AN ASSESSMENT OF HEAT STRESS STATUS IN PIGS AND ADAPTATION OPTIONS IN LIRA DISTRICT UGANDA

By

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DECLARATION

I declare that this dissertation/thesis is my original work and has not been submitted elsewhere for research. Where other people's work has been used, this has properly been acknowledged and referenced in accordance with the University of Nairobi's requirements.

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DEDICATION

This research project is dedicated to all smallholder farmers, those striving and living in hardship and whose families struggle day and night to ensure they have access to sufficient basic needs. It is through hard work, commitment and Lord's mercy that many farmers who are vulnerable strive to have a livelihood despite challenges posed by climate change.

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LIST OF ACRONYMS

AIC	-	Akaike Information Criterion
CGIAR	-	Consultative Group on International Agricultural Research
CIAT	-	International Center for Tropical Agriculture
CSA	-	Climate Smart Agriculture
EU	-	European Union
FGDs	-	Focus Group Discussions
GCM	-	General Circulation Model
GHG	-	Greenhouse gas
IPCC	-	Intergovernmental Panel on Climate Change
NAADS	-	National Agricultural Advisory Services
NGO	-	Non-Governmental Organization
NUSAF	-	Northern Uganda Social Action Fund
SSA	-	Sub Saharan Africa
CRP	-	CGIAR Research Program

ABSTRACT

There is limited attention to impacts of climate change on pigs in Uganda by stakeholders despite the potential vulnerability of pigs to climate change, especially heat stress. Pigs are very sensitive to heat stress as they do not have functioning sweat glands (as other livestock species do) and have small lungs which reduces their ability to disseminate heat by panting. The objectives of the study were to determine the heat stress status in pigs, factors influencing heat stress and explore the heat-stress adaptation options towards better pig production in Lira District, Uganda. Lira was selected because of high poverty level, presence of both rural & urban areas and expected heat stress throughout the year in the district. The data including management systems, age, color, breeds, body/skin temperature, rectal temperature and others were collected from 104 households and 259 pigs during the hot months in Ojwina and Barr sub-counties- Lira district. More data on adaptation options were collected during the four gender disaggregated focus group discussions. 63.46 % of the respondents were female and 36.54% of respondents were male. Majority of the respondents during the household survey were from Barr sub-county (56%) and the remainder (44%) were from Ojwina sub-county, which were the rural area and urban area respectively. Rectal temperature (RT=39.06°C ±0.83°C) and body/skin temperature (ST=36.32°C ±2 °C) were the key heat stress indicators (dependent variables) as have been used by other researchers. According to the farmers, 48.45% of the pigs had no heat stress, 51.55% of the pigs were heat stressed and both the rectal temperature & skin temperature of these groups were significantly different ($p<0.01$). There was a statistically significant correlation between heat stress status and heat stress action ($p<0.01$ The results showed that rectal temperature is influenced by the external temperature humidity index, pig management system, pig category, color, heart girth, water quantity given during day in dry season, pig's body condition score, and time of the day. Skin temperature is significantly influenced by external temperature humidity index, pig category, pig management, time of the day and body condition score. The preferred adaptation options were analysed using the average preference rating (using a rating scale of 1 to 5 where 1 was the least preferred option and 5 the highest preferred). The results showed that the most preferred adaptation options included constructing a high pig pen roof and allow easy air flow (Average Preference Rating = APR =4.75); pouring water on the pigs (APR=4.63); and allowing pigs to swim/wallow (APR=4.48). The least preferred adaptation options to heat stress included giving salt to replace lost electrolytes (APR=1.25); and addition of fans (APR=1.03). The percentage of the female members of the household making decisions and providing labour for particular adaptation options was higher relative to the male household members and non-household members; except for the adaptation option of constructing the pig houses. To adapt to heat stress, pig shelters should be designed to minimize overcrowding while incorporating ways to improve airflow and evaporative cooling by having a high roof, and / or using grass. Availing water ad lib or even mixing water in the feed is critical to reducing heat stress. Pig swimming/wallowing and pouring water on the pigskin are some of the interventions farmers may use. However, there is need for more awareness about the suitable adaptation option to heat stress while putting the local context into consideration.

CHAPTER ONE: INTRODUCTION

1.1: Introduction

Livestock sector is economically, socially and politically important sector globally. 40% of agricultural gross domestic product (GDP) is accounted by the livestock sector. 1.3 billion people is employed by the livestock sector and creates the livelihoods for one billion of the world's poor (Steinfeld et al., 2006). While better off farmers are likely to keep large livestock including dairy cattle, the resource poor farmers are more likely to own pigs and other small ruminants than large livestock (Udo & Steenstra, 2010).

In general, there are three main pig-farming systems: the extensive (small-scale subsistence) pig farming system where farmers keep pigs out-door, and they freely move around the homestead as they feed on their own, or tethered. A few farmers who have pens do confine pigs during night and rainy season (seasonal crop growing period); otherwise, they leave them to scavenge during day and dry season. Though farmers save costs on feeds, there is an issue of pigs destroying crops and being exposed to predators and thieves. There is poor disease control in this system because pigs move anywhere (Muhangi, Masembe, Berg, Ståhl, & Ocaido, 2014). Farmers usually keep breeds of low production performance, slow growth and inferior carcasses. Sows roaming may meet other boars for breeding which may lead to inbreeding or breeding with unwanted breeds (Dione et al., 2014). Semi-intensive/extensive is the other pig farming system where farmers confine pigs using rope. More farm inputs than in the extensive farming system are used for example-improved feeds are provided (mostly grass, crop residues, fruits and kitchen waste), disease and pest control, and other better pig production techniques may be provided. Small numbers of pigs are kept and mostly local breeds. Local breeds are locally adapted genotypes, and phenotypically similar animals (Karen Marshall, 2017). Most farmers in Lira district practice this type of pig farming system (Dione et al., 2014). Intensive pig farming system is the other pig farming system and in this system, pigs are kept housed all the time. They are provided with feeds, water, and shelter. Shelter protects pigs from unfavourable weather. The shelter may be made of floor (cement, concrete, bricks or ground, litter like coffee husks), wall (bricks, wood, trees, and stems) and roof. There shelter designs include raised floor and non-raised floor. The pigsty (shed or barn of pigs) floor type affects the productivity of pigs. Farmers practice improved pig-rearing techniques. Labour and/-or mechanization are highly demanded in the intensive farming system. Most pigs kept in intensive farming system are cross-breed (local breed by exotic breed) and exotic breeds. Cross breeds were found to be more profitable than the local breeds (Karen Marshall, 2017). Because of increased demand, land scarcity and improvement to information access, the adoption of intensive pig farming system is increasing (Tatwangire, 2014).

Pig production is a very important element of the livelihoods of 1.1 million households in Uganda (Tatwangire, 2014). To meet the increasing demand for pork due to high consumption (at around 3.4kg per person per annum: (Ouma et al., 2013), pork production is increasing in Uganda (Tatwangire, 2014). Pig meat is the only among other types of livestock meat that continues to show a rapid increase in the level of per capita consumption (Tatwangire, 2014). There are multiple benefits after selling the pigs including paying school fees, medical expenses, and for food. Pig production is influenced by climate (Elsa et al., 2013). Changes in a combination of climate factors like air temperature induce this imbalance. In face of climate change, the temperatures are projected to increase (IPCC, 2014). As the temperatures increases, heat stress in pigs will be increasing (Renaudeau et al., 2012a). For some areas in Uganda, like Kitayunjwa in Kamuli district, heat stress is the main cause of pig death (34% of all pig deaths) (Dione et al., 2014).

There are many challenges in pig rearing including limited access to technology information and services (Ouma et al., 2013). Limited opportunities for knowledge sharing among producers, public officials, development agents, and scientists, result in limited uptake of proven technologies. Regarding feeding, there is a lack of year-round stability of feed supply, and feed quality control measures are absent. Diseases especially African Swine fever, Foot & Mouth disease, and parasites are leading to low pig productivity and profitability (Dione et al., 2014). Inbreeding, poor housing infrastructure, environmental degradation and pollution, conflicts with neighbours, lack of sanitary control in slaughtering, lack of infrastructure for processing and selling pork, poor market infrastructure and institutional arrangements, high price difference between rural and urban markets (Ouma et al., 2015).

Many issues on pig production in Uganda have been studied. The CGIAR Research program on Livestock has done multiple pig research initiatives in Uganda. Previously, the following studies on pig production were conducted: situational analysis (Tatwangire, 2014), value chain assessment (Mangheni, 2014), baseline assessment of animal health (Dione et al., 2014), challenges and opportunities in pig production (Ouma et al., 2013). There is a research gap on pigs and climate change. Now more than ever we are having a critical issue of increasing temperature as a result of global warming which is potentially negatively impacting pig production and productivity in Uganda. With a wide number of pig production systems, there is a need to understand which production system is less or more vulnerable to global warming.

Lira district was selected as the study site due to reported higher exposure of pigs to heat stress with recorded heat stress emergency or heat stress danger throughout the year based on previous mapping as shown in figure 1 (Mutua, 2017). Lira district has high poverty level since above 80% of the Lira population live on less than 1.25 US dollar per day (Ouma et al., 2015). Lira district has both rural and urban areas which is important to include both more intensive and more extensive pig production systems. Pigs are important to the livelihood of many people in Lira district providing an opportunity to generate income especially for paying school fees, manure for improving soil fertility and contributing to food and nutritional security (Ouma et al., 2015).

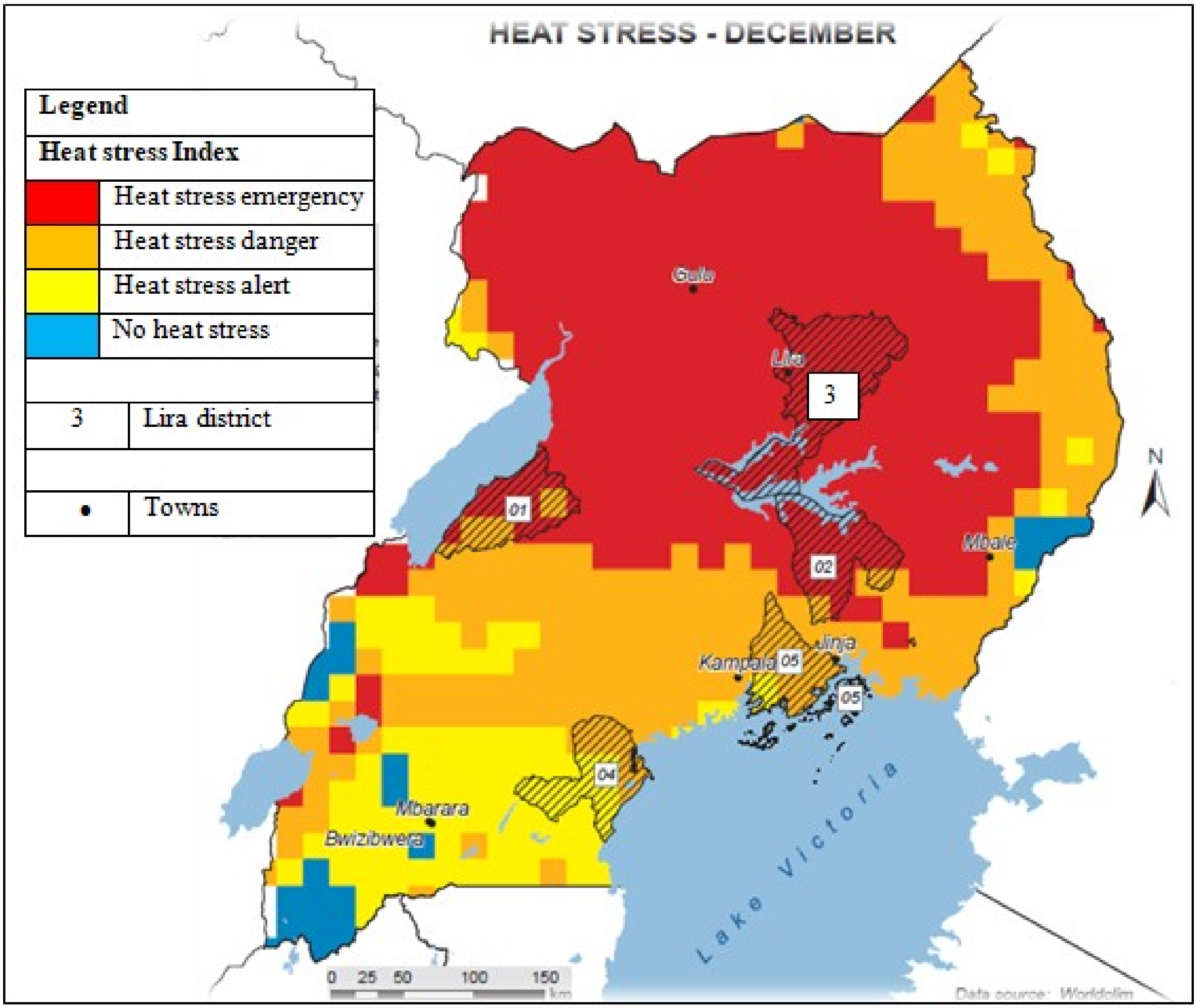

Figure 1: Map showing heat stress in pig in December in Uganda

Source: Mutua (2017)

1.2: Problem statement

Climate has great influence on livestock production (Elsa et al., 2013). Just like in many other countries globally, Uganda's climate is changing. IPCC (2014) reported a 0.85^{o}C average global warming increase for a period 1880 to 2012. The situation is likely to become worse, as temperatures in the African continent are projected to rise more quickly than in other land areas, particularly in more arid regions (IPCC, 2014).

The transition of pig production systems towards more intensive production with exotic breeds, improved management practices and increased use of purchased feed may come with trade-offs in regards to current and future climate change (Brown-Brandl, Nienaber, Xin, & Gates, 2004). Some pig breeds may have high metabolic activity and are therefore more susceptible to heat stress (St-Pierre, Cobanov, & Schnitkey, 2003). In addition to metabolic activity, heat stress in pig is caused by the forces external to the animal (Kadokawa, Sakatani, & Hansen, 2012). Pigs are very sensitive to heat stress as they do not have functioning sweat glands and have small lungs which reduces ability to disseminate heat by panting (Nardone, Ronchi, Lacetera, Ranieri, & Bernabucci, 2010). For some districts in Uganda, like Kamuli district, heat stress is the major cause of death accounting to about 34% of all pig deaths (Dione et al., 2014). Heat stress in pigs increases respiration rate, negatively affects voluntary feed intake and changes feeding patterns (Baumgard, Rhoads, & Rhoads, 2012). This lower feed intake results in lowered reproductive performance and growth (Renaudeau et al., 2012a). Heat stress can also result in a higher rate of secondary bacterial infections due to compromised intestinal defense mechanisms (Baumgard et al., 2012).

