variance
COPA/COGECA	:	Committee of Professional Agricultural Organisation/Committee of Agricultural Co-operation in the European Union.
CRD	:	Complete Random Design
EDS	:	Egg Drop Syndrome
FAO	:	Food and Agriculture Organisation
FRI	:	Farm Radio International
GenStat	:	General Statistics
GHRF	:	Growth Hormone Releasing Factor
IB	:	Infectious Bronchitis
ILRI	:	International Livestock Research Institute
ILT	:	Infectious Laryngotracheitis
KDFA	:	Kibaale District Farmers' Association
KSA	:	Kingdom of Saudi Arabia
MCH	:	Melanin Concentrating Hormone
NCD	:	Newcastle Disease
NPY	:	Neuropeptide Y
NRC	:	National Research Council
SDGs	:	Sustainable Development Goals
SPSS	:	Statistical Package for Social Scientists

TCZ	:	Thermal Comfort Zone
TNZ	:	Thermal Neutral Zone
TS	:	Thermal Stress
UBOS	:	Uganda Bureau of Statistics
UN	:	United Nations
UPFG	:	Uganda Poultry Farming Guide
USA	:	United States of America
USDA	:	United States Department of Agriculture

ABSTRACT

Despite the presence of a large number of chickens in Uganda, their contribution to the national economy is still limited due to thermal stress, tropical diseases and nutritional limitations. This study carried out in Kibaale, Mid-Western Uganda was therefore meant to assess farmers' awareness of the effect of Thermal Stress (TS) on egg production, determine the effect of TS on egg production in layers under deep litter system and assess farmers' acceptability of measures to control TS and its effects. A survey was carried out in the area of study to assess farmers' awareness of the effect of thermal stress on egg production after which a CRD experiment was conducted on a farmer's poultry farm in the study area to determine the effect of TS on feed intake, egg production end egg weight. A total of 180 Hy-line brown layers of 24 weeks were randomly assigned to three thermal treatments of 18^0C, 24^0C, and 32^0C for two weeks. The 24^0C treatment acted as a control set up since it is within the TCZ. Each treatment was replicated 4 times with each replicate having 15 birds. The survey data obtained was analyzed using SPSS while GenStat was used to analyse experimental data. The ANOVA at a significance level of 95%, (0.05) was used. Whereas survey results revealed that most respondents (82%) had no knowledge of the effect of TS on egg production, experimental results showed that temperature treatments significantly ($p<0.05$) affected feed intake, number of eggs laid an egg weight. At 18^0C feed intake increased by 9.5% but egg production decreased by 33.3%. At 32^0C both feed intake and egg production decreased by 20.8% and 40.0% respectively. Farmers' acceptability to adopt efficient, flexible and recommended methods to control TS was low at only 11.11%. Although both low temperature and high temperature stress depressed egg production and need to be controlled effectively to improve on egg productivity, high temperature stress was more disastrous than low temperature stress. Findings indicate that there is need for an action research which is participatory where selected farmers can be involved in the study under farmer conditions so that they can effectively control thermal stress.

CHAPTER ONE: INTRODUCTION

1.1 Background to the study

Uganda is estimated to have 46.1 million chickens of which 40 million are hybrids while the rest are local types (UBOS, 2016). Most of the hybrids are kept in constructed shelters. Although most local chickens are commonly referred to as “enkoko enganda” (Buganda chicken), Buganda is not the leading local chicken producing region in the country. Bunyoro, Lango and Teso regions have the highest number of local chickens. On the other hand, Buganda region has most of the hybrids estimated at 90% (UPFG, 2013). Although the population of Uganda is 42.86 million people (World Bank, 2019), and lower than that of poultry, which is 46.1million chickens, (UBOS, 2016) poultry products are still expensive and insufficient. By 2016, egg production stood at 882,562,000 eggs per annum, (UBOS, 2016). The retail prices for eggs have risen from 6,000/= for a tray of 30 eggs in the last three years to the current price of 9,500/= (FRI, 2016). One of the reasons why chicken prices have risen is the emerging market in the region particularly South Sudan which got her independence in July 2011. Hence the need for efficient management of poultry to increase productivity and for more farmers to engage in poultry production.

Thermal Stress (TS) is one of the major factors that cause losses in poultry production especially among layers. Its economic losses are significant in both tropical and temperate regions. In the tropics mean ambient temperatures frequently exceed 30^0C (Brown, 2005). These high temperatures have been reported to cause a decline in egg production. In temperate countries, exposure to heat waves occurs mainly in summer (COPA/COGECA report, 2004). In the USA, TS has been estimated to increase mortality of layer birds by 0.03 to 0.96% and to decrease egg production by 0.5 to 7.2%, leading to a yearly economic loss of $98.1 million (St-Pierre *et al.*, 2003). Layer birds are particularly vulnerable to heat stress because they have to maintain a long production cycle of 50 to 70 weeks. Under heat tress conditions, the deterioration is manifested as reduced feed intake, respiratory alkalosis and decreased flow to several organs of a bird (Etches *et al.,* 1995). Respiratory alkalosis is a state due to excess loss of CO_2 from the body (Borges *et al*., 2004). Metabolic alkalosis is a disturbance in which acid-base status of the body shifts toward the alkaline side because of changes in the fixed (non-volatile) acid and bases (Sandercock *et al.,* 2001). This is characterized by the alteration of plasma electrolytes and blood gases yielding influence on formation of eggs with good shell quality. Besides thermal stress' effects on egg quantity, it has also been known to decrease egg quality (Balnave and Muheereza, 1997), reproductive efficiency (Novero *et al.*, 1991), and the immune response efficiency (Bollengier-Lee *et al.,* 1998).

Heat stress occurs as a result of a combination of high environmental temperature, high humidity and low air velocity (Yahav *et al.,* 2004; Balnave and Brake, 2005). The chicken's thermoregulatory mechanisms to avoid heat stress are normally activated above 24^0C, i.e., above the Thermal Neutral Zone (TNZ) which is 18^0C to 24^0C. Etches *et al.*, (1995) and St-Pierre *et al.*, (2003) observed that this limit can even be lower depending on air humidity. Heat stress effects become noticeable when temperatures exceed 30^0C (Arima *et al.*, 1976). This stress is accentuated by the fact that chickens cannot dissipate heat efficiently because of the insulating property of feathers and the lack of sweat glands (Yahav *et al.*, 1996). Apart from the intensity and duration of the heat stress itself, several factors affect a bird's sensitivity to high temperatures. The most frequently reported factors are the age of the bird, the cyclic variations of the temperature, and genotype of the birds. For example, egg shape is less affected by high temperature in older hens than young hens (Tuekam *et al.,* 1994). Laying intensity is more affected by a severe heat stress (37^0C) at the end than at the beginning of the laying period (Borges *et al.*, 2004). Cyclic variations of temperature reduce the effect of heat stress by providing recovery periods for birds during the cooler periods (Mashaly *et al*., 2004).

Most poultry production methods world over involve large numbers of birds kept in controlled environmental housing. Under the supervision of the farmer, the houses provide for all the factors birds need to maintain their welfare and performance, including protection from bad weather. However, a number of aspects of poultry production have changed through the 1990s and beyond 2000. There are many factors that can adversely affect egg production. Unraveling the cause of a sudden drop in egg production requires a thorough investigation into the history of the flock. Egg production can be affected by such factors as feed consumption (quality and quantity), water intake, intensity and duration of light received, parasite infestation, disease, and numerous management and environmental factors including heat intensity.

The birds themselves have different genetic characteristics, such that they differ in production, in response to thermal stress, to medication and to nutrition. High temperatures can have a major impact on performance of commercial poultry layers. When they are coupled with high humidity, the combination can become critical. Therefore, there is a need to re-evaluate the management of poultry and equipment used in hot weather so that heat stress is minimised. Heat Stress not only causes suffering and death in the birds, but also results in reduced or lost production that adversely affects the profit from the enterprise.

Birds are 'heat stressed' if they have difficulty achieving a balance between body heat production and body heat loss. This can occur at all ages and in all types of poultry. In the TNZ birds can lose heat at a controlled rate using normal behaviour whereby there is no heat stress and body temperature is held constant. When the 'upper critical temperature' is exceeded, birds must lose heat actively by panting. Panting is a normal response to heat and is not initially considered a welfare problem.

1.2 Contextual background

Growth of the agricultural sector is critical in sustaining poverty reduction and wealth creation. Seventy five per cent of the world's 1.2 billion extremely poor people who earn less than 1.25US$ per day live in rural areas. They derive their income from agriculture and / or agriculture related activities (World Bank, 2008). The pace of poverty reduction does not only depend on the overall rate of agricultural growth, but also on the ability of poor households to participate in that growth effectively that is on the quality or inclusiveness of the growth process (Sonaiya, 1996). Given that about three quarters of the extreme poor people keep livestock as part of their livelihood portfolios (FAO, 2010), safeguarding and increasing the returns from their livestock assets is expected to help them in their endeavour to escape poverty (Brown, 2003; ILRI, 2003; ILRI, 2007).

So much enthusiasm has been generated by the production and consumption of poultry meat and poultry products (Sonaiya, 1996). This is because the economic significance of poultry arises and varies considerably from production and sale of meat and eggs to earning foreign exchange (Balnave, 2004). Poultry provides ready cash for investment and income to poultry keepers, especially women and all age groups (Gueye, 2003). This can play a key role in poverty eradication in households. Poultry also has a short generation interval compared to other livestock. Income from poultry is also spread throughout the year unlike crops (Sonaiya, 1996). Poultry manure is becoming more important in improving crop yields more especially with the increase in poultry production under deep litter system (Balnave, 2004). The consumption of poultry meat and eggs has increased, and will increase by 200% between 2010 and 2020 for many Sub-Saharan Africa countries including Uganda (Byarugaba, 2007). Rapid growth in the demand for livestock products in developing countries is seen as a food revolution (FAO, 2004). This increased demand means that actors in the poultry industry will reap high incomes for development (FRI, 2016).

Poultry keeping can be one of the agricultural enterprises the government of Uganda can adopt to improve household incomes and welfare since birds are kept almost in every household (Byarugaba, 2007). Poultry production is becoming one of the most highly developed segments in the production of food of animal origin, in food security, income generation and manure production globally (Byarugaba, 2007). Accordingly, to gain the maximum profitability out of the industry, greater efforts have been put on making changes in the methods of production (Ensminger, 1992). In developing countries, apart from traditional back yard methods of raising chickens, commercialized poultry production is increasing and intensifying (Fabiyi, 1980)

Improving egg productivity increases profitability and sustainability of poultry projects which is in line with the 2016 Agricultural Sector Strategic Plan of Uganda whose overall objective is, “to achieve food and nutrition security and improve household incomes through coordinated interventions that focus on enhancing sustainable agricultural productivity and value addition; providing employment opportunities, and promoting domestic and international trade” (ASSP, 2016) and subsequently Uganda’s vision 2040 of a transformed Ugandan society from a peasant to a modern and prosperous country within thirty years (NPA, 2013). The vision involves changing from a predominantly low income to a competitive upper middle income country within thirty years. Under Operation Wealth Creation (OWC), it is the objective of Government of Uganda that national policies, interventions and programmes aim at transforming agriculture from subsistence to commercial agriculture with a target of raising household incomes to a minimum UGX20 million per household per year (NPA, 2013). It equally addresses the first two goals of the Global Vision for Humanity in the 2030 agenda of the seventeen Sustainable Development

Goals (UN Summit, 2015). "End poverty in all its forms everywhere", being the first goal and second being, "End hunger, achieve food security, improve nutrition and promote sustainable Agriculture", (UN summit, 2015). Therefore, investigations into factors that are otherwise not perceptible to farmers in a rural setting and affect poultry productivity would add to knowledge and skills for managing poultry enterprises in a rural setting.

1.3 Statement of the problem

Despite the presence of a large number of chickens in Uganda, their contribution to the national economy is still very limited due to thermal stress, tropical disease and nutritional limitations (Kyomugisha, 2008). In the wake of rising consumption of poultry products and its widespread production, stressors including temperatures that fall out of the thermal neutral zone have negative impacts on the health and productivity of chickens thereby affecting nutrition of humans. Due to the steadily rising global average surface temperature with expected rise of 1.4 to 5.8°C by 2100, today heat stress has emerged as a major concern in poultry industry (IPCC, 2007). The industry suffers most in hot climate areas of Asia, South America and the tropics (Daghir, 2008). The challenge is further intensifying with global warming. In chickens, high ambient temperatures affect the endocrine system, reproduction and egg-laying performance. High temperatures also affect feed intake, bird behaviour and subsequently affect growth and productivity of the adult birds. They also lead to a significant reduction in eggshell weight, egg specific gravity and increased eggshell breakage (de Andrade *et al.*, 1977; Lin *et al.*, 2004, Smith, 1987). These factors have implications for the management of poultry projects and performance of such projects, particularly in household settings aimed at improving household income and welfare through poultry keeping.

1.4 Purpose of the study

The purpose of the study was to investigate the effect of thermal stress as a management factor on egg production in layer chickens under deep litter system in household settings.

1.5 Specific objectives

The study was carried out under the following objectives:

a) To assess farmers’ awareness of the effect of thermal stress on egg production.

b) To determine the effect of thermal stress on feed intake and egg production in chickens under deep litter system.

c) To assess farmers’ acceptability of measures to reduce thermal stress in laying chickens.

1.6 Hypotheses

The study was guided by the following hypotheses:

a) Famers are not aware of the effect of thermal stress on egg production.
b) Thermal stress has no effect on feed intake and egg production in layer chickens under deep litter system.
c) Farmers’ cannot readily accept measures to reduce thermal stress in laying chickens.

1.7 Significance of the study

Evidence from documented research on the effect of thermal stress on egg production in layers under deep litter system in Uganda is still limited. Uganda lies in the tropics where daily atmospheric mean temperature is about 28^0C (Anderson *et al*., 2007). A deviation from the TNZ of chickens has a detrimental effect on the life and productivity of the domestic fowl. Either an increase or decrease of temperature from the TNZ is stressful to the laying hen. Thermal stress is a management factor whereby if it is adequately managed, poultry maintains optimum egg productivity.

Poultry keeping is one of the household enterprises that can improve household income and welfare in Uganda. The study assessed the awareness of farmers on the effect of TS on egg production, determined the effect of TS on feed intake and egg production of layer chickens under the deep litter system, assessed farmers' acceptability of measures to reduce TS and suggested appropriate managerial practices to overcome TS for optimum egg production particularly at household level.

1.8 Assumptions of the study

The main assumption of the study was that the layer chickens used for the study were of the same quality, breed and performance. The experimental units were assumed to be homogeneous. All environmental factors except temperature were the same in all replicates such that they did not affect feed intake, rate of lay and egg weight. The treatments were assigned to experimental units in a completely randomized design. Each treatment had an equal chance to end up in a given experimental unit. Feeding, watering, vaccination and other management practices were the same in all experimental units.

1.9 Limitations of the study

The limited sample size of the birds understudy due to resource constraints may not have allowed a deeper investigation of the variations in response to heat treatments. The use of a single breed of layers also did not allow comparison of response to heat treatments by different breeds of poultry. The period of experimentation of two weeks and a number of three treatments only could also have been another limitation.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Literature review focused and elaborated on the relationship between thermal stress and egg production in layers under the deep litter system. Findings of research works on the effect of thermal stress on feed intake, rate of lay, egg weight and behaviour of birds under deep litter system was discussed.

2.2 Effect of thermal stress on feed intake

Over the last three decades, many researchers have studied the regulation of feed intake in birds and animals. Some peptide hormones, for instance, neuropeptide Y (NPY), melanin concentrating hormone (MCH), growth hormone releasing factor, (GHRF), and ghrelin regulate appetite in mammals and birds. Feeding and energy homeostasis are fundamental actions necessary for survival. In birds, the hypothalamus plays a pivotal role in integrating external environmental cues (especially for stressors) and generates the appropriate responses to influence feed intake.

Laying hens undergo various environmental stresses including high or low temperature stress which may last for a few hours, several days or weeks. The hypothalamic pituitary-adrenal (HPA) axis plays an integral role in the maintenance of homeostasis during stress as suggested by Bobek *et al.* (1980). Hypothalamic neurons perceive increases in body temperature and exert an inhibition on cells that are responsible for controlling feed intake.

The feed intake of laying hens decreases when the environmental temperature increases. Bobeck *et al.* (1980) reported lower feed intake of laying hens and egg production in pullets reared under elevated temperatures. The suitable temperature for poultry is between 18^0C and 25^0C. It has been estimated that for every one degree celicious increase in temperature between 21^0C and 30^0C appetite decreases by 1.5%, and for every one degree celicious increase in temperature between 32^0C and 38^0C, the reduction is about 4.6%. The heat production of birds decreases with lower feed consumption under high ambient temperature. Heat stress results from the combined effects of relative humidity and ambient temperature. The effects of heat stress include decreased voluntary feed intake, growth rate and feed efficiency and metabolizable energy intake (Van Kampen, 1977); reduction of egg production (Scott and Balnave, 1988) including degradation of the egg shell quality in the hot season; increased breathing (panting); increased mortality and morbidity (Reece *et al.,* 1972).

High environmental temperatures or heat stress has marked effects on the behavior, food and water consumption, blood composition, cardio-respiratory behavior, heat production and body temperature of poultry.

2.3 Effect of thermal stress on rate of lay

Some researchers have been investigating the effect of high environmental temperature on the performance of different poultry birds. Chronic heat stress is more detrimental to chickens (Aengwanich, 2004). In laying hens, it depresses body weight (Scott and Balnave, 1988), egg production (Muiruri and Harrison, 1991; Whitehead *et al.,* 1998) and eggshell quality (Mahmoud *et al.,* 1996). It is generally accompanied by suppression of feed intake, which could be the cause of the decline in production. In addition, Aengwanich (2004) found out that chronic heat exposure significantly decreased protein digestion. Bonnet *et al.*(1997) reported that the feed digestibility of the different components of the diet (proteins, fats, starch) decreased with exposure of chickens to high temperatures. However, heat exposure during the night did not significantly affect egg or albumen weights (Wolfenson *et al*., 1979). Bobeck *et al.* (1980) indicated that acute heat stress had no adverse effects on dietary amino acid digestibility in laying hens. The differences in the above results could be due to differences in heat stress treatments or the type of birds used. Regarding the decline in the reproductive performance of acutely heat-stressed hens, Mahmoud *et al.* (1996) suggested that alterations in acid-base balance, the status of Ca^{2+} and diminished ability of duodenal cells to transport calcium could be critical factors in the detrimental effects of heat stress on egg production, egg shell characteristics, and skeletal integrity often documented in laying hens.

The regulatory mechanism responsible for impaired reproductive efficiency of hyperthermic hens has been suggested to be linked to impaired ovarian function, as demonstrated by a significant reduction in ovarian weight and the number of large follicles observed at days 6 and 15 in heat stressed (42°C) White Leghorn hens compared to those in thermo-neutral environments (24 to 26°C) (Rozenboim *et al*., 2007). Marsh and Dawson (1989) and Rozenboim *et al*. (2007) suggested a reduction in ovarian blood supply because of peripheral vasodilation as a possible underlying mechanism responsible for the characteristic reproductive failure of heat-stressed hens. Insufficient blood supply to the ovary in contrast to the increased supply to the outer skin might be one of the emergency physiological responses that alleviate endogenous thermal load via vasodilatation of the skin, shank, comb and wattle. The ovary plays a critical and ubiquitous role in the reproductive activity of female poultry. Follicles (small white follicles) produced by the ovary are the major sources of oestrogen, producing over 80% of the total ovarian oestrogen (Senior and Furr, 1975; Armstrong, 1984; Nitta *et al.,* 1991). Oestrogen from ovarian follicles is also responsible for the growth of the reproductive tract (Campbell *et al*., 2003), while progesterone, a major steroid hormone is secreted by the granulose cells of large ovarian hierarchical follicles of laying hens (Huang *et al*., 1979; Barh *et al.,* 1983; Porter *et al.*, 1991). Mahmoud *et al.*, (1996) and Kohne (1976) reported that plasma calcium levels was significantly decreased in laying birds when they were exposed to high temperatures. Sohail *et al.,* (1999) also reports that the retarded production is due to oxidative damage of some internal organs in layers. Heat stress is also thought to increase maintenance requirements of birds (Yahav, 2007; Huston, 1983). The enhanced energy expenditure during heat stress is believed to originate from panting, sweating, and other physiological responses that take place in response to thermal stress (Hughes, 1986).

2.4 Effect of thermal stress on weight of eggs produced

Egg weight is generally affected at temperatures above 24^0C. It falls by about 0.4% per 1^0C between 23 and 27 ^{0}C; above 27 ^{0}C the reduction is about 0.8% per 1^0C. Growth at start of lay is reduced above 24^0C and is extremely low above 28^0C (Mashaly *et al.*, 2004). The feed conversion ratio is minimum at a temperature around 28^0C, above 28^0C it increases due to the lowering of production. These figures are only indicative, because the speed of moving air and its relative humidity affect thermoregulation. In the absence of any specific methods of temperature control, the heat loss by convection is proportional to the difference between environmental and bird body temperatures. The quantity of heat, which needs to be removed, increases drastically with increases in ambient temperature. If it is not possible to lose this, the thermoregulatory mechanisms gradually come into play with the consequential lowering of feed consumption. During the laying period energy intake is not modified by dietary energy level. Growth and production are reduced more and more as the temperature is increased. In rearing, as in production, increasing the level of energy in the feed does not avoid the loss of production due to heat (Reece *et al.*, 1983).