Heat stress alert for some pig occurs between 24^{o} C to 27^{o} C, and heat stress danger occur between 26^{o} C and 30^{o} C, depending on the relative humidity (Figure 2). Temperatures above 31 ^{o} C are considered a heat stress emergency for all humidity levels.

Understanding the linkages between heat stress and pigs and the implication at the real farm communities may is very important. Involving local pig farmers is important for incorporation of heat stress impact information on pigs with local knowledge and on-farm assessments to create pathways for climate change adaptation.

Issues around lower productivity from heat stress are relevant now and will become more important with system intensification.

1.3: Research questions

1) What is the heat stress status and the factors influencing heat stress in pigs in Lira district –Uganda?
2) What are the preferred heat-stress adaptation options?
3) What gender implications are associated with the different adaptation options.

1.4: Hypothesis:

1) Most pigs are under heat stress and heat stress is influenced by pig breeds, pig management, pig colour, pig size and, pig age groups, weather parameters and other aspects

2) Farmers already have their preferred adaptation options to heat stress in pig

3) The adaptation options have gender implications

1.5: Objectives

1.5.1: General objective

To determine climate change impacts on smallholder pig farming with focus on heat stress status and explore the heat-stress adaptation options towards better pig production in Lira District, Uganda.

1.5.2: Specific objectives

1) To determine heat stress status for pigs and the factors influencing heat stress in pigs in Lira District, Uganda
2) To identify, rank and recommend adaptation options to heat stress
3) Assess gender implications of adaptation options especially labour and decision making

1.6: Justification and significance of research

Pig production is very important in Lira district because of the high level of poverty in the area (Ouma et al., 2015). Resource poor farmers are more likely to own pigs and other small ruminants than large livestock (Udo & Steenstra, 2010). Most pig farmers sell pigs either to butchers (75%), to traders (20%) or direct to consumers (5%) (Ouma et al., 2013). The average producer price by the butchers was UGX 5200 per Kilo while the traders offered UGX 6000 (Ouma et al., 2013). The average retail price in UGX per Kilo is reported to be: 4800, 5500, 8500 and 11000 for large piece of pork, ready to roast/fry chops, sausages and ready to eat pork respectively (Tatwangire, 2014). If a farmer rears a pig for six months and it attains a weight of about 60 kilos, then the farmer could generate an income of UGX 300,000 if each Kilo is sold at UGX 5000. When an income is generated either by selling pigs, pork or piglets, it can be used for catering for school fees, pay hospital bills, and even pay for debts.

Many scholars who have determined heat stress on pigs have done it at pig research stations. However, many times the situation on farms especially on the diverse smallholder farms is different. This study was carried out on-farm to determine heat stress for various pig age categories and breeds in the real life pig production systems in the field. In Uganda, there is knowledge gap on heat stress in pigs in various pig production systems and for various pig breeds. More-over heat stress may be enhancing other constraints for pig production including feeding constraints, pests, diseases and others. Farmers are striving in the face of this challenge and have various local practices they are doing. This study identified and prioritized the practices, technologies and other actions to adapt to heat stress in pig. This will be helpful in advising the farm planners, policy makers and project implementers in Uganda and other countries on the heat stress status and possible adaptation options.

For application purposes, the study assessed practical, and community based interventions that improve pig rearing with focus on adaptation options to heat stress in pig. This research assessed the heat stress status of pigs and the factors influencing heat stress which may influence the development of policy, practice or service provision, shaping legislation, changing behaviour. There was capacity building of the research team through technical and personal skill development. There were social and cultural benefits including getting more knowledge about the relationship of various pig categories and heat stress. Conceptually this research contributed to the understanding of pigs and their environment and reframe debates on pigs and climate change.

1.7: Scope of the Research

This study focused on pig production in Lira district, Uganda and made an assessment of heat stress status and factors influencing heat stress during day in dry season and identified adaptation options. To maximise the potential for effective transformative action, the gender differences for the adaptation options were identified.

However, there were some limitations. Being an on-farm research, there was low level of control which means that extraneous variables were not minimised and there is possibility of a lot of outside influences. This was overcome by using power analysis to estimate the sample size to know in advance the minimum sample size required to have a high chance of detecting the effect of heat stress on pigs using indicators used by other researchers.

1.8: Overview of the methodological approach

Assessment of heat stress status was done during day in the hot period of January and February 2018. This study was not an experiment, but an on-farm research which enabled the assessment of pigs in real complex on-farm situations which is a reality pigs live in everyday. Weather parameters and time of the day were recorded. Adaptation options were identified and rated according to farmers' preference during the study. Focus group discussions were organized to further understand the heat stress in pigs, adaptation options to heat stress and their gender implications.

This research followed the ethical standards and was approved by Gulu University Ethical Research committee (GUREC) in accordance with the Uganda National Council for Science and Technology (UNCST) for legal compliance before doing research in Uganda (Application No. GUREC 22/11/2017). International Livestock Research Institute (ILRI) research approved this research (Research compliance No. IACUC-RC2017-22). The research was approved by University of Nairobi (Ref: I58/89910/2016) and participation in research was voluntary.

CHAPTER TWO: LITERATURE REVIEW

2.1: Heat stress in livestock

Many factors influence livestock production. However, in face of climate change, heat stress is becoming one of the primary factors affecting livestock production. Under extreme environmental conditions with high thermal heat index, it is difficult for the animal to regulate its temperature. In such circumstances, the animal activates mechanisms to survive. Heat stress is defined as any combination of environmental and metabolic parameters producing conditions that are higher than the temperature range of the animal's thermal neutral zone (Huynh et al., 2005). The thermal neutral zone explains about the inter-relationship between the livestock and the environment and it is defined as the range within which metabolic rate is minimal, and a healthy animal can make physical adaptation to maintain the normal body temperature with minimal change in metabolic activity (Dash et al., 2016).

2.2: Heat dynamics on pigs

Pigs are homoeothermic/endothermic/warm blooded animals, which can maintain body/skin temperature within a narrow range of values, even when there are significant fluctuations in external temperature. Pigs achieve this depending on the heat produced and heat lost to the environment.

2.2.1: Heat production in pig

Multiple factors affect the heat produced metabolically in pigs. These factors include genetic potential, air temperature, acclimation to a given temperature, quantity and quality of feed, feed patterns, age, pig mass, and exercise (Brown-Brandl et al., 2004; Souza, 2014). Heat production in pigs may be through conduction, radiation and evaporation (Randall, 1993). The higher the food taken in by the pig, the more the heat produced (Brown-Brandl et al., 2004).

2.2.2: Heat loss in pig

Heat loss in pig occurs through three processes including radiation, convection, and conduction. First, the radiation process occurs when heat loss occurs from the pig surface to the environment. Second is through convection when air circulates near the pig body/skin. Sweating of pigs is not possible because they do not have active sweat glands (Lucas, Randall, & Meneses, 2000; Nardone et al., 2010). Sometimes pigs do pant but it is not effective and instead resort to wallowing (Bracke, 2011). Conduction can occur if the animal alters its position like leaning towards a cool surface (Lucas et al., 2000)[CITATION Luc00 \l 2057]. Generally, with increasing temperature due to climate change, heat stress threatens pigs (Nardone et al., 2010).

2.2.3: Heat stress in pig

Theoretically, pigs experience heat stress when a particular temperature threshold is exceeded. Heat stress occurs when the heat energy from the pig body/skin to the environment is less than the 'heat energy produced by the body and that from the environment to the pig' (St-Pierre et al., 2003). Changes in a combination of factors like air temperature induce this imbalance (Dash et al., 2016).

Heat stress is not good for the animals including pigs and may lead to death (Kadokawa et al., 2012). During conditions of heat stress, most energy is diverted to balance the pig temperature and reduce the heat stress effects in pigs instead of using the energy for growth (Mishra & Palai, 2014). Heat stress reduces animal milk production, feed intake (Brown-Brandl et al., 2004), growth rate (Lucas et al., 2000), physical activity and reproductive ability is compromised (Dash et al., 2016; Wilson et al., 1998). Heat stress to gilts during the gestation period may also lead to poor offspring performance (Ross et al., 2015).

Heat stress affects the behaviour of the pigs (Bloemhof & Knol, 2014; Randall, 1993). Pigs under heat stress increase the rate of water intake per day above the normal daily water intake. Pigs under heat stress show increased rectal temperature, skin/body temperature, and respiration rate (Huynh et al., 2005). This constitutes the heat stress indicators that have been used by many researchers as shown in table 1.

Table 1: Selected heat stress indicators

Indicators	Source
Rectal temperature	(Baldwin & Ingram, 1968; Fraser, 1970; Huynh et al., 2005; Kadokawa et al., 2012; Renaudeau et al., 2012a)
Body/skin/skin temperature	(Fraser, 1970; Huynh et al., 2005; Renaudeau et al., 2012a)
Increased respiratory rate	(Baldwin & Ingram, 1968; Fraser, 1970; Huynh et al., 2005; Kadokawa et al.,

	2012)
Open mouth panting	(Baldwin & Ingram, 1968)
Reduced feed intake	(Kadokawa et al., 2012)
Pulse rate	(Fraser, 1970)

Some previous researchers have assessed blood components in relation to heat stress. Heat stress induces heat shock proteins/ stress proteins for example Hsp60, Hsp70 and Hsp90 in blood (Romanucci, Bastow, & Della Salda, 2008). Mishra & Palai, (2014) emphasized that HSP70 is the best indicator for heat stress. Recently heat stress led to observation of elevated insulin secretion (Ross et al., 2015).

Mapping heat stress in pigs

A heat stress index mapping conducted in Uganda showed that the Northern and Western parts of Uganda are most vulnerable to heat stress, more so in November – February than other months (Mutua, 2017). The index was composed of maximum temperature and humidity on a monthly basis.

The monthly averages at 10-minute resolution for relative humidity and maximum temperature datasets sourced from CliMod (Kriticos et al., 2012). The underlying datasets were sourced from Worldclim database and the Climate Research Unit database (contains data for the 1961-1990 period). ArcMap conducted pixel-based calculations and producing maps.

There are three categories based on heat stress including heat stress emergency; heat stress danger; and heat stress alert. Heat stress alert occurs between 24^0 C to 27^0 C, and heat stress danger between 26^0 C and 30^0 C, depending on the relative humidity. Temperatures above 31^0 C are considered a heat stress emergency for all humidity levels. However this was for a particular pig breed, and there is a possibility that this heat stress index varies for other pig breeds and production systems.

The heat stress maps by Mutua, (2017), showed that pigs in Lira District have heat stress emergency (according to the ISU heat stress index) from October to April and heat stress danger from May to September. This may be because of high air temperature and other factors.

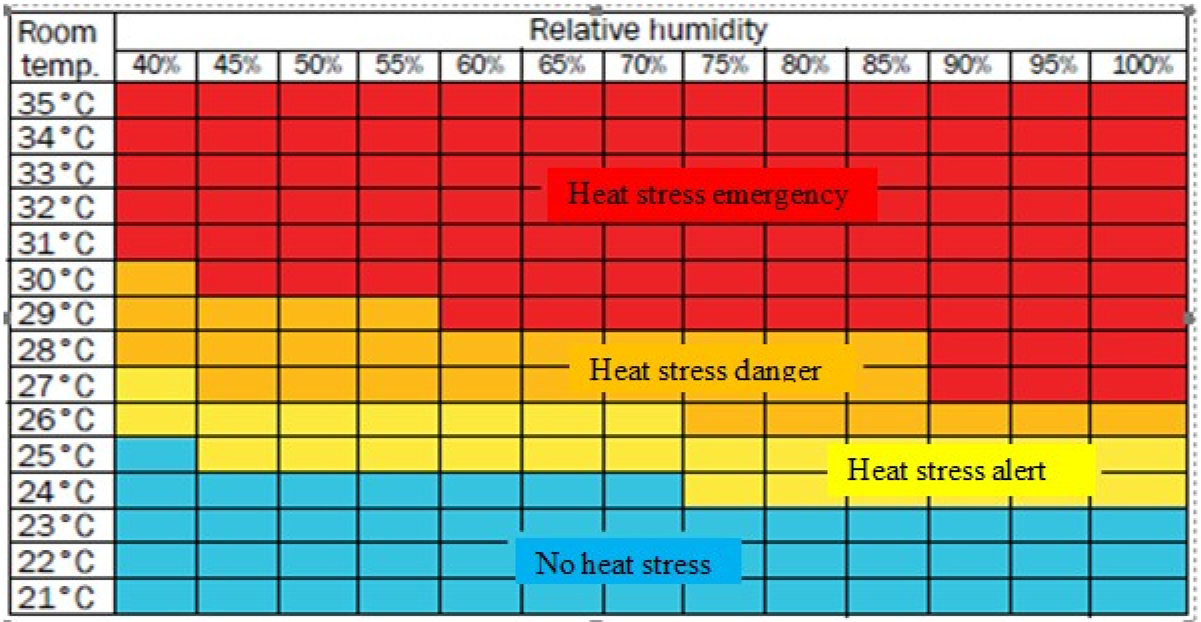

Figure 2: Index of heat stress in pigs (Source: Iowa State University)

The ranges for heat stressed pigs vary from study to study. Sutherland, Niekamp, Rodriguez-Zas, & Salak-Johnson, (2006) during the study, considered stressed pigs to be those kept at air temperature of 33±5 ^{0}C and approximate relative humidity of 50%. The upper critical rectal temperature for 60kg group-housed pigs fed ad libtum (all the time) is between 24.6 ^{0}C and 27.1 ^{0}C (Huynh et al., 2005).

2.3: Adaptation to heat stress in pig

The strategies to reduce heat stress in pig may be categorised into three groups: some leading to lower metabolic heat production and low exposure to heat source, those increasing heat loss, and others enhance pig heat tolerance (Renaudeau et al., 2012b). To adapt, pigs are fed on nutrient concentrated feeds, addition of water in the feed intake and feeding during the coolest periods of the day (Souza, 2014).

Though pigs lack functional sweat glands, they do regulate their temperature by other means. Pigs enhance heat loss by panting though they have small lungs or by cooling skin for example by wallowing (Bracke, 2011). Pig respiratory rate rises to regulate body/skin heat during heat stress situation (Bloemhof & Knol, 2014). Pigs prevent hyperthermia by wallowing (coating the body/skin surface with mud) as an effective behavioural control mechanism (Bracke, 2011). Wallowing has a co-benefit of mitigating ticks (Dione et al., 2014). Just like availing water, feeding pigs at right time and including electrolytes in the pig diet can help reduce heat stress effects (Roger, 2014).