Losses to the Australian egg industry, resulting from poor egg shell quality which subsequently affects egg weight, have been estimated at 10% or more of total egg production. One known cause of egg shell quality problem which occurs commonly in Australia is heat stress caused by high ambient temperatures (Balnave *et al.*, 1987). The extent of stress will be influenced by factors such as humidity, and the extent to which the hens have become acclimatized. The deleterious effects of heat stress on eggshell quality and egg weight appear to be due to several reasons. Feed intake is usually depressed (Marsden and Morris, 1987) and this may result in a decreased calcium concentration. Also, at high temperatures, birds pant to enhance evaporative cooling. Panting results in respiratory alkalosis which is caused by loss of carbon dioxide from the blood and involves an increase in the blood ph. (Mongin, 1978). This, in turn, decreases the proportion of the blood calcium that is in the ionised form and thus reduces the amount of calcium which is available for egg shell formation. The activity of carbonic anhydrase (the enzyme which produces bicarbonate for egg shell formation) may also be reduced during heat stress and blood flow to the uterus (shell gland) may decrease. These reactions result in production of small sized eggs with thin shell all of which affect egg weight.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Introduction

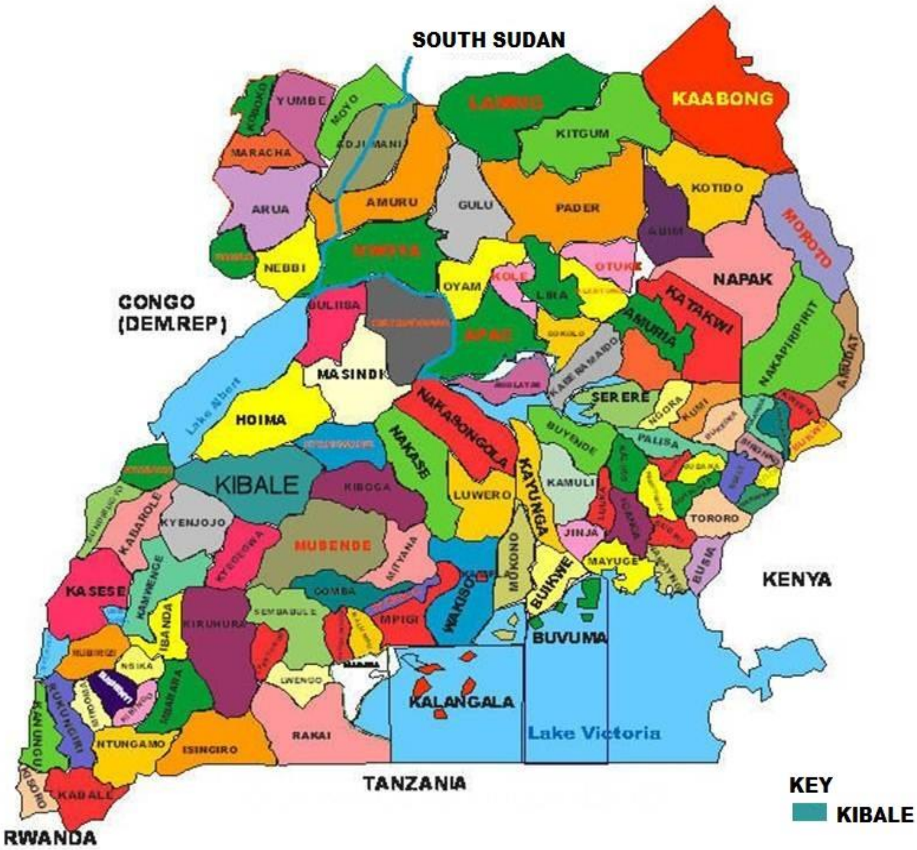
This study was carried out in Kibaale, Mid-Western Uganda to assess the effect of thermal stress as a management factor on egg production in layer chickens under deep litter system in household settings. The study had three aspects, that is to say; a survey of the farmers' awareness of the effect thermal stress on egg production, an experiment to determine the effect of thermal stress on egg production and an assessment of the farmers' acceptability of measures to reduce thermal stress in layer chickens under deep litter system.

3.2 Study methodology

3.2.1 Study area

Although effective first July, 2016 Kibaale district was divided into three districts of Kibaale, Kagadi and Kakumiro, the study covered the entire geographical area of the mother district. The experiment was conducted on a poultry farmer's farm in Mabaale Town Council while the survey was conducted all over the three districts. Kibaale is located in the Western Region of Uganda. It is bordered by Hoima district to the north-east, Mubende to the east, Kyegegwa to the south-east, Kyenjojo to the south-west and Ntoroko to the west. The district headquarters at Kibaale district are approximately 219Km by road west of Kampala, Uganda's capital and largest city. Its coordinates are $00^0$47'00.0"N, $31^0$05'00.0"E (Latitude: 0.78333; Longitude: 31.083333). It is at an altitude of 1,130meters (3,710ft) above sea level. Its daily temperature range is 22-32^0 C depending on the season of the year. Humidity ranges from 21% to 31% but is greatly dependent on the season of the year (Wikipedia, 2017). It has a total area of 5,100.8km^2 of which 4, 245.8 km^2 is covered by land and 855$km^2$is covered by water. The annual rainfall range of 800 to 1500mm is received in the region. It is mainly covered by the savannah vegetation. The district is located in the equatorial climatic region of

Uganda (Fig.1). It has five constituencies with twenty nine sub counties and three town councils.



Source: UIHB, 2008.

Figure 1: Map of Uganda showing the location of Kibaale

3.2.2 Study population

Kibaale district has a total population of 717,500 people (UBOS, 2013) out of which 323 have commercial poultry projects mainly in urban and peri-urban centers. The study focused on the 323 commercial poultry farmers, (KDFA, 2016) as its target population.

3.2.3 Sampling of study population

Sample size was determined according to Mugenda and Mugenda (2003) who asserts that a sample size of 30% of the target population is a sufficient sample in data collection for a research study. The sample size of farmers was 30% of 323 farmers which made 96.9, that was approximated to 100 respondents. For sub counties 30% of 32 sub counties/town councils made 9.6, which was approximated to 10 sub counties/town councils.

3.2.4 Sampling procedure

The sampling carried out aimed at collecting data from all the three districts of Kibaale, Kagadi and Kakumiro which the government of Uganda recently created out of former district of Kibaale. Each of the two districts of Kakumiro and Kagadi contributed 40% of the respondents to the study while from Kibaale district only 20% was sampled. This is because Kibaale is relatively smaller than the other two districts. Kibaale district has only one constituency of Buyanja while the other districts have two constituencies each. All the five constituencies of Buyaga west, Buyaga east, Buyanja, Bugangaizi east and Bugangaizi west contributed an equal number of respondents of 20%. Purposive sampling was used to sample urban and peri-urban sub counties/town councils since they were the ones mostly practicing commercial poultry farming. Simple random sampling was used to select ten farmers from each of the considered sub county/town council.

3.3 Data collection

Data was collected from poultry farmers on their farms through surveying to assess their awareness of the effect of thermal stress on egg production on layer chickens under deep litter system and also to assess farmers' acceptability of measures to control thermal stress. The questionnaire was first pre-tested before the actual data collection. In addition to questionnaire data collection, general inspection regarding thermal stress control and housing for poultry was carried out. A Complete Randomized Design experiment was used to obtain data for determining the effect of thermal stress on feed intake and egg production.

3.3.1 A survey of the farmers' awareness of the effect of thermal stress on egg production.

In a bid to achieve this, a pre-tested self-administered questionnaire was used to collect data from the poultry farmers on their poultry farms. Respondents' bio data/demographic characteristics were captured and recorded directly into the spaces/boxes provided in the questionnaire. Farmer respondents' main farming activities were a second major item to bio data on which information from the respondents was obtained in the same way. It focused on farmers' main farming business, their experience in poultry keeping and the type of birds most kept by the poultry farmer respondents. Additionally, data about the poultry farmer respondents' main source of livelihood, size of land (in hectares) used for agriculture, number of birds kept by each respondent and poultry farmers' average monthly income from their poultry projects was collected using a questionnaire survey by filling in the blanks according to the respondents' responses.

In another section of the questionnaire, data regarding farmers' awareness of the effects of thermal stress on egg production was collected. Poultry farmer respondents were required to state whether they had knowledge of the effect of thermal stress on layers. They were also asked to state whether they had experienced thermal stress on their poultry farms. Those who had experienced it were also interrogated on the type of thermal stress that they experienced on their poultry farms, the type of birds that was most affected by each type of thermal stress and the season or month of the year when each type of thermal stress was most faced. Respondents were further asked to identify the indicators of thermal stress in a deep litter house. Poultry farmer respondents' opinion on whether thermal stress causes serious economic losses in poultry birds under deep litter system was also sought.

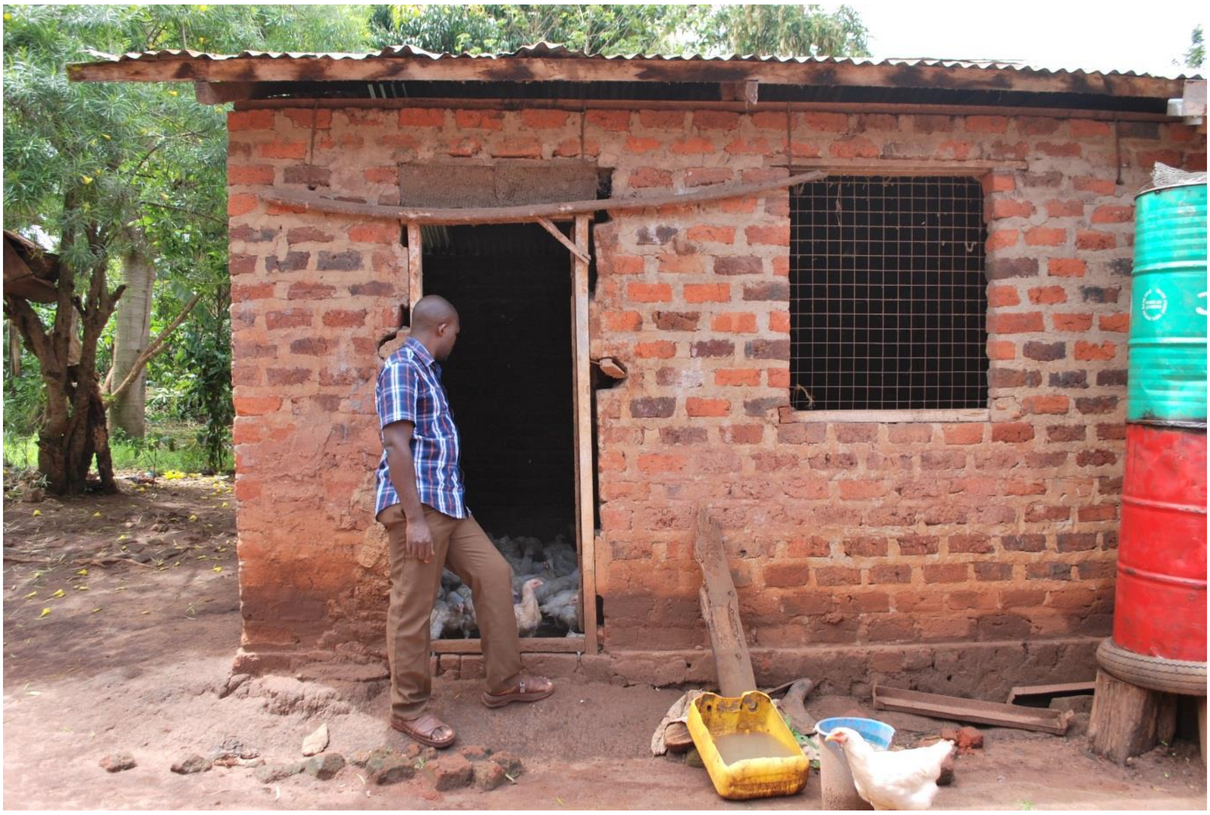


Plate 1: Researcher at one of the respondents' broiler poultry house hold farm.

3.3.2 Experiment to determine the effect of thermal stress on poultry production

3.3.2.1 Experimental Design

A Completely Randomized Design, (CRD) experiment was used to study the effect of thermal stress on poultry production under deep litter system. In this experiment, three thermal treatments were used. The first treatment, (A), was a temperature of 18^0C, the second treatment (B) was a control, in which layers were kept at temperatures within the thermal comfort zone of 24^0C, (Etches *et al*., 1995). In the third treatment (C), birds were kept at a temperature above their thermal neutral zone, i.e., 32^0C. Each treatment ran for 12 hours of day time for two weeks. High temperature treatments were achieved by using portable luxell LX-2830 halogen room heaters running from morning to evening in each experimental unit receiving this treatment. Low temperature treatments were achieved by using portable evaporative air coolers of 50-60HZ, 80W, 0.8amps, and 230V alternating current in each experimental unit receiving this treatment. The number of layers at the age of 24 weeks used in each replicate was 15. Replication was done four times to make a total of 12 replicates. A sample size of 180 experimental layers was used in this study.

All the 180 birds were kept under the same management practices and conditions. Temperature was varied accordingly to create the three treatments, monitored and regulated to ensure that it was maintained within a narrow range of the required degree. The amount of feed offers and any leftovers were collected and weighed on a daily basis for all the fourteen days of the experiment. The daily number of eggs laid was recorded for each experimental unit and treatment at the end of each day for the duration of the experiment. Weight of the laid eggs for each replicate was equally recorded on a daily basis. The weight of eggs was measured using an electronic weighing scale.

3.3.2.2 Experimental birds

A total of 180 Hy-Line brown layers at the age of 24 weeks were used. These birds were obtained in a slot of 500 as one day old chicks from Biyinzika Poultry International, Uganda. Currently, Hy-line International claims that the Hy-line brown layers are the world's most balanced egg layer. The Hy-line brown produces over 355 red brown eggs in her laying regime. It can produce eggs for about 80 weeks. It grows faster and begins laying early with optimum egg size. It has a high feed efficiency which makes it profitable. Hy-line international was founded in 1936 in the USA as the first modern layer genetic company. It was incorporated by Biyinzika Poultry International in Uganda on 26 August, 1990. The susceptibility to heat stress varies among strains (Arad *et al.,* 1975) and it is reasonable to assume that some strains may be better suited to high ambient temperatures than others. It is, therefore, of particular interest to study the effect of thermal stress on the performance Hy-line brown in Uganda.

Plate 2: Experimental birds

3.3.2.3 Variables measured in the experiment

Two basic variables were recorded on daily basis to study whether thermal stress affected poultry production. These were feed intake and egg production. Feed intake was estimated by measuring daily feed offers and leftovers. The difference between feed offers and leftovers was taken to be the daily feed intake. Egg production was studied basing on the number and weight of eggs produced by each experimental unit in the experiment.

3.3.2.4 Data collection procedures

Recording was done on a daily basis on all the days of the experiment. Feed offers, leftovers, number of eggs produced and egg weight were recorded. Precision was a major consideration during recording to avoid errors. Weights of feeds in kilograms were weighed using an Ohaus spring balance of 8008-MN with a dimension of 23mmX193mmX46mm, accuracy of 0.1g and maximum capacity of 5000g, made in India while egg weights in grams were weighed using a digital Virgo acromec pocket electronic weighing scale of 0.001g accuracy and capacity of 200g, made in China.

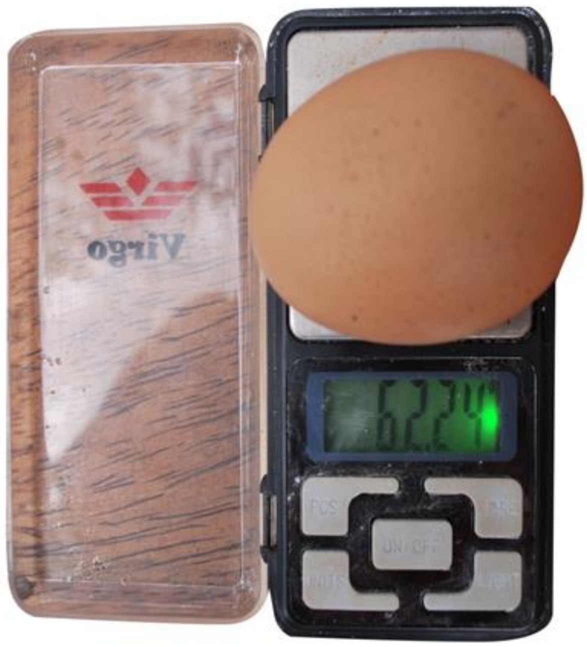


Plate 3: Weighing an egg using a digital electronic weighing scale

3.4 Data management and analysis

Survey data was entered using Microsoft excel spreadsheet and analyzed using SPSS (Version, 17) to assess farmers' awareness on the effect of thermal stress on egg production and farmers' acceptability of measures to reduce thermal stress. Experimental data was subjected to one-way Analysis Of Variance (ANOVA) using GenStat 14th edition statistical package (VSN International 2011) to generate Means, Least Significant Differences (LSDs), Standard Error of Differences (SEDs) and F-probability at different thermal treatments of 18^{0}C, 24^{0}C, and 32^{0}C. The means, LSDs and SEDs generated were extracted from the GenStat output and tabulated as shown in the results section and the appendix. The ANOVA tables were generated at a significance level of 95%, ($P<0.05$).

CHAPTER FOUR: RESULTS

4.1 Respondents' demographic characteristics

The demographic characteristics of the respondents are shown in Table 1 below.

Table 1: Respondents' demographic characteristics

Variable	Level	Percentage
District		
	Kagadi	40
	Kibaale	20
	Kakumiro	40
Constituency		
	Buyaga East	20
	Buyaga West	20
	Buyanja	20
	Bugangaizi West	20
	Bugangaizi East	20
Gender		
	Male	41
	Female	59
Age (years)		
	Below 20	00
	21-40	32
	41-60	59
	Above 60	09
Level of Education		
	No School	00
	Primary	57
	Secondary	31
	Tertiary	12
Marital Status		
	Single	04
	Married	93
	Divorced	00
	Widow	03

The data shown in Table 1 above show the respondents' demographic characteristics indicating that more than half (59%) of the respondents were female. In regard to their age, none of the respondents was 20 years or less. Only about one third (32%) of the respondents was between 21-40 years. Majority (59%) of the respondents were above the age of 40 and 9% were even above the retirement age of civil service of 60 years. Concerning their academic background, all the poultry farmer respondents had at least been to school. More than half (57%) of the respondents had studied in a primary school. About a third of them (31%) had at least attended secondary school while a few had had a tertiary training in a collage, farm school, university, and other institutions that offer tertiary education. Findings also revealed that the greatest number of the poultry farmer respondents (93%) was married. None of the farmers had divorced while very small percentages were either single (04%) or widowed (03%).

4.2: Major Farmer respondents' farming activities

The major farming activities of respondents in the study area are given in Table 2 below.

Table 2: Major farming activities of respondents in the study area

Variable	Frequency (n=100)	Percentage
Commercial poultry farming	33	33
Back yard poultry keeping	00	00
Piggery	00	00
Dairy and beef farming	00	00
Crop farming	67	67
Others, specify	00	00

The results in Table 2 show that the major farming activities of poultry farmer respondents in the study area were crop farming and commercial poultry farming. Majority of the respondents (67%) did crop farming as their major economic activity while about a third (33%) of the respondents had commercial poultry farming as their main farming activity.

There were also other farming activities which respondents participated in such as back yard poultry keeping, piggery, beef and dairy cattle farming, however, these were not major farming activities for most of the poultry farmer respondents.

The respondents' experiences in poultry farming are given in Table 3 below.

Table 3: Respondents' experience in poultry farming

Variable	Frequency (n=100)	Percentage
One year or less	13	13
Two-three years	54	54
Four-five years	24	24
Six years and above	09	09

Results in Table 3 show poultry farmers' experiences in poultry keeping. The results indicate that only 13% of the respondents were starters in the poultry business. They had an experience of one year or less. They were handling the first stock in the poultry business. More than a half (54%) of the poultry farmer respondents had been in the poultry keeping business for two to three years. About a quarter of them (24%) had been in the poultry keeping business for four to five years. A few of them (09%) had been keeping poultry birds for six years and above. The findings indicate that commercial poultry keeping is one of the new farming business enterprises that people are adopting to embrace wealth creation in rural areas of Uganda.

The types of poultry birds kept by poultry farmer respondents are shown in Table 4 below.

Table 4: Type of poultry birds kept by poultry farmer respondents.

Type of poultry birds	Frequency (n=100)	Percentage
Layers	76	76
Broilers	21	21
Dual purpose	03	00

The results in Table 4 above show that slightly more than three quarters (76%) of the poultry farmer respondents reared layer birds under deep litter system. About a quarter of them (21%) reared broilers while a very small fraction of the respondents reported that they were rearing Kuroilers that were dual purpose. These results show that most poultry farmers in Kibaale were interested in egg production. Therefore, finding ways of overcoming factors that reduce egg production is of great importance to them.

The major sources of income of the poultry farmer respondents are shown in table 5 below.

Table 5: Major source of income of farmer respondents.

Source of livelihood	Frequency (n=100)	percentage
Subsistence farming	09	09
Commercial Agriculture	43	43
Employment	31	31
Others (agribusiness and other businesses)	17	17

The results in Table 5 above show that most of the respondents (43%) were commercial agricultural farmers, growing crops such as maize from which maize bran would be obtained to feed their birds. About a third (31%) of the respondents was either employed or retired civil servants such as teachers, nurses and agricultural extension officers. They were supplementing their monthly salaries/pension with income from poultry projects. Some respondents (17%) were engaged in other economic activities such as agribusiness, agro-processing and general merchandise trade. Those dealing in agro processing obtained maize and rice bran to feed their poultry birds from their milling machines. A few of the respondents were subsistence farmers, producing a little agricultural output beyond home consumption which they sold for money.