However, a look at other animals especially cattle in developed countries, some farmers opt for modified shelter that enhances passive ventilation, and the addition of fans and sprinklers to increase body heat loss, and lowering body temperature. New technologies including providing cows with self-controlled showers (Polsky & von Keyserlingk, 2017), tunnel ventilation (Smith et al., 2006) and roofing with reflective coating (Bucklin, Bottcher, Van Wicklen, & Czarick, 1993) were investigated and showed that they offer cooling advantages. Some are opting for genetic selection for heat tolerance since it is an great possibility (Mackinnon, Meyer, & Hetzel, 1991; Polsky & von Keyserlingk, 2017; Ravagnolo & Misztal, 2000, 2002; Turner, 1984). This is a shift away from previous continued selection for greater performance in the absence of consideration for climate change adaptation which would result in greater susceptibility to climate change (K. Marshall, 2014; Turner, 1984). Some farmers are exploring addressing the changes in the nutritional needs of the animals during heat stress, and ration reformulation to account for decreased dry matter intake, the need to increase nutrient density, changing nutrient requirements, avoiding nutrient excesses and maintenance of normal rumen function is necessary (West, 2003).

While some adaptation options to heat stress can be known in farming systems of other countries, there is gap on the best heat stress adaptation options in the farming systems in the devloping countries.

2.4: Gender dimension

In Northern Uganda, there are differences in association of men and women to livestock. Cattle are associated with men due to high economic benefits and expectation of dowry payment (Mwongera et al., 2014). Fish and bees are associated to men because of hard work expectation in fish rearing and the reason that women fear being stung by bees (Mwongera et al., 2014). Pig enterprises are mostly owned by women (Ouma et al., 2015). However pork consumption is highest among men compared to women because men can easily access pork both at home and at pork roasting joints (Mangheni, 2014).

There has been a reduction in the gap between male-headed and female-headed household in pig ownership. In 2009/10 the gap was only 1.3%, with female-headed households owning pigs being higher than their counterparts at 31.7% (Tatwangire, 2014). Previous studies have stated different findings on the role played by men and women in pig enterprises. Some studies found that the activities of women in pig production include pig feeding, watering and cleaning of pens while men are mainly involved in marketing (Ouma et al., 2015; Sillitoe, 2017). However, Maass, Wanjiku, Clementine, Luvumu, & Nadiope, (2015) found that in Uganda whoever owns the pig(s) saves the revenue from pig sales irrespective of their gender. Though all assessed previous studies agreed that women are in charge of feeding the pigs irespective of ownership (Maass et al., 2015).

There are constraints women encounter including limited time due to their triple roles of production, reproduction and community work. Previous studies consistently showed that female headed farming households are more vulnerable to the climate change impacts and women in all types of households are relatively more vulnerable to food insecurity in those cultural settings in which men control food distribution (Davidson, 2016; IPCC, 2014). Climate change is causing the gender roles to shift for example women fetch water from distant places during dry season (Muhanguzi et al., 2012). Adapting to heat stress in pigs, may bring more gender issues due to labour and cost implications. There is need to assess who makes decisions and provides labour for particular adaptation options for better planning of the interventions.

CHAPTER THREE: STUDY AREA AND METHODS

3.1: Study area

3.1.1: Location and Description

Lira District- the study area is located in Northern Uganda. There are ten sub-counties in Lira District including Adekokwok, Aromo, Lira, Railway, Adyel, Barr, Ogur, Amach, Central, and Ojwina. Physically, the district lies between Latitudes 1^0 21'N, 2^0 42"N Longitudes 32^0 51"E, 34^0 15"E. The annual average rainfall in Lira district is 1200-1600 mm. The average minimum and maximum temperatures are 22.5ºC and 25.5ºC, respectively. Absolute maximum temperature hardly goes beyond 36 ºC, and absolute minimum hardly falls below 20ºC (Lira District Council, 2017).

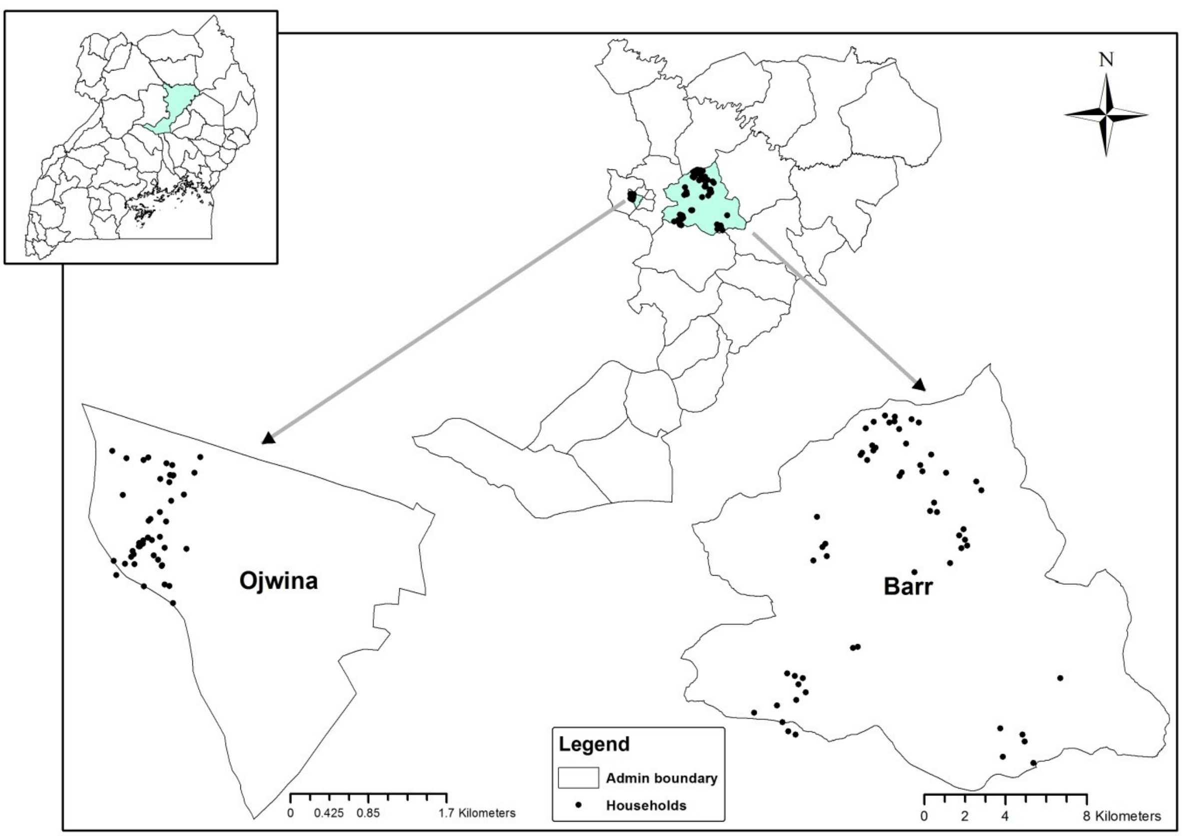

Figure 3: Map of study area

3.1.2: Biophysical Setting

Climate

El Niño–Southern Oscillation (ENSO) and other climate drivers can strongly influence East Africa’s seasonal rainfal**l;** however, Inter□Tropical Convergence Zone (ITCZ) mainly drives Uganda’s seasonal rainfall (Mcsweeney, New, & Lizcano, 2006; USAID-ARCC, 2013).

There is a 3.5% decline of annual rainfall per decade; particularly high rainfall totals in 1960□61 strongly influenced this trend (Mcsweeney et al., 2006). The projection in future is that rainfall levels will not change significantly. However, the extreme cases associated with rainfall have already been observed. In Uganda, more than 300 people died in Bududa, Eastern Uganda as a result of landslides due to heavy rains in 2010 and 2012 (Vlaeminck et al., 2016). Heavy rains with strong winds – destroy crops and affect productivity resulting in food insecurity and hunger. Other associated impacts include increased infestation of diseases such as cholera and malaria and food crises.

Basing on the datasets from KNMI climate change atlas at Ngetta Meteorological Station, Lira (located at 2.3N and 32.9E) - figure 4 below shows an incremental change in mean near surface temperature relative to a reference period of 1987 to 2017. The projections shows an increase in the mean near surface temperature in the period of 1987 to 2017.

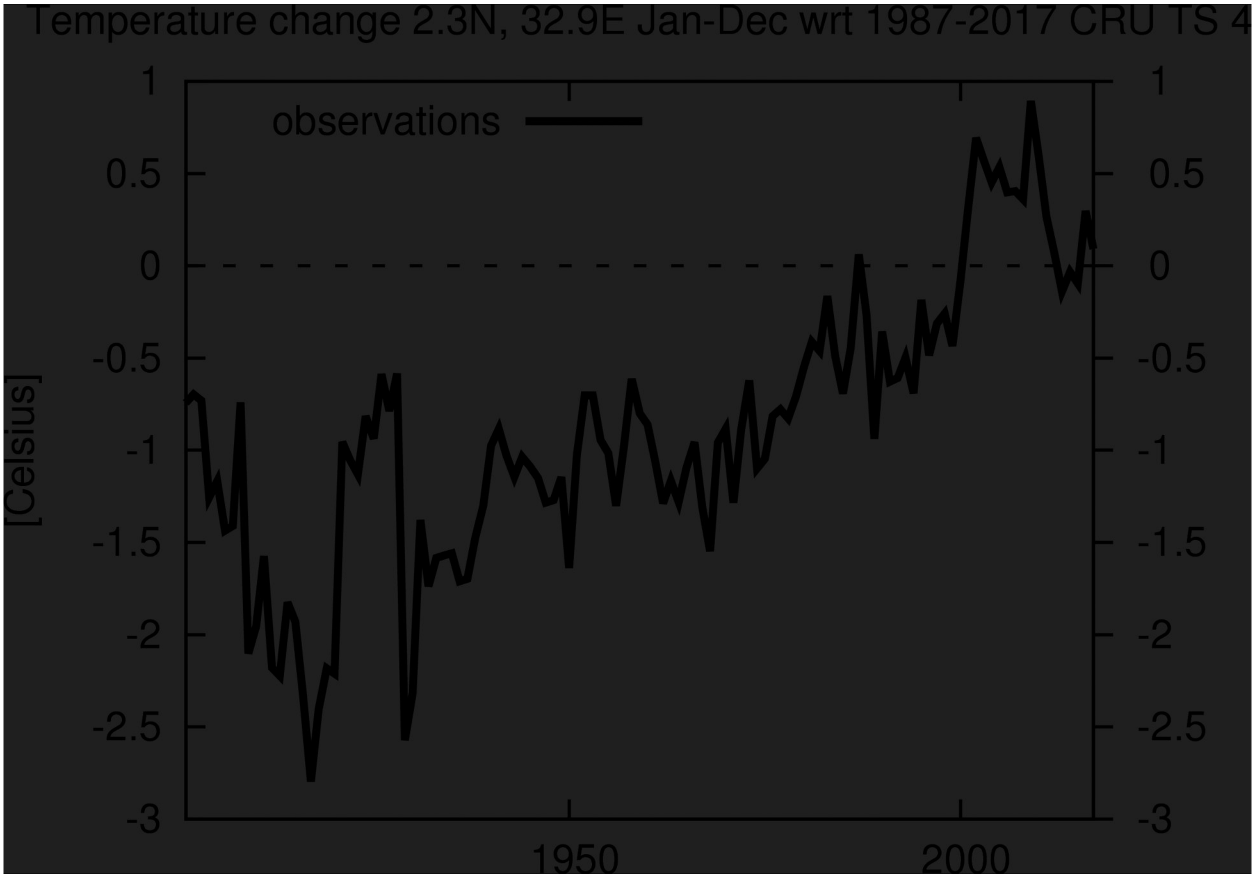

Figure 4: Trend in mean annual near surface temperature anomaly at Ngetta Meteorological Station, Lira;

Source: (KNMI, 2019)

Biophysical Vulnerabilities:

The agriculture sector, just like many other Ugandan sectors is affected by high temperature (USAID-ARCC, 2013). Prolonged droughts destroy crops and affect productivity resulting in hunger and food insecurity. Reduced water levels of rivers Kagera, Nile and L. Victoria in Uganda led to reduced hydropower generation, reduced industrial output, redundancies and unemployment due to low water supply (USDA, 2005). Climate change has increased incidence/ severity of pests and diseases for crops and livestock. More frequent and intense drought periods are causing an increase in desertification and land degradation, reducing the amount of viable land for crop production (USAID-ARCC, 2013).

3.1.3: Socio-economic Setting

Political and administrative context:

Before 1975, pig rearing in Lira was restricted to the government prison farms and the district farm institute. The most farmed breeds included Landrace and Large White. In late 1970's the government farms collapsed due to poor management. Between 1986 and 1989 cattle rustling by the Karamojong forced the farming communities to instead start rearing pigs most of them were local breeds. This is because the Lira communities feared that the Karamojong people would come and steal their cattle so they resorted to rearing pigs that were not being stolen. However in 1990's, pig rearing in Lira declined due to issues like crop destruction, hosting jiggers, which are human parasites and instead focus shifted to cattle rearing. Pig rearing declined between 2000 and 2005 because the Lord's Resistance Army threatened to kill any person found keeping pigs due to belief of pigs having demons or associated with misfortunes. Since 2005, improved pigs including Landrace, Large White, Cambrough were introduced into Lira district by National Agricultural Advisory Services (NAADS), Research Institutes, Northern Uganda Social Action Fund Project (NUSAF), NGOs, individuals and others. About 30% of the pig population in Lira district are local breeds. Majority of local breeds are found in rural areas while majority of improved/cross breeds are in the urban and peri-urban areas (Okwir, 2017). Lira district is located in Northern Uganda. In 2008, there were 340,460 pigs in Northern Uganda which was a relatively high increase compared to 138,000 pigs in 2005 (MAAIF and UBOS, 2009; Uganda Bureau of Statistics (UBOS), 2007). The total pig numbers in Lira district in 2008 were 28631±4480 (MAAIF and UBOS, 2009).

Social Setting:

The pig production domains in Lira into three based on location and purpose; rural production for rural consumption (rural-rural), rural production targeting urban consumption areas (rural-urban) and urban production for urban consumption (urban-urban) (Emily et al., 2015). The characterisation included pig density, poverty level and market access. ILRI team conducted stakeholder consultations to define criteria, and select the sub-counties for the study. Sub-counties were categorised into domains based on accessibility to market in hours and in about 50km. Four sub-counties selected by ILRI in particular domains include Ojwina (Urban-Urban); Adyel (Urban-Urban); Adekokwok (Rural-Urban); Barr (Rural-Rural).