The poultry farmer respondents' size of land in hectares used for agriculture is shown in

Table 6 below.

Table 6: Size of land used for agriculture (hectares) by farmer respondents.

Size of land (hectares)	Frequency (n=100)	Percentage
Below 0.5	09	09
0.5-1	14	14
1.1-1.5	10	10
1.5 And above	67	67

The results in Table 6 above show the size of land used for agriculture by farmer respondents. The results reveal that about ten percent of the respondents had land equivalent to half a hectare or less. Another small portion of the respondents (14%) were found to be using between 0.5 to 1.0 hectare of land for agriculture. The percentage of farmers using 1.1 to 1.5 was even smaller standing at 10%. More than a half (67%) of the respondents had more than 1.5 hectares of land under agricultural use, although some land was said to be some kilometers away from home.

The number of birds kept by farmer respondents is shown in table 7 below.

Table 7: Number of birds kept by poultry farmer respondents.

Number of birds	Frequency (n=100)	Percentage
100 birds or less	00	00
101-200 birds	11	11
201-300 birds	13	13
301-400 birds	15	15
401-500 birds	28	28
501 and more	33	33

The results in Table 7 above indicate that none of the farmer respondents was keeping 100 birds or less. These results also show that the numbers of farmers keeping higher number of birds was increasing. However, only about one tenth of the farmers kept 101 to 200 birds, a relatively higher number of the respondents (13%) kept 201 to 300 birds. The 301 to 400 bird bracket had more farmers (15%) compared to the previous bracket. More than a quarter (28%) of the poultry farmer respondents kept 401 to 500 birds. The highest proportion of the farmer respondents of about one third (33%) reared 501 birds or more. The number of birds kept shows that they can have a commercial purpose since a high number of birds kept can have a good profit margin.

The average monthly income of the farmer respondents rearing poultry birds is shown in

Table 8 below.

Table 8: Respondents' average monthly income from poultry enterprises.

Monthly income	Frequency (n=100)	Percentage
0-100,000/=	00	00
100,001/= - 200,000/=	00	00
200,001/=-300,000/=	27	27
300,001/= and above	73	73

The results in Table 8 above show that none of the farmer respondents earned less than 200,000/= Ugandan shillings a month from poultry projects including those who were keeping 200 birds or less. More than a quarter (27%) of the respondents earned between 200,001/= to 300,000/= Ugandan shillings per month while the remaining about three quarters (73%) of the poultry farmer respondents earned more than 300,000/= Ugandan shillings per month from their poultry projects.

4.3 Farmers' awareness of effect of thermal stress on egg production on layer chickens under deep litter system.

In the questionnaire (Appendix 1) poultry farmer respondents were asked to indicate whether they were aware of thermal stress and its effects on layer chickens under deep litter system. The results showed that majority of the farmer respondents (82%) were unaware of thermal stress and its effects on layer chickens under deep litter system. A few of the respondents (18%) reported having knowledge of thermal stress and its effects on layers chickens under deep litter system on their poultry farms. All the farmer respondents who indicated to be aware of thermal stress also reported that they had experienced it on their poultry farms. Most (83.33%) of these respondents had noticed low temperature stress particularly in chicks which were obvious victims of low temperature stress under the deep litter system. A few

(16.66%) respondents reported having noticed both low and high temperature stress in their deep litter houses. These results show that thermal stress is a common challenge to poultry farmers. Farmer respondents who indicated having experienced thermal stress were further interviewed on the type of thermal stress they experienced most. Most of them (83.33%) had experienced low temperature stress on their poultry farms especially among chicks. The rest of the respondents (16.66%) had experienced both low and high temperature stress.

The types of chickens affected by thermal stress as reported by farmer respondents are shown in Table 9 below.

Table 9: Type of chickens affected by thermal stress as reported by farmer respondents.

Chickens	**Poultry farmer respondents (%)**	
	LTS	HTS
Layers	11.11	11.11
Broilers	5.55	11.11
Dual purpose	00.00	00.00
Chicks	83.33	77.78

The results in Table 9 above show that of the farmer respondents who responded that they were aware of the effect of thermal stress on chickens, most of them (83.33%) indicated that low temperature stress occurs mostly in chicks. Few (11.11%) poultry farmer respondents reported that low temperature stress affects layers. Only 5.55% of the farmer respondents reported that low temperature stress can occur among broilers. None of the poultry farmer respondents reported the dual purpose scavenger birds to be victims of either high or low temperature stress.

The results further show that more than three quarters (77.78%) of the farmer respondents who had knowledge of thermal stress, indicated that high temperature stress mainly affects chicks. Few of them (11.11%) reported that HTS can have detrimental effects among layers.

Another similar smaller number of farmers reported that high temperature stress can also affect broilers.

The seasons of the year when chickens are temperature stressed are shown in Table 10 below.

Table 10: Season of the year when chicks are thermal stressed as reported by poultry farmer respondents.

Season	Poultry farmer respondents	(%)
	LTS	HTS
Dry season only	00.00	83.33
Wet season only	22.22	11.11
Year round	77.77	16.66

The results in Table 10 above show that majority (77.77%) of the famers who had knowledge of thermal stress, reported that low temperature stress especially among chicks can occur on a poultry farm throughout the year. This implies that regardless of the season of the year, low temperature stress must be controlled especially among chicks. About a quarter (22.22%) of the respondents who had observed low temperature stress in their birds reported that it was more severe in the wet season especially among chicks. Poultry farmer respondents further reported that low temperature stress among layers is characterized by increased feed intake, decreased egg production and water intake and crowding close to each other or to a source of heat. They further reported that noise stress made by rain on iron sheet roofing of poultry houses was another stressing factor that was causing a drop in egg production during the rain/wet season. On the other hand, results in table 10 also show that most respondents (83.33%) reported that high temperature stress is mainly a poultry production constraint in the dry season. Few respondents (11.11%) reported that chickens can be high temperature stressed even during the wet season. A small number of the respondents (16.66%) reported that high temperature stress can be a poultry production problem throughout the year.

Temperature stress indicators as observed and reported by the farmer respondents are given in Table 11 below.

Table 11: Indicators of temperature stress as reported by poultry farmer respondents

Indicator	**Poultry farmer respondents**	**(%)**
	HTS	LTS
Crowding on sources of heat	0.00	66.66
Increased water intake	16.66	0.00
Reduced water intake	0.00	5.55
Reduced feed intake	22.22	0.00
Reduced quantity of eggs	11.11	11.11
Panting and spreading wings	44.44	0.00
Isolation	5.55	0.00
Increased Mortality	0.00	5.55
Increased feed intake	0.00	11.11

The results in Table 11 above show that about a half (44.44%) of the poultry farmer respondents who had knowledge of thermal stress reported that the main indicator of high temperature stress was panting and spreading wings apart and about a quarter (22.22%) of the respondents reported reduced feed intake. A few respondents (16.66%) reported that they realized that birds were high temperature stressed if water consumption went above daily usual water intake. A small number (11.11%) of the farmer respondents reported that high temperature stress caused a drop in egg production. The lowest number (5.55%) of the respondents reported that HTS caused isolation of birds from one another and running away from materials that may produce or store heat.

On the other hand, results in Table 11 also show that more than a half (66.66%) of the poultry farmer respondents who had knowledge of thermal stress reported the crowding of birds over each other or over a source of heat as the indicator of LTS. A few of the respondents (11.11%) reported that LTS increased feed intake. A small number of less than a quarter of the respondents reported reduced egg quantity as an indicator of LTS while a smaller number reported reduced water intake. A small number of the poultry farmer respondents (5.55%)

reported increased mortality rate particularly among chicks, without an outbreak of a disease as an indicator of LTS.

In the questionnaire farmer respondents who had knowledge of thermal stress were also asked to indicate whether thermal stress caused serious economic losses and needed immediate and effective control measures. Majority of the respondents (88.89%) reported that thermal stress did not cause fundamental economic losses and does not need immediate attention to control it on their poultry farms. Few of the respondents (11.11%) believed that thermal stress caused fundamental economic losses and needed immediate, appropriate and effective control methods within deep litter poultry houses.

4.4 Effect of thermal stress on egg production

The results in Table 12 below show that feed consumption was highest ($p<0.05$) at low temperature (18^0C) treatment and lowest ($p<0.05$) at the high temperature (32^0C) treatment. At low temperature treatment feed intake increased by 9.5% while at high temperature treatment feed intake reduced by 20.8%. Feed consumption at the TCZ (24^0C) was in between that at the low and high temperature treatment consumption levels. The number of eggs laid per day was highest ($p<0.05$) at the TCZ (24^0C) and lowest ($p<0.05$) at the high temperature (32^0C) treatment. The number of eggs laid decreased by 40% at high temperature treatment and by 33.33% at low temperature treatment. Average egg production per day at low temperature (18^0C) treatment was between that at the TCZ and the high temperature (32^0C) treatment. Egg production at low temperature treatment was, however, almost as low as egg production at high temperature treatment. Accordingly, egg weight in grams per day was always highest at the TCZ (24^0C) and lowest at the high temperature (32^0C) treatment. Average egg weight at the low temperature treatment (18^0C) was between egg weight at the TCZ and the high temperature treatment but closer to that at the high temperature treatment than that at the TCZ. This daily average egg weight for all the days of the egg collection during the experiment reduced by 36.6% and 42% at low and high temperature treatments respectively. Therefore, egg number, egg weight and feed consumption were significantly different at different temperature treatments.

Table 12: Effect of thermal stress on egg production

	Temperature Treatments (^{0}C)					
Response	18	24	32	LSD	SED	F-ratio
Feed intake (g/day)	2549.9^a	2328.1^b	1843.1^c	54.24	23.98	<.001
Number of eggs per day	10.0^b	15.0^a	9.0^b	0.46	0.20	<.001
Weight of eggs (g)	523.5^b	826.6^a	479.4^c	18.87	8.34	<.001

Means in rows with different superscripts are significantly different (p<0.05). LSD=Least Significant Difference, SED=Standard Error Difference

4.5: Farmers' acceptability of measures to control thermal stress

Results in table 12 indeed indicate that there is need for controlling thermal stress because it retards egg production. Temperature treatments above the TCZ reduce feed intake, rate of lay and egg weight. Tables 9 through to 11 indicate that most farmers were unaware of thermal stress and its effects on layer chickens. In the questionnaire farmer respondents who had knowledge of thermal stress were asked to indicate whether they undertook thermal stress control measures in their deep litter. All farmers that had knowledge of thermal stress reported that they controlled it.

The poultry farmer respondents who had knowledge of thermal stress were further asked to indicate the method/methods they used to control low temperature stress. The results are shown in table 13 below.

Table 13: Respondents' methods of controlling low temperature stress in layers chickens under deep litter system.

Variable	Frequency (n=18)	Percentage (%)
Using charcoal stoves	00	00.00
Using burning charcoal in pots	00	00.00
Using electric heaters	00	00.00
Using air conditioners	00	00.00
Proper stocking density	18	100.0

Results in table 13 above indicate that all poultry farmer respondents who controlled low temperature stress used proper stocking density method. They argued that once layers are properly stocked in the deep litter house, they produce enough heat to produce enough heat to sustain them.

Through the questionnaire farmers were also asked to indicate whether they controlled high temperature stress on their farms among layers under deep litter system. Results indicated that all farmer respondents who had knowledge of thermal stress controlled high temperature stress on their poultry farms among layers under deep litter system. They were further asked to indicate the method/methods they used to control high temperature stress.

The methods used by farmers to control high temperature stress are shown in Table 14 below.

Table 14: Respondent's methods of controlling high temperature stress among layer chickens under deep litter system.

Variable	Frequency (n=18)	Percentage (%)
Proper stocking density	03	16.67
Proper ventilation	03	16.67
Using electric coolers	00	00.00
Using air conditioners	00	00.00
Others, adequate water	12	66.67

The results in Table 14 above show that two thirds of poultry farmer respondents who were knowledgeable about thermal stress and controlled it on their poultry farms in deep litter houses in which layer chickens were kept indicated that they controlled it by supplying adequate water to layer birds during times of high temperature stress. Each half of the remaining third of poultry farmer respondents was using either proper stocking density or proper ventilation to control HTS among layers.

There are thermal stress control measures recommended by Hy-line International and the 1994 International Welfare of Livestock Regulations for use in the control and management of thermal stress. These methods are mainly electrical methods. In the questionnaire farmer respondents who were aware of thermal stress were asked to indicate their acceptability of the recommended methods to control thermal stress. The farmer respondents' responses are shown in Table 15 below.

Table 15: Respondents' acceptability of methods recommended by Hy-line international and the 1994 International Welfare of Livestock Regulations to control thermal stress.

Variable	Frequency (n=18)	Percentage (%)
Yes	02	11.11
No	15	83.33
Undecided	01	5.56

Results in Table 15 above show that more than three quarters (83.33%) of the farmer respondents would not readily accept to take up recommended methods to control thermal stress. A very small section of the farmers (11.11%) would accept to adopt the recommended methods while yet another small fraction of the farmer respondents was undecided.

CHAPTER FIVE: DISCUSSION

5.1 Introduction

This study was carried out to assess farmers' awareness of the effect of thermal stress on egg production, determine the effect of thermal stress on feed intake and egg production in layer chickens and to assess farmers' acceptability of measures to reduce thermal stress among laying chickens.

5.2 Respondents

5.2.1 Demographic characteristics

Most of the respondents in this research study were female (Table1). These findings concur with those of Babatunde *et al.,* (2012) who reported the majority of the poultry farmers in Nigeria were females. A farmer based research in which most respondents are female can yield valid results since agriculture and the welfare of many rural households in developing countries engages women. This is in line with FAO (2011) in which women are said to be playing a pivotal role in the day to day agricultural activities in homes and farms where poultry is basically reared. Secondly, majority of the respondents were 41 years and above (Table 1). Most Africans at the age of forty have old children. These children provide domestic labour at home including participating in agricultural activities since one in five of Africa's children are in child work and the vast majority is performed in agriculture (ILO, 2019). Close to ten percent of the respondents were retired civil servants above the age of 60 years (Table 1). These carried out poultry farming as both a hobby and an economic activity to supplement their monthly pension. They were always there to take care of their birds. The findings are in accordance to those of Guangcheng *et al.,* (2015), who reported that aging isolates people from rigorous farm activities to passive farm activities such as taking care of birds. In regard to education background (Table 1), none of the respondents was found not to have gone to school. The highest percentage of the respondents had at least been to a primary school. Also many of the respondents had at least been to a secondary school while the rest had been at a tertiary institution such as a college, nursing school, farm school, technical school or a university. Such a level of education observed is expected to have a positive influence since most poultry farmers could read, write, keep records, read instructions on feeds and other poultry inputs. They can also learn and understand basic skills in poultry keeping to help them improve their poultry projects performance and income. Education is also important in agriculture because it makes agriculture less harmful to the environment, reduces contamination of feeds and food, increases output, profits and improves on efficiency standards, (USDA, 2019). The findings concur with those of Babatunde *et al.,* (2012) who reported a high literacy rate among poultry farmers in Nigeria. Most of the respondents were also married and with children (Table 1). This implies that the birds can always have someone to attend to them, either by parents or children. The results were also in line with those of Alabi and Haruna (2005) who reported that 61% of the poultry farmer respondents were married with 3-5 children. The results of this study are also in consonant with Bamiro (2008) who revealed that the average family size of poultry farmers in Ibadan, Oyo state was five.

5.2.2 Farmer respondents' major farming activities

Although the respondents had major farming activities, none of them practiced a single farming activity. Most of them had crop farming as their major farming activity (Table 2). This implies that farmers can locally get feeds of plant origin such as maize bran to feed their birds. Less than a half of the respondents were commercial poultry farmers. This implies that farmers were rearing poultry birds for business as well as participating in other enterprises. A high level of diversification was noticed among the poultry farmer respondents because farmers were also involved in other farming activities such as piggery, dairy and beef farming, back yard poultry farming among others. This finding is backed by Milestadt *et al.,* (2012), who reported that diversified systems such as crop-livestock systems are an interesting alternative and path forward for agricultural development in the face of climate change and volatility of commodity and input prices. Farming systems need to be robust to overcome hazards (Milestadt *et al.,* 2012), therefore, diversity should be a major lever of that flexibility, whether that be through activities such as crop and livestock for sale or resources such as crop, fodder, intercrop cultures, permanent grasslands, among others. (Andrieu *et al.,* 2007). The integration is of further importance because whereas crops provide feeds for livestock, livestock provides manure for crops.

In regard to experience in poultry management, most of the respondents (54%) had been in the poultry farming business for two to three years (Table3). Few of the respondents were just one year old or less in the poultry farming business. Most farmer respondents had been in the poultry farming business for six or more years. These results imply that most of the respondents had a good experience required to rear poultry birds. They had acquired basic skills such as vaccination, feed mixing, identification of sick birds for culling and treatment, among others. Experience in poultry management is important because Mukhtar (2012) argued that the more experienced the farmer is the more profit efficient he/she will be. Nwaogu (2006) also argues that the more the years of layer farming the more exposed the farmer becomes and the more efficient he is expected to be. Results in Table 4 also reveal that most of the respondents (76%) reared layer chickens under deep litter system. A few of the respondents reared broilers while as few as 3% had dual purpose birds that they described as Kuroilers. The findings are in consonance with those of Flake and Ashitey (2008) who reported that most poultry farmers in the rural and peri-urban areas of Ghana were shifting from meat production to egg production. The results imply that the respondents were the right sample for the study since the study looked at the effect of thermal stress on layer chickens under deep litter system and most of them were keeping layers under deep litter system. Most poultry farmer respondents expected better financial returns for wealth creation from eggs. Layers are also of preference because when they reach laying age they provide a daily income through the sale of the laid eggs for about fifty weeks. At the end of the egg production period off layers are finally sold off for meat.

A small number (9%) of the poultry farmer respondents (Table 5) practiced subsistence farming as their major source of livelihood. The majority of the respondents depended on commercial agriculture while some were employed civil servants who reared poultry birds to supplement their monthly salary incomes. The remaining 17% was involved in business, produce dealing and agro processing. The findings imply that some respondents had selected poultry farming as an enterprise to supplement their income for wealth creation. Those dealing in agro processing obtained bran from their agro processing mills to feed their birds. The findings coincide with those of Stamen (2010) who reported that maize provides more feed for livestock than any other cereal grain and is the preferred grain for feeding poultry birds worldwide. FAO (2005) also reported that up to 65% of the maize grown worldwide is used for livestock feeds. Findings also showed that respondents used large pieces of land for agriculture (Table6). Those with one and a half acres and less under agricultural use accounted for 33%. All the remaining had two acres of land or more under agricultural use. This implies that the poultry farmer respondents had enough land for mixed farming. Mixed farming is good because birds provide manure for crop fields while crops provide feeds for birds. This finding is backed by Milestadt *et al.*, (2012), who reported that diversified systems such as crop-livestock systems are an interesting alternative and path forward for agricultural development in the face of climate change and volatility of commodity and input prices.

The research findings also revealed that majority of the respondents reared 400 birds or more, although none of them had 10000 birds. This number of birds kept by poultry farmers implies that all farmers were operating on a small scale. According to Aning (2006), poultry stock classification is: 50-5000 birds for small scale; 5001-10000 medium scale and 10001 or more for large scale.

Monthly earnings from poultry projects were found to be substantial. None of the respondents earned less than 200,000/= per month from the poultry farming business. Only 27% reported having earned 200,001 to 300,000/= while majority of the respondents had earned more than 300,000/= per month. Some farmers with 400 birds or more reported earnings of more than one million Ugandan Shillings per month in the days of peak production. This means that poultry is a lucrative business and can be used to create wealth and eradicate poverty.

5.3 Farmers' awareness of the effect of thermal stress on egg production.

Thermal stress is a deterrent factor to poultry production in spite of the gains made by poultry farmers in the area of this study. In regard to farmers' awareness of the effects of TS on egg production, findings revealed that only 18% of the respondents were aware of thermal stress and its detrimental effects on egg production in layer chickens more especially those under deep litter system. Since most poultry farmer respondents had no knowledge of TS and its effects on egg production among layer chickens, thermal stress causes unknown financial losses to local farmers by reducing the rate of lay. All the poultry farmer respondents who reported having knowledge of TS reported having experienced it on their poultry farms. This implies that TS is a real poultry production problem in the area of study. In regard to the type of thermal stress reported, majority of the poultry farmer respondents indicated that low temperature stress was the most disastrous particularly among chicks (Table 9) where it could cause high mortality. This implies that most farmer respondents who had knowledge of thermal stress understood it as a poultry production constraint among chicks and not layers. Thermal Stress is equally disastrous among layers in which it causes a reduction in egg production and reduced egg weight (Scott and Balnave, 1988). Very few of the farmer respondents reported that low temperature stress could be a menace to broilers and layers (Table 9). Additionally, most respondents believed that high temperature stress was severe among chicks. These findings imply that most farmers had no concern with thermal stress among layers and yet Muiruri and Harrison (1991) reported that in laying hens, thermal stress depresses body weight and egg production. They also reported that it suppresses feed intake and, therefore, farmers need to effectively control it if they are to realize good returns from laying chickens. This means that they incur egg production losses resulting from thermal stress. Only a small number of the poultry farmer respondents reported that high temperature stress could affect layers and broilers as well as the dual purpose birds (Table 9). Most farmer respondents who had knowledge of thermal stress reported that low temperature stress was severe throughout the year while high temperature stress was severe in the dry season (Table 10). This indicates that LTS control measures should be in place all year round. Knowing when to anticipate periods of thermal stress is key to minimizing its effects by preparing and implementing appropriate management and nutritional measures prior to the onset of the thermal stress (Mashaly *et al*., 2004). Preventing thermal stress prior to its onset is also more effective than starting the control after the onset of stress.