Regulatory Framework:

This research is in line with the existing policies at all levels including national and international. Policies to create an enabling environment for adoption of climate smart technologies are important (Tumushabe, Muhumuza, Natamba, Bird, & Tilley, 2013) and should be based on understanding practices and interventions in other parts of the country or region. The lack of such knowledge impedes smooth mainstreaming of CSA policies (Knaepen, Torres, & Rampa, 2015). Existence of strategy at the national and district level in Uganda is still limited (Namanya, 2009). Policy formulation process, to a large extent is unidirectional and top-down (Ampaire, Happy, Asten, & Radeny, 2015). Policies are unlikely to be effective for Uganda's farming communities if they are not based on locally relevant and tested strategies (USAID-ARCC, 2013).

Table 2: Selected policies and their linkage to this study

Policy	Linkage
National Climate Change Policy	Objectives 2: To identify and promote adaptation policy responses for Uganda
National Development Plan (2010/11 - 2014/15)	Strategy 4: Intervention (i) Identify climate effects, vulnerabilities and coping measures as they relate to the various agricultural production strategies pertaining across Uganda. Objective 2, Intervention (v); Conduct climate change research (adaptation and mitigation) and technology development.
Uganda NAPA	Impact of high temperatures on agricultural production needs to be investigated
Paris Agreement 2015	Establishes the obligation of all Parties to contribute to climate change mitigation and adaptation.
The Berlin Charter on Rural Development 2017	Climate resilience and adaptation within rural populations is a key priority for action, (9) noting the potentials of indigenous local knowledge and locally adapted production systems

3.2: Theoretical and/or conceptual framework

Typically, pigs should maintain their temperature in a thermal-neutral zone to keep their metabolic activities under normal conditions. The homeostasis process enables pigs to be in a thermal-neutral zone. During heat stress, the amount of heat gained with metabolic processes and from the external environment, is greater than the amount of heat lost throughout the most efficient energy exchange routes including: 1) sensible heat: conduction, convection and radiation, and 2) latent heat: panting . The pig characteristics for example age, weight, sex, breed, category, and colour influence positively or negatively on these routes. The environmental temperature, solar radiation, relative humidity and wind speed influence positively or negatively on these routes (Renaudeau et al., 2012a). Initial pig's reaction will depend on the pig's instinct cooling mechanisms. For example, a pig may pant (breathing very fast) to remove heat, or reduce feed intake to reduce metabolic heat production. Pig farmers use various adaptation options to heat stress to cool the pig or reduce/prevent heat stress.

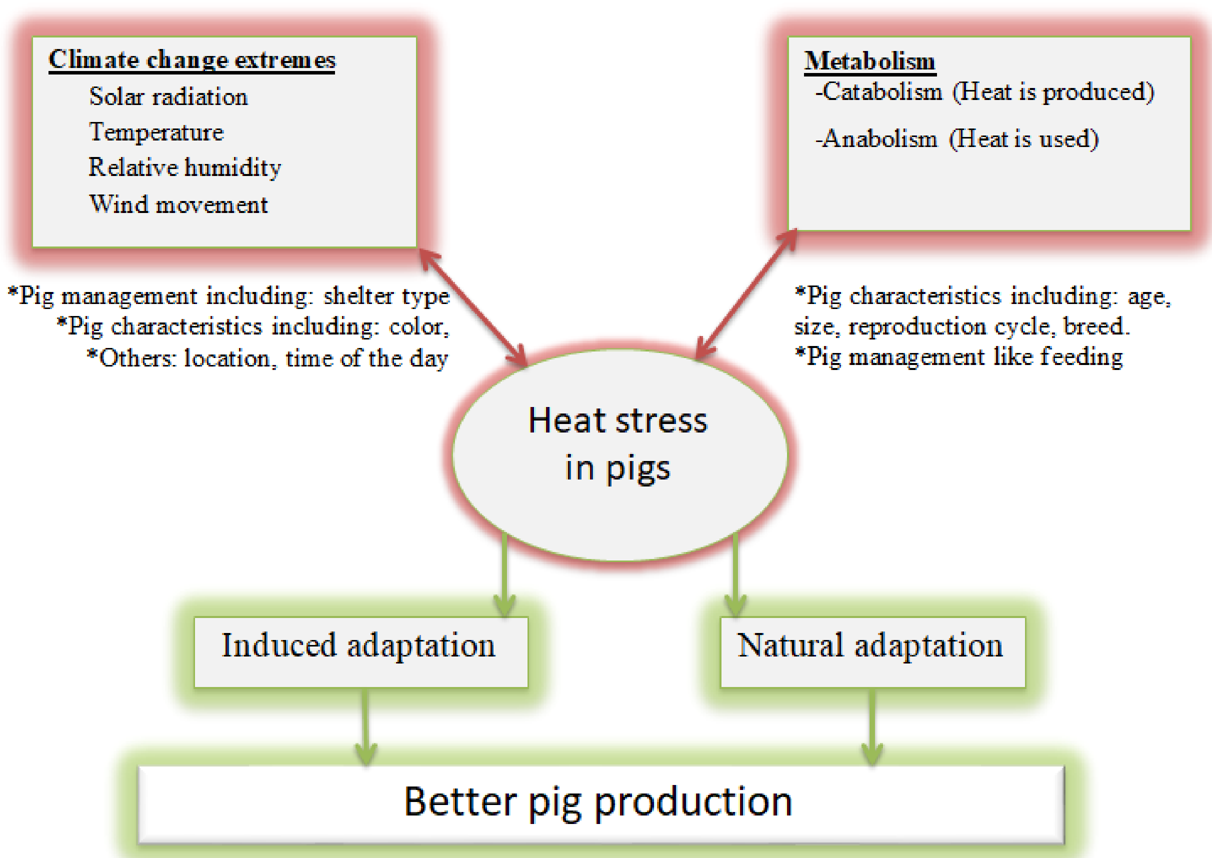

Figure 5: Conceptual framework

3.3: Methods

3.3.1: Sample size and sampling

Sample size

The sample size was determined using power analysis to know in advance the minimum sample size required to have a high chance of detecting the effect of heat stress on pigs using indicators (rectal temperature and skin temperature) used by other researchers. To determine the minimum sample size using power analysis, the standard deviation (SD=0.6481) was calculated from results by Pearce (2011). This was for comparison reasons for example rectal temperature for crossbred versus exotic pigs under similar management levels. Power of 0.80 and Type I error probability for a two sided test of 0.05, and using the standard deviation (SD) as given above was considered basing on study by Pearce (2011). The minimum sample size to detect a difference of 1.0 º C is 8 per group; and 0.5 º C is 28 per group assuming no intra-class correlation. With an intra-class correlation of 0.2 (arising from the genetic relationship between the pigs within a household and any management practices applied to all pigs in the household that are not otherwise accounted for) the minimum sample size to detect a difference of 1.0 º C is 10.4 per group; and 0.5 º C is 36.4 per group.

Equation (1) intra-class correlation coefficient (ICC) calculations

Deff =1+ICC(K-1)…………………….Equation 1

Where Deff is the design effect; k=average number of pigs per household (2.5) and ICC=0.2

Deff =1+0.2(2.5-1)=1.3

Assuming five pig-type, breed-type and management combinations (e.g. sows-exotic-housed) and a group size of 36.4 (from calculations above as per equation (1)), 182 pigs (36.4x5) are required; however 200 pigs were targeted to allow for some pigs not falling into the defined management categories. Assuming an average of 2.5 pigs per household (excluding piglets), this meant that about 100 households had to be visited.

Homogenous/heterogenous of the sample size:

The sample was largely heterogeneous. This is because of the different variables including breed, age, size, management (housing/confinement, feeding, watering, manure management).

Sampling

During sampling, stratification based on the typical pig farming systems (extensive, semi-intensive and intensive) would be an option. However, it was difficult to decide that a particular pig farm is in a particular pig farming system without data/survey. However, existing literature stipulates that urban areas tend to have more intensive pig production systems while rural areas tend to have more extensive pig production system (Dione et al., 2014; Ouma et al., 2015). This guided on stratification when sampling.

Using a list of pig farmers in Lira district generated by International Livestock Research Institute, 50 households were randomly selected from Ojwina (an urban community) and 50 households were randomly selected from Barr Sub County (a rural community). Further 15 reserve households were randomly selected from each of the sub-county.

Data was collected in January and February 2018 the period expected to be of high temperature in Lira district to capture the heat stress situation in pig farm systems. During data collection, most pig farmers in Ojwina (the urban area) had sold their pigs during the festive/Christmas season. Therefore, in Ojwina, 46 households participated in the study. In Barr, 58 households participated in the study. The survey collected data by interviewing the farmers to describe different pig production systems and existing heat adaptation strategies.

Two gender sensitive focus group discussions were organized in each of the sub counties. In each of the sub counties, one focus group discussion involved female pig farmers (Barr=7 farmers; Ojwina= 9 farmers) and another focus group discussion involved male pig farmers (Barr=7 farmers; Ojwina=8 farmers). The planned number of participants during the focus group discussion was seven; however, at some venues the number of participants was relatively higher because the attendees exceeded the invited participants.

Questionnaires were pre-tested in Lira with the data collection team including a translator, veterinary doctor and a restrainer to improve clarity and to ensure cultural appropriateness.

3.3.2: Methodology for objective 1:

To determine heat stress status for pigs and the factors influencing heat stress in pigs in Lira District, Uganda

Data collection for objective 1

The data that addressed objective one was collected during the household survey and during the focus group discussion.

The first section of the household survey consisted of sections identifying the household and study site, household characteristics, pig enterprise characteristics, and others. The second section of the household survey consisted of pig measurements and meteorology measurements.

During data collection, most pig farmers in Ojwina (the urban area) had sold their pigs during the festive/Christmas season. Therefore, in Ojwina, 46 households participated in the study. In Barr, 58 households participated in the study. A questionnaire was used to collect data. All measurements of the variables (refer to table 4) were done during day. Data for all variables from the farm was collected once at each farm visit and recorded (there was only one data point for each variable). In total 104 households and 259 pigs were involved in the study. The selection of variables to test influence on heat stress was based on factors that affect heat stress on existing literature. These numbered 29 variables in total as shown in table 3. Variables were both at household and pig level. Four sex disaggregated focus group discussions were organized to gather information about pig farmers perceptions and opinions about heat stress in pigs and the adaptation options. All data was collected with assistance from translator, veterinary doctor and a restrainer.

Pig bio-data and measurements were collected once at a single farm visit and recorded in pre-prepared data collection forms at the same time the questionnaire was administered Rectal temperature measurements were made using a digital thermometer. The skin/body temperature was measured using the infrared thermometer model: IT-122 (Shenzhen BRAV Electronic Technologies Co. Ltd, China). Both ambient air temperature and relative humidity were measured using digital thermometer-hygrometer Griffchem™ (Shenzhen Zhiboxun Electronics Technology Co. Ltd., China) and recorded at the exact pig location and at a random open space at the pig farm. Each animal was assigned to a breed group either based on phenotypic characteristics information and farmer-given breed type. Where phenotypic characteristics did not match the farmer-assigned breed, further probing on the pig parents was done. The pig category was farmer given in consultation with the Veterinary doctor. Pig color was determined through observation. Pig weight was measured using a standard weighing scale by putting the pig in the pig into a disinfected plastic sac and hanging it in the suspended weighing scale. The pig length and pig heart girth were measured using a standard tape measure. The body condition score was assessed by observation using a scale of 1 to 3 (1=thinner; 2=ideal; 3=fatter). The pigs with thinner body condition score had hips and backbone visible and easily felt and with bone structure apparent. The pigs with ideal body condition score had hips and backbone only felt with firm palm pressure and with tube body shape. The pigs with fatter body condition score had hips and backbone heavily covered and with bulbous body shape.

Weather data was collected during the time of administering the questionnaire, and it was complemented with data from Ngetta Meteorological Station, Lira. Air temperature was measured using a thermometer. Relative humidity was measured using a digital hygrometer. Wind speed at the farm was measured using anemometer CR2032 (Huizhou Winpow Electronic Co. Ltd, China). Location and altitude was recorded using a GPS device (Garmin Ltd, USA). In addition, the weather data including daily maximum air temperature and relative humidity was collected at the nearest Ngetta weather station in Lira district was obtained.

The meteorology variables at the pig location at the farm were measured within arm's length of the pig and at a height of approximately two meters from the ground. The meteorology variables at the pig farm but outside the pigsty or away from the pig location were done at an open space within the farm and approximately two meters from the ground (Dikmen & Hansen, 2009).

Table 3: Definition of variables used in the ordinary linear regression model

Variables	**Definition**[3]	Mean (SD)[1]
Dependent variables		
Rectal temperature	The rectal temperature of the pig (ºC)	39.06 (0.83)
Skin temperature	The body or skin temperature of the pig (ºC)	36.32 (2.00)
Independent variables		
External THI	Temperature humidity index (THI) at the farm outside the pigsty (°C)	43.48 (3.11)
The pig category group of the pig		
Pregnant	Pregnant sow or gilt but not lactating (1=yes; 0=otherwise)	0.17 (0.38)
Non-pregnant	Non-pregnant sow or gilt but not lactating (is	0.26 (0.44)

	the base, 1=yes; 0-=otherwise)	
Lactating	Lactating sow (1=yes; 0=otherwise)	0.08 (0.28)
Male	Mature male including castrated, not castrated or boar (1=yes; 0=otherwise)	0.33 (0.47)
Young	Young weaner or piglet (1=yes; 0=otherwise)	0.14 (0.35)
The color of the pig skin coat		
Fully white	Pig with fully white coat color (1=Yes; 0=otherwise)	0.61 (0.49)
Not fully white	Pig which is not fully white (is the base case; 1=Yes; 0=otherwise)	0.39 (0.49)
The body condition score		
Thinner	Pig with thinner body condition score (1=Yes; 0=otherwise)	0.25 (0.43)
Ideal	Pig with ideal body condition score (is the base case; 1=Yes; 0=otherwise)	0.45 (0.50)
Fatter	Pig with fatter body condition score (1=Yes; 0=otherwise)	0.30 (0.46)
Heart girth	The heart girth of the pig (cm)	67.91 (19.54)
Pig management system		
Free range	Pig under free range management system during day in dry season (is the base case; 1=Yes; 0=otherwise)	0.25 (0.43)
Tethered	Pig under tethering management system during day in dry season (1=Yes; 0=otherwise)	0.10 (0.30)
Housed	Pig under housing management system during day in dry season (1=Yes; 0=otherwise)	0.39 (0.49)
Mixed Management	Pig under mixed management system during day in dry season (1=Yes; 0=otherwise)	0.27 (0.44)
Time	The number of hours from 7 am until data was collected	5.4 (2.22)
Water quantity	Water quantity given per day per pig during dry season (liters)	7.24 (5.87)
Heat stress action	An action done to reduce heat stress (1=Yes; 0=otherwise)	0.44 (0.50)

[1] Standard deviation in parentheses

Data analysis for objective 1

Calculating thermal heat index (THI)

The thermal heat index was calculated using the commonly used formula (Vitali et al., 2009). This formula uses ambient temperature (AT, °C), and the relative humidity (RH). The RH was divided by one hundred to express the percentage in decimals.

THI = AT – (0.55 – 0.55 × RH/100) × [AT– 58]…..Equation 2

$$THI = AT - (0.55 - 0.0055 \times RH) \times [AT - 58]$$

Where:

-AT is the ambient temperature (°C), and RH is the relative humidity

-The RH is divided by 100 to express the percentage in decimals that is accounted for

General analysis

All rectal temperature and body/skin temperature variables were tested for departures from normality using STATA 14.2.

The heat stress status was assessed based on the farmers' perception. The groups of heat stress and not heat stress status for pig were statistically regressed with rectal temperature and body/skin temperature variables to see if there is a statistically significant relationship between sets of variables.

To know the factors influencing heat stress, the variables related to pig characteristics, biophysical and systems aspects were analysed using the STATA package version 14.2. A criterion was applied to select the explanatory variables for analysis. The independent variables were tested for multi-collinearity. Variables causing multi-collinearity were not included in the model. Dummy variables were developed for the remaining variables. Variables with associations found significant were subsequently input on an Ordinary Least Squares linear regression analysis used to assess the factors influencing each of the heat stress indicators. The best candidate model was developed following a backward stepwise elimination automatically using STATA 14.2.

Two best candidate models were developed- one for rectal temperature and another for body/skin temperature. The variables with significance level at 1 %, 5 %, and 10 % were highlighted.

3.3.3: Methodology for objective 2

Data collection for objective 2

Four gender disaggregated focus group discussions were arranged in the two sub counties Ojwina (urban) and Barr (rural). Each sub-county had an FGD for male farmers and one for female farmers.

Basing on literature review, scoping field trip details, farmers and focus group participants, a list of all possible adaptation options to heat stress were generated. The generated adaptation options were listed first and then farmers were asked to add more adaptation options to heat stress after explaining to them the concept of heat stress in pigs. Each adaptation option was given a preference-rating by FGD participants. Preference rating for the adaptation options was completed one at a time. The preference rating was on a scale between 1 (low) to 5 (high) for each option. Stones and beans were used to clearly illustrate the rating for each adaptation option. The rating for each adaptation option was recorded. Further probing was done to understand the reasons for the rating (either high or low preference for a particular management options). This was done during the focus group discussion.

Data analysis for objective 2

The rating and implication of the adaptation options to men and women pig farmers in Lira.

Qualitative data analysis was done basing on the data recorded from the FGDs. This focused on the reasons why particular adaptation options are preferred or not preferred.

Descriptive analysis was done to find the frequency of farmer that had used and ever heard about different adaptation options. The frequency for the farmers who make decision and provide labour were analysed using the data from the household survey.

The average preference rating was calculated using Microsoft office excel basing on the data from the FGDs.

Used Microsoft excel for graphs including the radar chart showing the preference rating for the adaptation options was designed using Microsoft Excel.

3.3.4: Methodology for objective 3

Data collection for objective 3

Some research questions for objective including who provides labour and makes decision were included in the household survey. This was aimed to understand the gender implications of each adaptation option especially in terms of providing labour and making decisions.

Data was collected during the focus group discussions using a triangulation approach. Triangulation was done by involving different present gender groups in Lira community (male and female), locations (rural and urban), research team members (local, non-local, male, female, youth and adults) to improve accuracy of the picture of the gender implication of the adaptation options. Focus was on generating experience, opinion, feelings, knowledge, and input on gender implications of adaptation, especially labour and control over income.

Data analysis for objective 3

The FGDs were designed such that there were four FGDs in rural and urban communities- one male FGD and one female FGD in rural community and one other male FGD and another female FGD in urban community. In this case, qualitative analysis was done to determine the gender differences in the responses, personal experiences, behaviour and other various approaches. The FGDs were gender disaggregated and the FGD data collection template provided guiding and probing questions that focused on providing a framework that explained Simple regressions were done to find the significance of relationships between variables using STATA 14.2. For example the income from pigs in 2017 were analysed and a simple regression to know whether there are differences on income based on gender were done. Qualitative data included the decision-making and provision of labour for particular adaptation options.

CHAPTER FOUR: RESULTS AND DISCUSSIONS FROM OBJECTIVE 1

4.1: Timing of data collection

According to farmers, January and February were the hottest months as shown in the figure 6. Further analysis showed that the monthly thermal heat index was highest in January and February as shown in table 4. This shows that the farmers' perception of the hottest months was consistent with the measured weather parameters at the weather station.

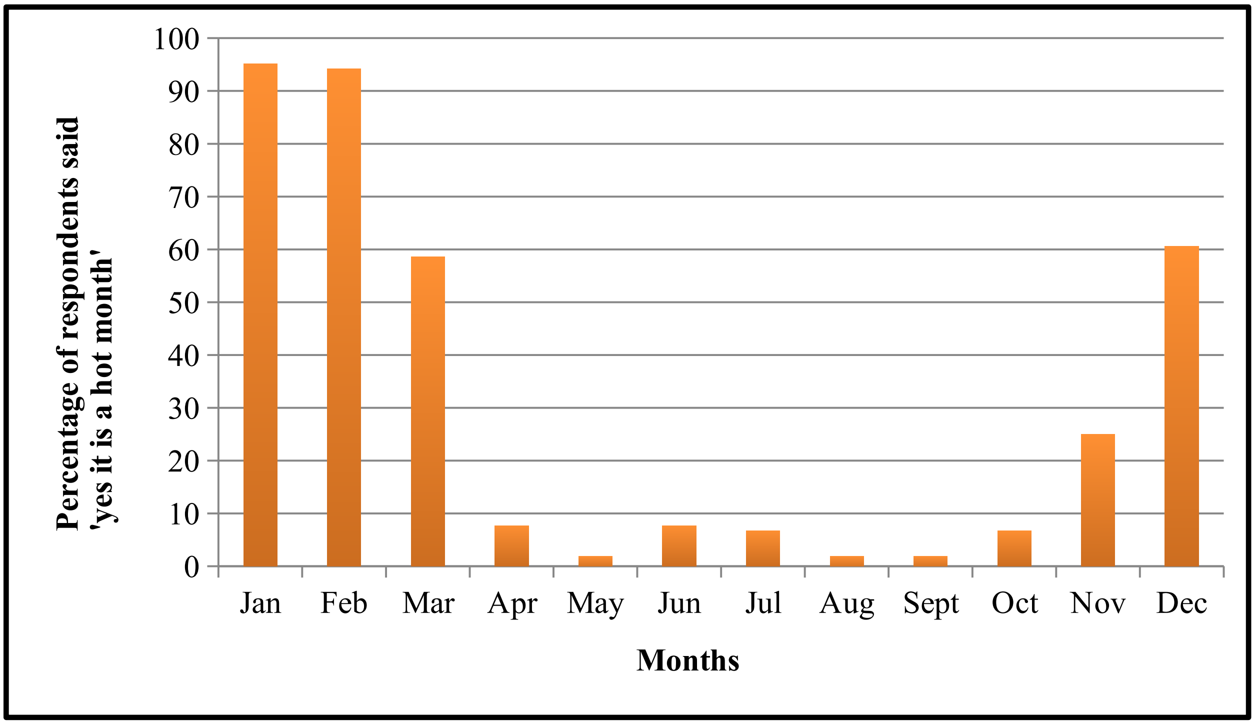

Figure 6: The months of the year in which pigs are most affected by heat stress basing on respondents' perception

Table 4: Changes in average monthly thermal heat index at the weather station before, during and after data collection

Months	AT_{max} [1]	RH_{Max} [2]	THI[3]
Nov-2017	29.98	49.00	78.12
Dec-2017	32.79	30.00	78.31
Jan-2018	32.38	54.22	82.16
Feb-2018	34.47	29.00	79.97
Mar-2018	28.99	54.71	77.66

[1] AT_{max} Mean maximum air temperature

[2] RH_{Max} Mean maximum relative humidity

[3] THI Thermal Heat Index

4.2: Household demographics

As shown in table 9 in the appendix, generally in all interviewed households, the majority of respondents were female (63%), and 37% were male. The mean age of the respondents was 39.24 years, with a standard deviation of 12.76 years. Forty five percent of the respondents were household heads, 40% of the respondents were spouses to the household head, and 15% were other family members. Majority of the respondents were from Barr sub-county (56%) and the remainder (44%) were from Ojwina sub-county. Most pig farms were located on a plain topography (17%), those on sloping topography were 17% and few ones on mixed plain-sloping topography (10%). The highest level of education by most respondents was primary school (45%), and others had reached high/secondary school (27%), those who had no formal education but illiterate were 13% and those who had no formal education but literate were 2%, 8% had finished college, 4% reached university level and 2% finished religion based school. All respondents were Christians. The pig enterprise type was mainly both farrow to wean and farrow to finish (88%), and then wean to finish (8%), farrow to finish (3%), and farrow to wean (1%).

4.3: Description of the heat stress indicators

The mean rectal temperature was 39.06ºC±0.83ºC with 243 observations ranging between 36.8ºC and 41.2ºC. The mean body/skin temperature was 36.32ºC±2ºC with 245 observations ranging between 29.8ºC and 42.7ºC. The dependent variables data were normally distributed using a histogram with normal curve as shown in figure 7 and figure 8 for rectal temperature and skin temperature respectively. There was a significant relationship between rectal temperature and body/skin temperature (p=0.000).

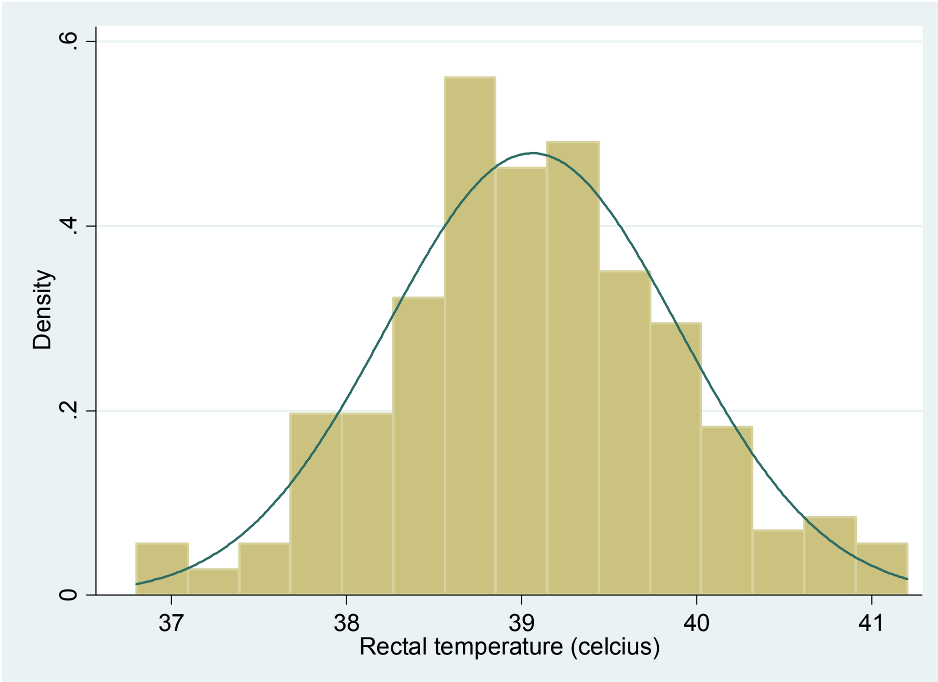

Figure 7: Histogram with normal curve of rectal temperature

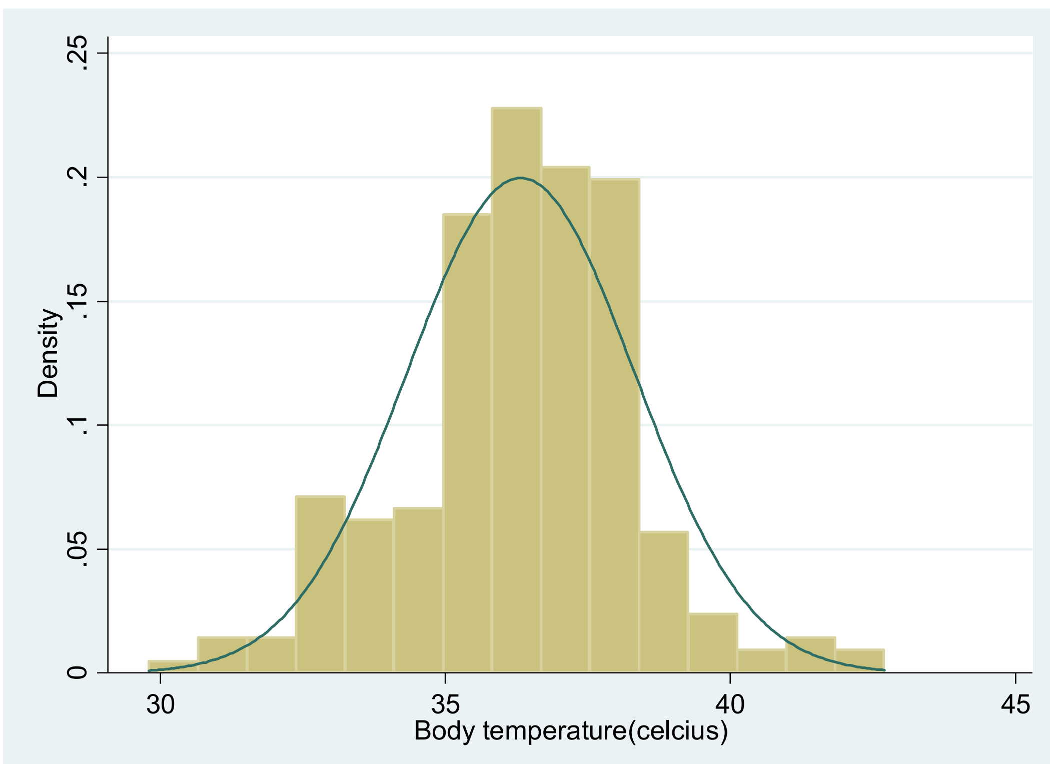

Figure 8: Histogram with normal curve of body/skin temperature

4.4: Heat stress status according to farmers' perception and relationship with heat stress indicators

According to the farmers, 48.45% of the pigs had no heat stress, 51.55% of the pigs were heat stressed. The mean rectal temperature for pigs with no heat stress was 38.75 (0.74)ºC and those with heat stress were 39.31 (0.83)ºC. The mean skin temperature of pigs with no heat stress was 35.85(1.88)ºC and those with heat stress were 36.70 (2.02)ºC. A simple regression analysis showed that there was significant differences of rectal temperature and skin temperature ($p<0.01$) between heat stressed and not heat stressed pigs ($p=0.000$). The heat stressed pigs had significantly ($p<0.01$) higher rectal temperature and skin temperature than the pigs which were not heat stressed. This means that the farmers' assessment of heat stress status was in line with the rectal and body/skin temperature measured values.