Some farmers who had knowledge of TS (Table 11) reported that high temperature stress was characterized by panting, spreading wings apart, increased water intake, reduced feed intake, isolation of birds and resting on cold surfaces such as on soil and walls. On the other hand, low temperature stress was characterized by crowding on each other and on the source of heat. Increased feed intake, reduced water intake, reduced egg production and increased death rate can occur. The findings were in agreement with those of Nardone *et al.* (2010) who reported that thermal stressed birds gasp and pant, spread wings apart, develop pale combs and wattles, and they close their eyes most of the time. Other indicators he reported were diarrhea, increased water intake and cannibalism, decreased appetite, reduced rate of lay, reduced egg weight, poor egg shell quality and loss of body weight.

Unfortunately, most of the farmer respondents who had knowledge of thermal stress indicated that it did not cause serious economic losses and it did not need immediate measures to control it among laying chickens and other poultry birds. This indicates that farmers need to be helped through agricultural extension services to understand the effects of thermal stress on egg production among layers so that they can adopt measures to control it.

5.4 Effect of thermal stress on feed intake and egg production

Experimental results in which birds were subjected to three temperature treatments of 18^0C, 24^0C and 32^0C (Table 12) showed that the 18^0C treatment significantly ($p<0.05$) increased feed intake by 9.5%. Birds have a high surface area to volume ratio. They can easily lose or absorb excess heat, depending on the weather conditions. During cold weather the birds' metabolic rate increases. The bird requires extra calories from carbohydrates and fats to maintain their normal body temperature. These extra calories are converted into heat energy so that the bird's body temperature can be maintained within a narrow range. Birds are homoeothermic organisms i.e., they have a constant and relatively high body temperature which is internally regulated. Their bodies respond to changes in external environmental temperatures in various ways to maintain a constant body temperature. The findings tally with those of Logue (1986) who reported that appetite and feed intake increased with decrease in temperature up to a certain level.

Additionally, in the experiment, feed consumption at the TCZ (24^0C) was 2325.1g per day per experimental unit (Table 12). It was between that at the low and high temperature treatment consumption levels. This is because at the TCZ no extra calories are needed to maintain the bird's body temperature within the required narrow range. At the high temperature treatment (32^0C) there was a significant decrease in feed intake of 20.8% ($p<0.005$). The hypothalamic pituitary-adrenal (HPA) axis plays an integral role in the maintenance of homeostasis during heat stress (Bobek *et al*., 1980). Hypothalamic neurons perceive increases in body temperature and exert an inhibition on cells that are responsible for controlling feed intake. This causes feed intake of hens to decrease as environmental temperature increases.

The findings agree with those of many other scholars who studied the same topic in other geographical areas who discovered that productivity of laying chickens is affected by a multitude of factors, including environmental stress (such as heat stress), which is probably one of the most commonly occurring challenges in many poultry production systems around of the world (Deng *et al*., 2012). Decreased feed intake is very likely the starting point of most detrimental effects of heat stress on production, leading to decreased body weight, feed efficiency, egg production and quality (Mashaly *et al.*, 2004). However, in addition to decreased feed intake, it has been shown that heat stress leads to reduced dietary digestibility, and decreased plasma protein and calcium levels (Zhou *et al.*, 1998). In another study (Deng *et al.*, 2012), reported that a 12-day heat stress period caused a daily feed intake reduction of 28.58 g/bird, resulting in a 28.8% decrease in egg production. Star *et al*. (2009) reported a reduction of 31.6% in feed conversion, 36.4% in egg production, and 3.41% in egg weight in laying hens subjected to heat stress. In another study, heat stress caused decreased production performance, as well as reduced eggshell thickness, and increased egg breakage (Lin *et al.*, 2004). Additionally, heat stress has been shown to cause a significant reduction of egg weight of 3.24%, egg shell thickness of 1.2%, eggshell weight of 9.93%, and eggshell percent of 0.66% (Ebeid *et al*., 2012). Corroborating these reports, Mack *et al*. (2013) also observed decreased egg production, egg weight and egg shell thickness in laying hens subjected to heat stress. An interesting series of experiments by Farnell *et al.* (2001) demonstrated the increasing detrimental effect that chronic heat stress has on egg production. In these experiments, a reduction of 13.2%, 26.4% and 57% occurred in egg production in laying hens subjected to heat stress during 8–14 days, 30–42 days and 43–56 days, respectively. In another study (Mashaly *et al.,* 2004) a marked decrease in egg production (28.8%), feed intake (34.7%) and body weight (19.3%) was also observed in laying hens subjected to chronic heat stress, during a 5-week period. Although much variation of effects is observed between many of the studies published, the consistent finding of significant impacts of heat stress on egg production and quality is noteworthy. The variability of the effects reported may be easily explained by the use of birds of different age or genetic background, as well as being due to the variability in intensity and duration of the heat stress treatments applied.

Bobek *et al.* (1980) also reported lower feed intake of laying hens in pullets layered under elevated temperatures. In addition, findings are also in agreement with those of Mahmoud *et al.* (1996), Bonnet *et al* .(1997) and Zhou *et al.* (1998) who also reported that feed intake in White leghorns decreased when they were exposed to high environmental temperatures. Mustaf *et al.* (2009) also reported that heat stress reduced feed intake and limited the availability of blood calcium for eggshell formation. In addition to reduced feed intake, it has been shown that heat stress leads to reduced dietary digestibility and decreased protein and calcium levels (Zhou, 1998).

The experiment also showed that the number of eggs laid per day (Table 12) was highest ($p<0.05$) at the TCZ (24^0C) and lowest ($p<0.05$) at the high temperature (32^0C) treatment where it decreased by 40%. Egg production at low temperature treatment (18^0C) decreased by 33.3%. Egg production at low temperature treatment was, however, closer to egg production at high temperature treatment than at the TCZ, indicating that both low temperature stress and high temperature stress are disastrous to layers. Heat Stress depresses egg production because at low temperatures food nutrients are used to provide extra calories for maintaining a constant body temperature instead of being used for egg formation and production. On the other hand, high temperatures depress feed intake. This reduces the food nutrients from which eggs are made. HTS is also associated with decreased protein digestibility. Proteins are essential in egg formation and, therefore, a decrease in protein digestion, absorption and assimilation directly depresses egg formation and production.

Accordingly, egg weight in grams per day decreased by 36.6% at low temperature treatment and by 40% at high temperature treatment. At high temperatures feed intake is depressed and this results in a reduced calcium concentration. At high temperatures birds pant to enhance evaporative cooling. Panting results in respiratory alkalosis which is caused by loss of carbon dioxide from the blood and involves increase in the blood ph. This, in turn decreases the proportion of the blood calcium level that is in the ionised form and thus reduces the amount of calcium available for egg shell formation. The action of carbonic anhydrase and the flow of calcium to the uterus also reduce. These actions reduce egg size and egg shell thickness resulting in light eggs.

These findings are also in agreement with those of Muiruri and Harrison (1991), Kirunda *et al*. (2001) Mashaly *et al.* (2004) who reported that egg production in White Leghorns decreased when they were exposed to high environmental temperatures. Deng (2012) also reported that a 12-day thermal stress period resulted into a 28.8% decrease in egg production. The decrease in egg production in the study was due to the decrease in feed consumption, reducing the available nutrients for egg production. Daniel and Balnave (1981) indicated that feed intake is reduced prior to subsequent loss in egg production. Heat stress not only reduces feed intake but also reduces digestibility of different components of the diet. Furthermore, it has been reported that exposure to high temperatures decreased plasma protein concentration and plasma calcium concentration both of which are required for egg formation (Mahmoud, 1996).

Egg weights per day for both low temperature (18^0C) and high temperature (32^0C) treatments were less than egg weight at the TCZ (24^0C) (Table 12). Egg weight at the high temperature treatment (32^0C) was less than egg weight at low temperature (18^0C) treatment. Egg weight decreased by 36.6% and 42% at low and high temperature treatments respectively. These findings were also in agreement with Mahmoud (1996) who reported that exposure of hens to high temperature stress resulted in a significant decrease in egg weight. Egg shell weight, shell thickness and specific gravity were all significantly decreased when birds were exposed to heat stress. Eggs from the thermal stressed group weighed significantly less than eggs from the control set up. Results further agree with those of Kirunda *et al.* (2001), Mashaly *et al,* (2004) who reported that reported that either high environmental temperature or low environmental temperature decreased egg weight. This result could be due to the adverse effects on egg shell quality. Heat stressed birds produce eggs with decreased egg shell thickness and specific egg gravity. The decrease in shell quality is partially due to a reduction in plasma calcium. Mahmoud (1996) also reported that calcium use and calcium uptake by the duodenal epithelial cells are reduced by exposure to high environmental temperatures leading to thin shelled eggs with lesser weight.

5.5 Farmers' acceptability of measures to control thermal stress among layers

The findings revealed that all respondents who had knowledge of thermal stress were controlling thermal stress (Table 13). This meant that all farmers without knowledge of thermal stress suffer economic losses resulting from it. The respondents who controlled TS used methods such as proper ventilation and appropriate stocking density (Table 14). However, most of the poultry houses of the respondents were poorly constructed and yet respondents claimed to use appropriate housing/proper ventilation as the main methods of controlling TS. The recommended spacing for the Hy-line Brown layers was five layers per square meter (Xin, 2015). From the observations made, most farmers were not following this spacing rate and yet they claimed that they controlled TS by proper stocking. The reason for failure to follow the recommended spacing was lack of information about appropriate spacing. Out of the few farmers who controlled high temperature stress in layers, 66.67% controlled it by adequate watering (Table 14) while 16.66% indicated proper ventilation to be their method of controlling TS. None of the respondents used electric appliances such as foggers, misters, coolers, air conditioners and cooling fans, among others. A very high percentage of the respondents (88.89%) of the respondents (Table 15) were not willing to adopt TS control methods recommended by the 1994 International Welfare of Livestock Regulations and Hy-line International among layers (FAO, 2010). Most farmers reported that they were not aware of the necessity to control TS among layers. Some farmers reported that some recommended methods are too expensive for them, not cost effective for small farms and sophisticated for local farmers to use. Other arguments against it were lack of power in rural areas and the unreliability of power. The recommended methods include; the use of foggers, misters and roof sprinklers. Others are; air conditioners, room heaters, fans and thermostats. These methods were recommended because they were efficient and flexible. They can keep temperatures within a required small range under which egg production can be optimum.