At the time of day data was collected, the farmers had initiated an action on heat stress on 44.4% of the pigs. No heat stress-action was initiated on 81.67 percent of all pigs farmers perceived not to be having heat stress. On the other hand an action on heat stress had been initiated on 70.25% of all pigs farmers perceived to be under heat stress. There was a statistically significant correlation between heat stress status and heat stress action ($p<0.01$).

4.5: Factors influencing heat stress in pigs

Table 5: Stepwise elimination Ordinary Least Squares linear regression estimates of the determinants of rectal temperature among pigs in Lira district

Rectal temperature	Coefficient	Standard error	t[1]
External THI	0.056	0.020	2.83***
Housed[3]	-0.213	0.108	-1.97*
Pregnant[4]	-0.428	0.150	-2.85***
Young[4]	-0.409	0.209	-1.96*
Fully white[5]	0.182	0.106	1.71*
Heart girth	-0.008	0.004	-2.20**
Water quantity	-0.023	0.008	-2.89***
Thinner[2]	-0.293	0.125	-2.34**
Fatter	0.127	0.136	0.93
Time	0.085	0.028	3.03***
Constant	36.981	0.830	44.54***
N = 225			
F(12, 212) = 6.19			
Prob > F = 0.000			
R-squared = 0.259			
Adj R-squared = 0.217			
Root MSE = 0.733			

[1]***, **, * denote significance at 1 %, 5 %, and 10 % level, respectively

[2]The base group is ideal body condition score

[3]The base group is free range management system

[4]The base group is non-pregnant pig

[5]The base group is non-fully white pig

Table 5 shows the ordinary OLS linear regression result of the factors influencing heat stress. The dependent variable was rectal temperature. The independent variable influencing rectal temperature included in the model are supported by scientific knowledge and reasonable assumptions derived from existing knowledge on heat stress(Ferguson et al., 2008). The model explained variation of about 21.7% of the variability of the rectal temperature response variable around its mean. The F-statistic for overall model ($p<0.01$) is statistically significant. The results show that rectal temperature is influenced by the external THI, pig management system, pig category, color, heart girth, water quantity given during day in dry season, pig's body condition score, and time of the day.

External THI

For every additional one degree Celsius of external THI, there is an additional increase in rectal temperature of 0.056 degrees Celsius ($p<0.01$). Ambient air temperature humidity index is a function of ambient air temperature and ambient relative humidity. High values of ambient air temperature will interact with ambient relative humidity to lead to high heat load to the pigs. This result is similar to result by Dikmen & Hansen, (2009), who found a significant association between the temperature-humidity index for meteorology variables taken an arm's length from the lactating dairy cow at three farms in United States of America. High THI can lead to death of vulnerable animal (West, 2003). It is important to know meteorology parameters at the farm and not rely on measurements at weather station which are typically far away from the farms and the landscape is complicated with hills, vegetation, farms and other issue of micro-climate making the weather at the weather station different from that at the farms (Freitas, Misztal, Bohmanova, & West, 2006). Ambient conditions at the pig farm are determined ambient air temperature and relative humidity (Ferguson et al., 2008). Huynh et al., (2005) showed that there is interaction between relative humidity and air temperature and this interaction. Huynh et al., (2005) reported that at high relative humidity and high air temperature, pigs had significantly higher rectal temperature because of low evaporation potential. The reason for this may be that relative humidity interacts with air temperature. At higher relative humidity, pigs are not able to lose heat from the body/skin thus a higher positive influence of air temperature on rectal temperature. Air containing higher levels of water vapor reduces the potential for evaporative cooling in a pig's environment. When body heat is not dissipated by way of evaporation, the pig retains that heat and rectal temperature increases. At lower relative humidity, pigs can easily lose heat from the body/skin to the atmosphere thus a higher negative influence of air temperature on rectal temperature.

Pig management

The coefficient for pigs kept in house (pigsty) during day in dry season was negative and statistically significant at $p<0.1$. This shows that the rectal temperature of the pigs kept in the pig houses was 0.213 degrees Celsius lower than those pigs which were kept on free range during day in dry season. This may be because pigs kept in pigsty are less exposed to harsh direct solar radiation compared to the pigs on free range. Rötter & Van De Geijn, (1999) reported that impacts of heat stress may be relatively minor for the more intensive livestock production systems where some control can be exercised over the exposure of animal to harsh environmental conditions. Pigs tethered in shades either in pigsty or under tree typically had lower rectal temperature because of the protection from solar radiation (West, 2003). Kamal et al., (2018) reported significant THI differences between all shade materials (compared to no-shade) for hourly summaries during peak daylight hour.

The coefficient of pregnant pigs but not lactating was negative and statistically significant at $p<0.01$. This shows that the rectal temperature of the pregnant pigs was 0.428 degrees Celsius lower than those with non-pregnant pigs and not lactating. This may be because pregnant pigs are given more care for example they are provided with high amount of water of 8.79 (5.96) liters compared to non-pregnant pigs which are given 8.09 (6.32) liters. At the time of data collection, heat stress action was done on 52.5% of all pregnant sows and gilts while heat stress action had been done on only 37.1% of all non-pregnant sows and gilts. This result is different from previous findings that pregnant cows are more susceptible to heat stress due to high metabolism heat production for foetal growth, general animal growth and increased maintenance requirements for heat loss (Kekana, Nherera-Chokuda, Muya, Manyama, & Lehloenya, 2018; Leles et al., 2017). Results from a study by (Omtvedt, Nelson, Edwards, Stephens, & Turman, 1971) reported that gilts were more suceptible to high ambient temperatures during the first few days after breeding than after implantation had occurred.

Pig growth category

The coefficient of the young pigs was negative and statistically significant at $p<0.1$. This shows that the rectal temperature of young pigs was 0.409 degrees Celsius lower than the non-pregnant pigs and not lactating. The large volume to mass ratio of the young pig enables them to lose heat. The thermogenesis of the pig is reported to be well developed at birth (Mount & Rowell, 1960). Sipos et al., (2013) found that as the age of the pig increased, the average rectal temperature of the pig decreased significantly.

Pig color

The coefficient for the pigs with fully white coat was positive and statistically significant at $p<0.1$. This shows that the rectal temperature of pigs with fully white coat was 0.182 degrees Celsius higher than pigs with coat not fully white. Fully white pigs were expected to have high coat reflectance and low rectal temperature. However, there is complexity on addition to the coat color including height, diameter of the hairs, and skin thickness that were not explored. The coat color of the pig mediates the impact of solar radiation and affects the extent of heat load on animals. However, any mention of pig color includes the linkage to particular breed of the pigs, though not absolute. Most fully white pigs may either be cross or exotic pigs that are considered to be more vulnerable to heat stress. Fully white pigs may not be adaptable to the environmental conditions. McManus et al., (2011) defined adaptability as the ability for the pig to adjust during extreme hot conditions. Many farmers choose to keep cross-breed which combines both the productive and adaptive traits (Marshall, 2014). Some researchers have used the animal color to explain differences in heat stress among different breeds highlighting that an animal color is a function of breed (Foster, Fourie, & Neser, 2009). Foster et al., (2009) found highly significant differences in rectal temperatures between breeds in heifers. Mount, (1959) reported no significant differences between Large White and Landrace pigs in respectively to rectal temperature. However Sutherland et al., (2006) reported that the breed of the pig had no influence to physiological responses to the chronic concurrent stressors including heat exposure. The color and the morphological characteristics of the skin coat of the cattle directly affected exchange of sensible heat and the loss of latent heat to the environment (Leles et al., 2017). Black color is expected to absorb heat while white color reflects light (McManus et al., 2011).

Heart girth

For every additional centimetre of heart girth, there is a decrease in rectal temperature of 0.008 degrees Celsius ($p<0.05$). Heart girth is a proxy estimate for weight. Pigs with higher heart girth were expected to have higher rectal temperature due to high metabolism. Mount & Rowell, (1960) reported that as the animal gets bigger, heat production per unit body weight decreases. The weaning weight is typically lower in extreme heat stress (Bradford, Fragomeni, Bertrand, Lourenco, & Misztal, 2016).

Water quantity

The pigs given more water during day in dry season were significantly associated with lower rectal temperature ($p<0.01$). Heat energy is lost from the pigs through different of forms of water. This includes in urine with higher temperature or even through vapor via the body parts exposed to the environment. Water is the most important nutrient for an animal (West, 2003). West (2003) reported that water intake in dairy cow increased by 1.2kg/^{o}C increase in minimum ambient temperature. Water is important for cooling because heat is lost through water evaporation (Fialho, van Milgen, Noblet, & Quiniou, 2004; Kamal et al., 2018).

The coefficient for pigs with a thinner body score was negative and statistically significant at $p<0.05$. This shows that the rectal temperature of pigs with a thinner body condition score was 0.293 degrees Celsius lower than those with an ideal body condition score. The thinner pigs may have less fat and lower metabolic heat generation compared to pigs with ideal body condition score. The thinner pigs can easily lose heat to the environment from the body. The pigs with thinner body condition score have high body surface area per mass rate of metabolic heat (Mount & Rowell, 1960). Thinner pigs not only produce less metabolic heat but also have higher animal based specific metabolic heat release leading to less rectal temperature (Ferguson et al., 2008). Fialho et al., (2004) reported that the modern lean pigs behave differently to the thermal environment than their fatter counterparts used to.

Time of the day

For every additional hour of time from 7:00 am, there is an additional increase in rectal temperature of 0.085 degrees Celcius ($p<0.01$). This is because solar radiation is the major source of heat to pigs which typically increases as the number of hours increase from 7:00 am. Typically heat stress is high during the afternoon (Cardoso et al., 2015; Hoffmann, Fischereit, Heitmann, Schlünzen, & Gasser, 2018). A typical day during dry season is cooler in the morning and becomes hotter during the afternoon.

Table 6: Stepwise elimination ordinary linear regression estimates of the determinants of skin temperature among pigs in Lira district

Skin temperature	Coefficient	Standard Error	t[1]

External THI	0.106	0.039	2.74***
Tethered[3]	0.590	0.548	1.08
Pregnant[4]	-0.933	0.362	-2.58**
Mixed Management[3]	0.530	0.299	1.77*
Time	0.239	0.068	3.53***
Thinner[2]	-0.554	0.275	-2.02**
Constant	30.524	1.612	18.94***
N = 227			
F(6, 220) = 6.32			
Prob > F = 0.000			
R-squared = 0.147			
Adj R-squared = 0.124			
Root MSE = 1.896			

[1]***, **, * denote significance at 1 %, 5 %, and 10 % level, respectively

[2]The base group is ideal body condition score

[3]The base group is free range management system

[4]The base group is non-pregnant pig

Table 6 shows the ordinary linear regression of the factors influencing heat stress. The dependent variable is skin temperature. The independent variable influencing skin temperature included in the model are supported by scientific knowledge and reasonable assumptions derived from existing knowledge on heat stress (Ferguson et al., 2008). The model explained low variation of about 12.4% of variation in skin temperature. The results show that skin temperature is significantly influenced by external temperature humidity index, pig category, pig management, time of the day and body condition score.

External THI

For every additional unit of external THI, there is a statistically significant additional increase in skin temperature of 0.106 Celsius ($p<0.01$). Ambient air temperature humidity index is a function of ambient air temperature and ambient relative humidity. High values of ambient air temperature will interact with ambient relative humidity to lead to high heat load to the pigs. This result is similar to result by Dikmen & Hansen, (2009), who found a significant association between the temperature-humidity index for meteorology variables taken an arm's length from the lactating dairy cow at three farms in United States of America. High THI can lead to death of vulnerable animal (West, 2003). It is important to know meteorology parameters at the farm and not rely on measurements at weather station which are typically far away from the farms and the landscape is complicated with hills, vegetation, farms and other issue of micro-climate making the weather at the weather station different from that at the farms (Freitas et al., 2006). Ambient conditions at the pig farm are determined ambient air temperature and relative humidity (Ferguson et al., 2008).

Pig category

The coefficient for pregnant pigs was negative and statistically significant at $p<0.05$. This shows that the skin temperature of pregnant pigs was 0.933 degrees Celsius lower than the skin temperature of the non-pregnant pigs. This may be because pregnant pigs are given more care for example they are provided with high amount of water of 8.79 (5.96) liters compared to non-pregnant pigs which are given 8.09 (6.32) liters. This result is different from previous findings that pregnant cows are more susceptible to heat stress due to high metabolism heat production for foetal growth, general animal growth and increased maintenance requirements for heat loss (Kekana et al., 2018).

Pig management

The coefficient of pigs kept in mixed management (mixing "free range and tethered", "free range and housed", and "tethered and housed") during day in dry season was positive and statistically significant at $p<0.1$. This shows that the skin temperature of pigs kept under mixed management during day in dry season was 0.530 degrees Celsius higher than pigs kept under only free-range management system during day in dry season.

Time of the day

For every additional hour from 7:00 am, there is a statistically significant additional increase of skin temperature of 0.239 degrees Celcius ($p<0.01$). This is because solar radiation is the major source of heat to pigs that typically increases as the number of hours increase from 7:00 am. Typically heat stress is high during the afternoon (Cardoso et al., 2015; Hoffmann et al., 2018). A typical day during dry season is cooler in the morning and becomes hotter during the afternoon. Another study found that cooling strongly affected skin temperature in the afternoon but had no effect in the morning (Huynh, Aarnink, Truong, Kemp, & Verstegen, 2006).

Body condition score

The coefficient for pigs with a thinner body condition score was negative and statistically significant at $p<0.05$. This shows that the skin temperature of pigs with a thinner body condition score was 0.554 degrees Celsius lower than pigs with an ideal body condition score. The thinner pigs may have less fats and less metabolism heat generation compared to pigs with ideal body condition score. The thinner pigs can easily lose heat to the environment from the body. The pigs with thinner body condition score have high body surface area per mass rate of metabolic heat (Mount & Rowell, 1960). Thinner pigs not only produce less metabolic heat but also have higher animal based specific metabolic heat release leading to less rectal temperature (Ferguson et al., 2008). Fialho et al., (2004) reported that the modern lean pigs behave differently to the thermal environment than their fatter counterparts used to.

CHAPTER FIVE: RESULTS AND DISCUSION FROM OBJECTIVE 2

Objective 2: Identify, rank and recommend adaptation options to heat stress

5.1: Adaptation options awareness among farmers

Table 7: The percentage of respondents aware and using adaptation options

Adaptation option	Ever heard (%)	Ever used (%)
providing more water for drinking	100	100
Providing shade	97.12	96.15
Constructing well-designed pig pens	94.23	52.88
pouring water on the pigs	93.27	89.42
chopping feeds into small particles	86.54	85.58
mixing/addition of water to the feed	81.73	82.69
pouring water on the ground/floor	79.81	64.42
allowing pigs to swim/wallow	79.81	58.65
feeding pigs during the coolest time of the day	46.15	37.5
giving pigs salt to replace lost electrolytes	41.35	33.65
allowing pigs to rest by not disturbing them	34.62	33.65
Rearing heat resistant breeds	4.81	0.96
addition of fans	1.92	0

Between 4.81% and 100% of survey-respondents who had heard of an adaptation-option had applied it for all adaptations options. There was high correlation between the farmers that have ever heard a particular adaptation option and those that had ever used the adaptation option was significant (*p*=0.000).

5.2: Preference of the adaptation options

Table 8: Preference rating for each adaptation option according to focus group discussion participants

Adaptation option	Average preference rating	Ranking
Constructing the roof high	4.75	1
pouring water on the pigs	4.63	2
allowing pigs to swim/wallow	4.48	3
allowing pigs to rest by not disturbing them	4.38	4

providing more water for drinking	4.33	5
Reducing stocking density	4.30	6
Improve pig facility design	4.25	7
Provide shade	4.25	7
mixing/addition of water to the feed	4.08	8
Constructing a grass thatched house	4.00	9
feeding pigs during the coolest time of the day	3.75	10
pouring water on the ground/floor	3.73	11
Leaving the door open	2.45	12
Chopping feeds into small particles	2.13	13
giving pigs salt to replace lost electrolytes	1.28	14
Addition of fans	1.03	15

The adaptation options shown in table 8, were categorised into three basing on the preference rating as illustrated in figure 9. The first category included the highly preferred adaptation options and these had an average preference-rating (APR) equal and greater than four but below 5. The second category included the medium preferred adaptation options that had an average preference rating (APR) equal and greater than two, but less than four. The third category had an average preference rating (APR) equal and greater than one but less than two.

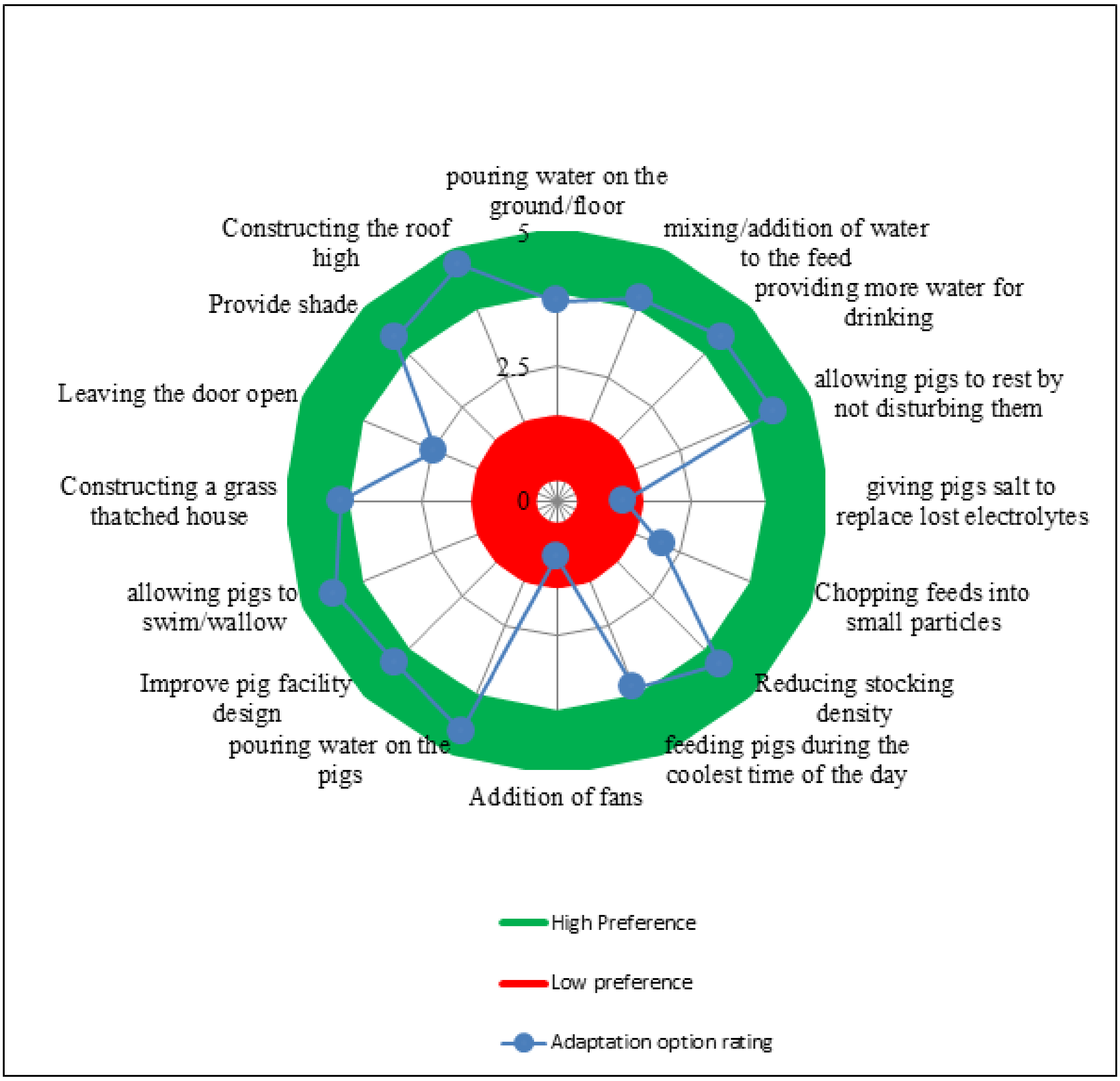

Figure 9: The preference rating categories for the adaptation options according to focus group discussion participants (1=low; 5=high)

5.2.1: The highly preferred adaptation options to heat stress

Constructing a high pig house roof adaptation option was given a high preference rating of 4.75 out of 5. High roof for the pig house allows proper air circulation and cools the pig house. It has co-benefit of allowing the person to easily enter and do any needed management practice. Men usually provide labour. There is cost involved during construction.

Generally, the average preference rating for pouring water on the pigskin was 4.63. However, female farmers gave a higher preference rating to the technique of pouring of water to the pigskin than the male farmers that participated in the FGD. Farmers in the FGD said they practice this adaptation option on pigs because the pigs have fats and pouring water on its body/skin cools them "when you pour water it wallows and enjoys it". It reduces panting and therefore heat stress instantly. However, some farmers who do not use this practice said they just prefer other adaptation options. It has a limitation of requiring the farmers' presence to do the pouring of water. All FGD participants said that women and children do the pouring of water to the pig when it is hot. In the urban area (Ojwina), men said that sometimes also men do this activity. In rural area (Barr), no cost is involved on water. Women and children do collect water from the well in rural areas. In the urban area, farmers bought water and typically, men pay for the water.

The adaptation option of allowing pigs to swim/wallow was given a high preference rating of 4.48 on average out of 5. The preference rating by male and female was approximately the same. Pig swimming or wallowing is preferred because it effectively cools the pig. Pigs naturally love swimming or wallowing and it could be used even in absence of the farmer. It has a co-benefit of reducing lice on the pig body/skin. The limitations are that when the water is muddy, it makes the pig dirty. Swimming/wallowing water when contaminated may bring infections. The water in the swimming or wallowing pool may become hot when it is a hot day. Another limitation is that no designs of swimming/wallowing pool so far are compatible with most housing types. Men or women could dig the swimming or wallowing pool. Men, women or children could do water refilling. In the rural area, there is no cost involved. However, in the urban area, there is cost of buying water. Through observation, pigs on free range would go and wallow in swamps, water source points, behind the bathrooms, at utensil washing points and any other place pigs would get water or mud. Some farmers constructed the wallows and others would deliberately take the pigs for wallowing in a swamp, in both instances, the pigs would instinctively wallow. Previous studies have appreciated the value of the behavioural mechanism of swimming/wallowing/mud-coating in regards to temperature regulation because it forms on addition to cooling, the mud coat dries on the skin and forms a protective insulation against solar radiation (Fraser, 1970; Huynh et al., 2005).

FGD participants gave the adaptation option of allowing pigs to rest by not disturbing them an average high preference rate of 4.38. On average, both male and female gave almost similar preference rating to this adaptation option. Farmers who preferred this adaptation option gave reasons including that it is a natural way for reducing heat stress. The pig does the resting by itself so it is effortless. When the pig rests in shade, the air blows on the pig and pig cools. Sometimes when the pigs have eaten, the farmer opens the door for them and the pigs come out and rest under the shade. Has a co-benefit of the pig not roaming so not destroy crops. However, some farmers suggested that pigs do not have an option but to rest because when they are in the pigsty, it is more like a prison. Another advantage is that this adaptation option generally does not require labour and no cost is involved unless pigs will be resting in pig house that could need money.

Providing water for drinking to pig is a highly preferred adaptation option with an average preference rating of 4.33 out of 5. During the FGD, female farmers on average gave this adaptation option a higher preference rating than the male farmers. According to the participants in the FGD, ‘water is life’ and helps to cool the pig body/skin very rapidly. For the farmers who keep pigs on free-range, there are co-benefits that when it is hot and pigs drink water, the pigs will stay amidst the homestead, sleep in shade and not roaming around. On the other side for those farmers who do not like giving water to the pig, they said that since they mix feed in water, for them they do not give water to the pig separately. Some farmers are reluctant to give pig more water, because pigs tend to pour water down and waste it, yet water is scarce during dry season. Just like the male FGD participants in the rural area, both female participants in the rural area (Barr) and urban area (Ojwina), said that women and children are the ones who give water to the pigs. However, the male FGD participants in the urban area (Ojwina) said that men are the ones who give water to the pigs. Both male and female participants in FGD in the rural area (Barr) said there is no cost implication on adding more water for the pigs to drink. Both male and female participants in the FGD in urban area (Ojwina) said that there is cost implication on adding more water for pigs to drink including for buying water and typically men pay for the water.

The option of reducing stocking density was rated a high average preference rating of 4.30 out of 5. Helps to enable pigs have enough space and less heat stress. Enables easy taking care of them during dry season when they are few. Allows for proper aeration; however, some farmers said this has no impact on those pigs on free range. Moreover, it was observed that most pigs were sold during the end of the year for mainly two reasons including available market during the festive season, and to reduce the stocking density as the dry season starts in January.

Both male and female farmers gave the adaptation option of ensuring the pigs are in a well-designed pig house a high preference of 4.25 on average out of 5. FGD participants said the advantage of this adaptation option include; protecting the pig from extreme weather conditions especially the sunshine that would cause heat stress. Pig houses provide shade to the pig. A pig house is important for preventing disease spread. However, there is a limitation since some pig houses are expensive to construct. Some poorly designed pig houses may not allow proper aeration. Men usually do construction of pig houses. It is important to note that any pig shelter is better than nothing basing on previous findings that found significant THI differences ($p < 0.05$) between all shade materials (compared to no-shade) for hourly summaries during peak daylight hour (Kamal et al., 2018).

Providing shade to pigs was a highly preferred adaptation option with an average preference rating of 4.07 out of 5. Shade such as trees create a microclimate for the animal because of the reduction of solar radiation exposure and reduced ambient temperature (Polsky & von Keyserlingk, 2017).

Mixing/addition water in the feed for intake was a highly preferred adaptation option with an average preference rating of 4.07 out of 5. During the FGD, female farmers on average gave this adaptation option a higher preference rating than the male farmers. Both male and female farmers prefer mixing or adding water in the feed intake because it softens the feed and water in the feed cools the pig. There is a co-benefit of dissolving and diluting salts thereby reducing salt concentration in pig feed. The challenges are that when feeds are mixed with water, the pigs tend to pour and waste the mixture. Some farmers mentioned that when feed is mixed with water, the pigs might not eat well because the stomach will be filled with water. It is also not applicable to mix some feeds with water, for example cassava. Some farmers would not mix water with maize bran, because when mixed the pigs cough and causes discomfort to the pig. The views on who does this adaptation option were divided. Both male and female farmers in rural area (Barr) said that women are the ones who mix or add water in the feed intake. While male and female farmers in urban area (Ojwina) said that all family members including men and women mix or add water in the feed for intake. All participants in the FGD said there is a cost implication for this adaptation option including buying feed, water and transportation.

Constructing grass thatched pig houses was given an average preference rating of 4.00 out of 5. However, it is important to note that the male farmers in the urban area gave this option a very low preference rating. Unlike the iron-sheets roofing which increases heat into the pig house or shelter, the grass roofing reduce and cools the pig house. Grass is locally available and cheaper especially in the rural areas. There is a risk of fire outbreak either due to natural reasons or by enemies. Unlike in rural area were grass is commonly free, in urban area the cost of buying and changing grass is high. Dry grass falls down and makes the floor dirty. Men and hired labourers provided labour when constructing a thatched pig shelter. In previous study, the maximum temperature was significantly lower in thatch roof shed as compared to that in asbestos roof shed (Kamal et al., 2018).

5.2.2: The medium preferred adaptation options to heat stress

Feeding pigs during the coolest time of the day was given a medium preference rating of 3.75 on average out of 5. Male participants in the FGD gave this option relatively higher rating than the participants who were female. The reasons for preference of this adaptation option included: eating in the cool hours allows pigs not to generate less heat in the afternoon that could have been generated during the metabolism process. This is similar to report by Polsky & von Keyserlingk, (2017) who reported shifting feeding to cooler periods during day as a behavioural coping strategy dairy cattle. This option is conducive for farmers who leave home early in the morning and return late in the evening. However, some farmers noted that pigs eat any time no matter the time. Another limitation is that in the morning, the feeds may be too cold and water too and therefore pigs may not eat well. Pig feeding was usually done my women and children.

Pouring water on the ground/floor was given a medium preference rating of 3.73 on average out of 5. It is easy and even when the farmer is not at home, children can do it. Women usually do it because men are usually away from home. However, pouring water on the ground /floor requires labor; sometimes it is not effective reduce heat stress in pig; the ground there are worms and diseases on the soil; can enter with infections. In rural area, there is no cost involved, however in urban area, there is cost of buying water.

Leaving the pig house door open option was rated a medium average preference rating of 2.45 out of 5. The benefit is that fresh air enters the pig house and cools the pig body/skin when the door was left open. There are disadvantages including that the pig may escape and it is labor intensive; other pigs may enter the pig house and cause infection or even eat the pig's feeds. Though no cost involved, men and women provide labour. The possible cost is for the wire mesh, to be fenced around the pig house.