SUMMARY, CONCLUSION AND RECOMMENDATIONS

Summary

This study was carried out to assess farmers' awareness of the effect of Thermal Stress (TS) on egg production, determine the effect of TS on egg production in layers under deep litter system and assess farmers' acceptability of measures to reduce TS and its effects. An understanding of the effect of thermal stress on egg production is essential in improving egg productivity in the tropics. A survey was carried out to assess farmers' awareness of the effect of thermal stress on egg production after which a Completely Randomized Design (CRD) experiment was conducted to determine the effect of TS on feed intake and egg production. A total of 180 Hy-line brown layers of 24 weeks were randomly assigned to three thermal treatments of 18^0C, 24^0C, and 32^0C for two weeks. The 18^0C is the low critical thermal temperature. Each treatment was replicated 4 times with each replicate having 15 birds. The Survey data was analyzed with SPSS while GenStat was used to analyse experimental results to test the relationship between thermal treatments and feed intake, egg production, and egg weight. An ANOVA at a significance level of 95%, (0.05) was used. The results showed that most respondents (82%) had no knowledge of the effect of TS on egg production. Temperature treatments significantly ($p<0.05$) affected feed intake, number of eggs laid an egg weight. At 18^0C there was increased feed intake but decreased egg production. At 32^0C there was inhibition of both feed intake and egg production. Farmers' acceptability to adopt efficient, flexible and recommended methods to control TS was low at only 11.11%

Conclusion

On the basis of the research findings it can be concluded that most poultry farmers were not aware of the effects of Thermal Stress on egg production in layers under deep litter system. Thermal stress manifests itself in two ways i.e., Low Temperature Stress and High Temperature Stress. Both types of Thermal Stress cause a depression in egg production affecting egg numbers, egg weight, and egg size. High Temperature Stress is more disastrous than Low Temperature Stress in the tropics where temperatures are always closer to the Upper Critical Temperature than the Lower Critical Temperature. Thermal Stress causes great losses. Most poultry farmers in the local setting are not ready to take efficient and effective measures to control TS. Among other reasons, farmers argue that it is only possible on well-established farms since it is expensive to install some technologies recommended by Hy-line international and the 1994 International Animal Welfare Regulations. Another constraint to such technologies was lack of and unreliability of power. Farmers also lack skills to run certain thermal regulators. Thermal regulators are also seen as not being cost effective on small farms. There is need to develop simple and appropriate technologies to control TS so as to improve egg productivity on house hold based farms. Government should also consider subsidizing costs on poultry inputs so as to boost the poultry sector to create wealth and eradicate poverty. Farmers should also be sensitized on the negative effects of Thermal Stress among layers so that they can choose to control TS.

Recommendations

Basing on the above conclusions the following recommendations were made.

-There is need for sensitization of farmers on TS and its effects on egg production by agricultural extension officers so that it can be controlled and egg productivity can be improved.

- Thermal stress, which retards egg production should in the meantime be controlled by farmers using local and affordable methods of controlling thermal stress such as providing adequate cold water for drinking, proper ventilation, proper stocking density and avoiding disturbing birds during the hottest hours of the day as they plan to adopt the recommended methods.

- Farmers should be sensitized on the effectiveness of the recommended methods of controlling thermal stress in layers under deep litter system so that they can be able to adopt them.

- Further research should be carried out on thermal stress related aspects so as to come up with affordable but effective measures to control thermal stress.

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APPENDICES

APPENDIX I: QUESTIONNAIRE FOR POULTRY FARMERS

Dear respondent,

I am **Muntukwonka Pascal,** a graduate student of Kyambogo University pursuing a degree of **Master of Science in Animal Production**. Am conducting a research study on "**The effect of thermal stress on egg production in layer chickens under deep litter system in house hold settings in Kibaale, Mid-Western Uganda".**

I request you to give information for the study. The information given will be confidential and used for academic purposes only.

Thank you

Name of respondent…………………………………………………………………………….

Town Council/Sub-County of respondent………………………………………………………

Constituency of the respondent…………………………………………………………………

District of the respondent…………………………………...……………………………….

Put a tick (√) in the appropriate box

Section A: Respondents' Demographic Characteristics

1. Sex

   a. Male……………………………………………………………………………… ☐
   b. Female ………………………………………………………………………… ☐
   c. Both…………………………………………………………………………. ☐

2. Age:

a. Below 20…………………………………………………………………….. ☐

b. 21- 40……………………………………………………………………… ☐

c. 41- 60……………………………………………………………………… ☐

d. Above 60………………………………………………………………….. ☐

3. Level of education:

a. No school……………………………………………………………….. ☐

b. Primary…………………………………………………………………… ☐

c. Secondary ……………………………………………………………….. ☐

d. Tertiary …………………………………………………………………... ☐

4. Marital status

a. Single…………………………………………………………………… ☐

b. Married…..……………………………………………………………… ☐

c.Divorced………………………………………………………………… ☐

d.Widowed……………………………………………………………...… ☐

Section B: Farmer respondents' main farming activities.

5.What is your main type of farming business?

a. Commercial poultry keeping………………………………………………… ☐

b. Back yard poultry keeping………………………………………………….. ☐

c. Piggery………………………………………………………………………… ☐

d. Dairy and beef farming……………………………………………………… ☐

e. Crop farming…………………………………………………………………… ☐

f. Others, specify……………………………………………………………… ☐

6. For how long have you been in the poultry business?

a. A year or less……………………………………………………………… ☐

b. Two-three years…………………………………………………………… ☐

c. Four-five years…………………………………………………………... ☐

d. Six and above……………………………………………………………… ☐

7. Which type of poultry birds do you keep most?

a. Layers…………………………………………………………………………….. ☐

b. broilers……………………………………………………………………………. ☐

c. dual purpose…………………………………………………………………… ☐

8. What is your major source of livelihood?

a. Subsistence farming………………………………………………………… ☐

b. Commercial agriculture……………………………………………………… ☐

c. Employment income………………………………………………………… ☐

d. Any other, specify…………………………………………………………… ☐

9. Size of land used for agriculture (in hectares)

a. Below 0.5 ……………………………………………………………………… ☐

b. From 0.5 to 1 ……………………………………………………………….… ☐

c. From 1.1 to 1.5………………………………………………………………… ☐

d. Above 1.5………………………………………………………………… ☐

10. How many birds do you keep?

☐

a. Less than 100 birds……………………………………………………………

b.101-200 birds……………………………………………………………

c. 201-300 birds…………………………………………………………..

d.301-400 birds……………………………………………………………

e. 401-500……………………………………………………………………

f. 501 and more…………………………………………………………...

11. Average income per month from poultry keeping.

a. From Shs. 0 to Shs. 100, 000…………………………………………………

b. From Shs. 100,001 to Shs. 200, 000…………………………………………

c. From Shs. 200,001 to Shs. 300,000…………………………………………

d. Above 300,000…………………………………………….…………..

Section C: Farmers' awareness of the effect of thermal stress on egg production.

1. Are you aware of the effect of thermal stress (TS) and its effect among layers?

   a. Yes……………………………………………………………………

   b. No…………………………………………………………………..

2. Have you ever experienced thermal stress among layers on your poultry farm?

   a. Yes……………………………………………………………………

   b. No ……………………………………………………………………

3. What type of thermal stress was it?

   a. Low temperature stress………………………………………….………..

   b. High temperature stress…………………………………………………………

   c. Both……………..……………………………………………………

4. Which type of chickens do you think can be affected most by low temperature stress?
   a. Layers…………….……………………………………………………..........
   b. Broilers…………………………………………………………………….
   c. Dual purpose……………………………………………………………….
   d. Chicks…………………………………………………………………
5. Which type of type chickens do you think can be affected most by high temperature stress?
   a. Layers…………….……………………………………………………........
   b. Broilers……………………………………………………………………
   c. Dual purpose……………………………………………………………….
   d. Chicks……………………………………………………………………….
6. In which season of the year (months) can low temperature stress be suffered here?
   a. Dry season…………………………………………………………………
   b. Wet season………………………………………………………………….
   c. Any other, e.g. throughout the year……………………………………….

7. In which season or months of the year can high temperature stress suffered here?

   a. Dry season……………………………………………………..………..
   b. Wet season………………………………………………………………
   c. Any other, e.g. throughout the year ……………………………………

8. How can you notice that birds are suffering from high temperature stress?

   a. Increased water intake……………………………………………………
   b. Reduced feed intake…………………………………………………………
   c. Reduced quantity of eggs……………………..…………………………
   d. Panting and spreading wings ……………………………..………………
   e. Other, specify………………………………………………..…………

9. How can you notice that birds are suffering from low temperature stress?

   a. Increased feed intake…………………………………………………………

   b. Reduced water intake…………………………………………………………

   c. Crowding on each other and/or on source of heat………………………

d. Reduced quantity of eggs……………………………………………………….

e. Others, specify…………………………………………………………….

10. Do you think thermal stress causes serious economic losses in poultry and needs immediate and effective control measures?

a. Yes..……………………………………………………………………

b. No………………………………………………………………………..

Section D: Farmers' acceptability of measures to control thermal stress

1. Do you control low temperature stress among layers on your poultry farm?

   a. Yes……………………………………………………………………….

   b. No………………………………………………………………………..

2. If yes, how do you control low temperature stress on your farm?

   a. Using charcoal stoves……………………………………………………….

   b. Using burning charcoal in pots…………………………………………………

   c. Using electric heaters………………………………………………………..

   d. Using Air Conditioners (A/C)………………………………………………

   e. Others (specify)…………………………………………………………………

3. Do you control high temperature stress on your poultry farm?

   a. Yes………………………………………………………………………..

   b. No …………………………………………………………………………

4. If yes, what methods do you use to control high temperature stress?

a. Proper stocking density………………………………………………………
b. Proper ventilation………………………………………………………..
c. Using electric coolers……………………………………………………….
d. Using Air Conditioners (A/C)………………………………………………
e. Others (specify)……………………………………..…………………

5 Electrical methods of controlling temperature in poultry houses is efficient, flexible and recommended by Hy-line international and the 1994 International Welfare of Livestock Regulations to control thermal stress. Would you make a choice to adapt them?

a. Yes………………………………………………………………………
b. No……………………………………………………………………..
c. Undecided………………………………………………………………

6. If no, what reasons do you have for not choosing them? Give at least four reasons.

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………….…………………………………………

7. What local measures do you use to control thermal stress on your farm?

……………………………………………………………………………………………

……………………………………………………………………………..…………………

……………………………………………………………………………………………

Thank you for your time and co-operation.

APPENDIX 2: ANOVA TABLES

Table 16: Analysis of variance of number of eggs produced at different temperature treatments

Variate: No. of eggs

Source of variation	D.F.	S.S.	M.S.	V.R.	F PR.
Temperature	2	92.16667	46.08333	553.00	<.001
Residual	9	0.75000	0.08333		
Total	11	92.91667			

Table 17: Analysis of variance of feeds consumed at different temperature treatments

Variate: Feeds intake (g)

Source of variation	D.F.	S.S.	M.S.	V.R.	F PR.
Temperature	2	1023399.	511699.	444.96	<.001
Residual	9	10350.	1150.		
Total	11	1033749.			

Table 18: Analysis of variance of weights of eggs produced at different temperature treatments

Variate: Weight (g)

Source of variation	D.F.	S.S.	M.S.	V.R.	F PR.
Temperature	2285836.1142918.1		1026.52	<.001	
Residual	91253.0	139.2			
Total	11287089.2				