The average preference rating chopping feeds into small particles was medium and 2.25 out of 5. Some preferred it because some feeds may have water when chopped and allows easy digestion. Some feeds may choke the pig if not chopped. Some FGD participants highlighted that this does not reduce heat stress. Some participants believed that pigs could eat anything whether chopped or not chopped. Women and children usually do the activity of chopping feeds.

5.2.3: The least preferred adaptation options to heat stress

The average preference rating giving pigs salt to replace lost electrolytes was low and was 1.25 out of 5. Farmers did not prefer giving salt to pigs because they believed that salt could kill pigs. Locally when the enemies want to kill your pigs they immerse salt to the pig body/skin so salt is associated to death of pigs. Farmers stated that salt does not reduce heat stress. There is a cost of buying salt.

A low rate of 1.03 out of 5 was rated to the option of adding fans. Probably using fans may not be applicable adaptation option in pigs given the local context, despite of its success in dairy cattle (Polsky & von Keyserlingk, 2017). Addition of fans would enhance the circulation of air and increase convection. However, fans are very expensive to procure and the maintenance costs are high.

CHAPTER SIX: RESULTS AND DISCUSION FROM OBJECTIVE 3

Objective 3: Assess the gender implications for the adaptation options especially labour and decision-making.

6.1: Income differences for male and female

Out of the total survey respondents interviewed 63.46% and 36.54% were female and male, respectively. The average household income was reported as UGX 572471.2 (with a range from UGX 0 to UGX 3500000) as the income in the year 2017: this did not differ for male and female respondents (p=0.210). The zero income for some farms was because some farms had not sold any pig in the year 2017.

6.2: Who makes decision and controls income

There were four categories of decision making according to participants in the focus group discussions as follows:

First is the joint decision making for which both males and females decide on who keeps the money or which particular pig or number of pigs to be bought or the buying of the feeds. Sometimes, they decide; a man keeps some pigs and a woman keeps some pigs.

Second is the specialized decision making of which males and females decide on the activities they are most efficient to do. One of them may do the negotiation or decide on who will buy the pig while the other may keep the money.

Thirdly, one person may make a decision in presence of another. Some men said sometimes women negotiate and keep the money. Some women said that even in presence of a man, that they make decisions of getting piglets, selling, management, and selling. However, this category of decision-making may be a source of chaos in the family. Some men said that when a man keeps the money, the woman becomes suspicious. Some women said that when men forcefully sell the pigs, they misuse the money by drinking alcohol and sometimes it ends up with domestic violence.

The fourth way of decision-making occurs when one person decides in absence of another: This typically occurs for single parents, unmarried men or women and widows.

According to the respondents that participated in the survey, there are more female decision makers than male decision makers when it comes to using the adaptation options as shown in Figure 10.

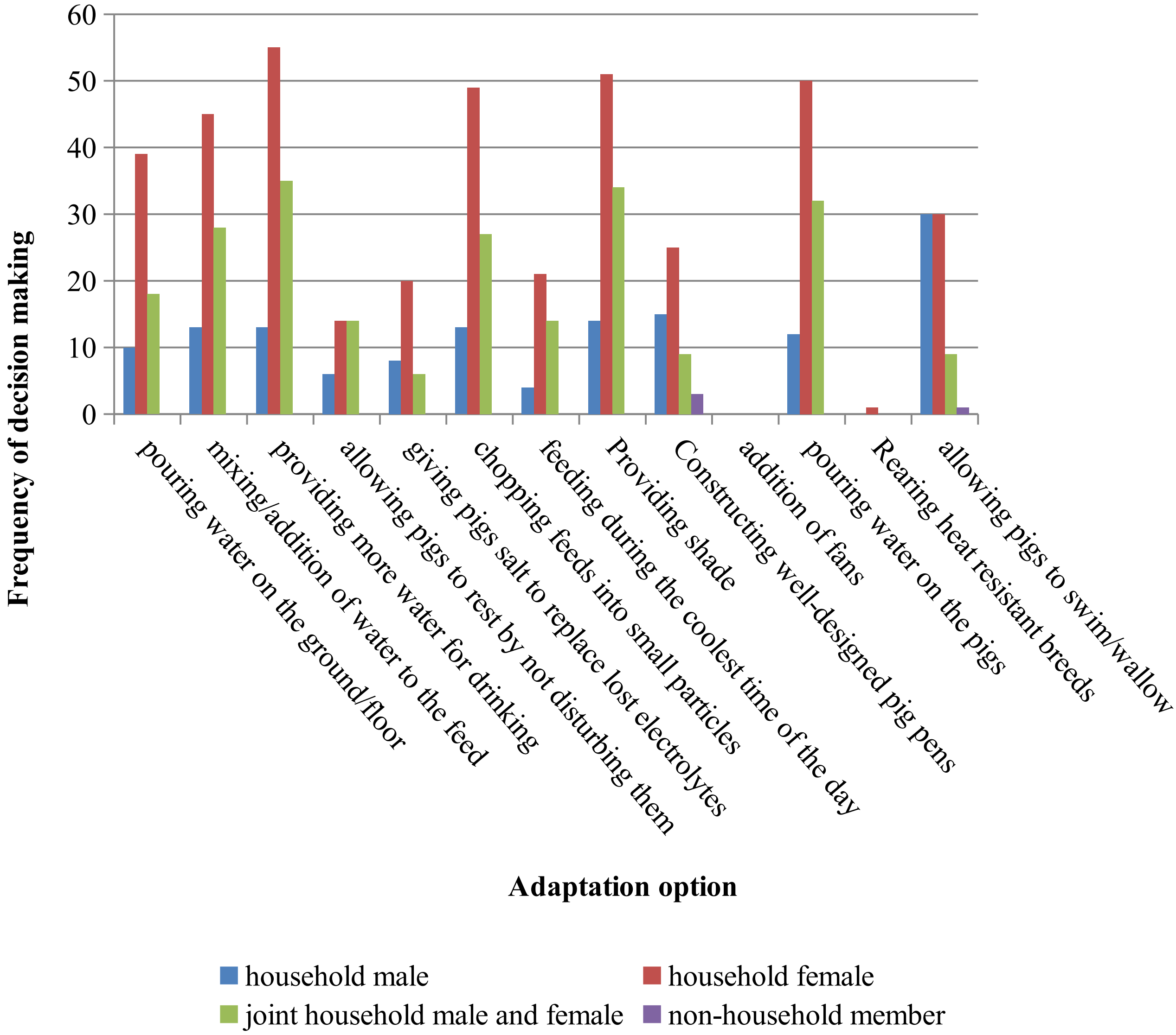

Figure 10: Who made decision for each adaptation option according to survey respondents

6.3: Who provides labour

The female members of the household as shown in Figure 1 provide most labour for the adaptation options. Labour is least provided my non-household members and household male members.

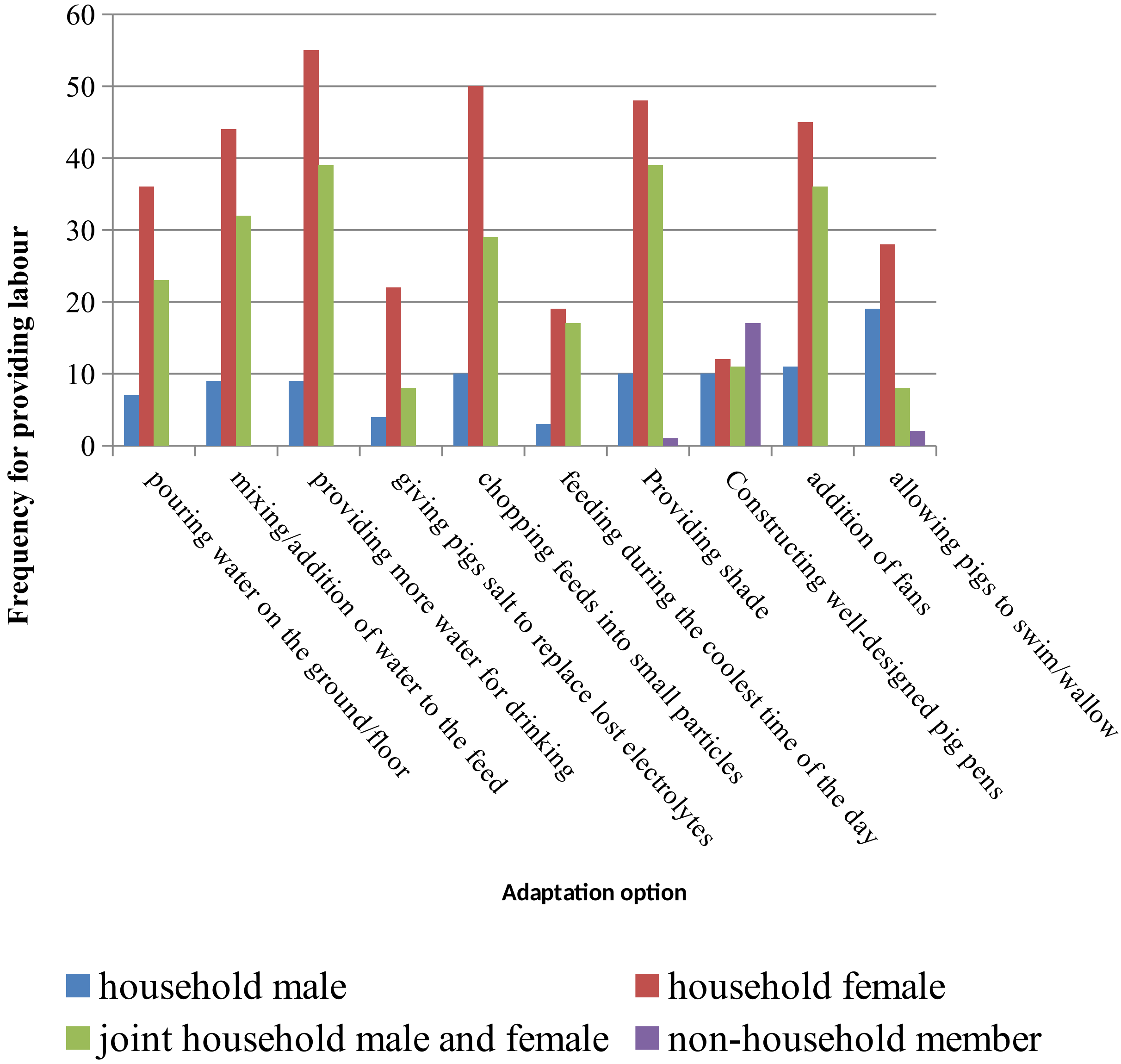

Figure 11: Who provided labor for each adaptation option according to survey respondents

CHAPTER SEVEN: SYNTHESIS AND DISCUSSION

As climate change becomes more catastrophic, temperature increases in Sub-Saharan Africa are projected to be higher than the global mean temperature increase (IPCC, 2018). The meteorology parameters, pig characteristics and farm characteristics are expected to influence the extent of heat stress in pigs.

Most number of pigs in during the period had heat stress as stipulated by the farmers. It is important to know the factors that influence heat stress. Heat stress or lack of heat stress is ultimately assessed through rectal temperature (Baldwin & Ingram, 1968; Fraser, 1970; Huynh et al., 2005; Kadokawa et al., 2012; Renaudeau et al., 2012a) and skin temperature (Fraser, 1970; Huynh et al., 2005; Renaudeau et al., 2012a). Skin temperature is always lower than the rectal temperature (Leles et al., 2017). Rectal temperature is better reliable to assess heat stress because skin temperature varies a lot on the various parts of the pig body (Leles et al., 2017).

The results and discussion section of the first objective deeply explains the factors influencing rectal temperature and skin temperature basing on the models. However, both models explain a low variation probably due to lack of some key input of variables (Freitas, Misztal, Bohmanova, & West, 2006) or probably a different unexplored set of combination of variables. However it is recognized that rectal temperature and skin temperature not only measure heat stress but also other aspects including absence or presence of diseases. During the study, this risk was minimized by not excluding pigs physically assessed to be diseased. There are potentially more independent pig parameters which could have significant effects on heat stress in pig in relation to which there is limited data or limited number of pigs per group or due reasons of correlation with other variables.

The adaptation options can be categorized into three categories. First, the adaptation options which reduce heat from metabolic activities for example chopping feeds into small particles, and feeding pigs during coolest time of the day. Second the adaptation options which reduce external heat from reaching the pig for example keeping pigs in shade and properly designed pigsty. Thirdly, the practices for cooling the pigs especially when they have heat stress for example pouring water on the pig skin, giving pigs more water for drinking, wallowing, and others. Since there was correlation between awareness of the adaptation options with the use of the adaptation options, then more awareness is needed in rural areas to adapt to heat stress.

Just like the findings in previous studies (Ouma et al., 2015), this study found that women make most decisions on the adaptation options and also do provide labour. This implies that women are relatively more responsible for what adaptions options to use relative to men.

However a look at other animals especially cattle in developed countries, some farmers opt for modified shelter that enhances passive ventilation, and the addition of fans and sprinklers to increase body heat loss, and lowering body temperature. New technologies including providing cows with self-controlled showers (Polsky & von Keyserlingk, 2017), tunnel ventilation (Smith et al., 2006) and roofing with reflective coating (Bucklin et al., 1993) were investigated and showed that they offer cooling advantages. Some are opting for genetic selection for heat tolerance since it is an great possibility (Mackinnon et al., 1991; Polsky & von Keyserlingk, 2017; Ravagnolo & Misztal, 2000, 2002; Turner, 1984). This is a shift away from previous continued selection for greater performance in the absence of consideration for climate change adaptation which would result in greater susceptibility to climate change (K. Marshall, 2014; Turner, 1984). Some farmers are exploring addressing the changes in the nutritional needs of the animals during heat stress, and ration reformulation to account for decreased dry matter intake, the need to increase nutrient density, changing nutrient requirements, avoiding nutrient excesses and maintenance of normal rumen function is necessary (West, 2003).

CHAPTER EIGHT: CONCLUSIONS AND RECOMMENDATIONS

In conclusion, this study has confirmed some of the factors that influence heat stress in practical farm conditions and not just at on-farm stations as had been done in earlier research. Heat stress was positively influenced by external THI, fully white color (white versus colored), time of the day (from 7:00 am), and mixed management (pigs on free range). Heat stress was negatively influenced by keeping pigs in pigsty (pigs on free range), pregnancy status (non-pregnant pigs and not lactating), young pig status (non-pregnant pigs and not lactating), heart girth, and thinner body condition score status (were 1=thinner; 2=ideal and 3=fatter pig; ideal body condition score). All these factors influence heat stress cumulatively and not in isolation. There is possibility that there were other factors influencing heat stress that were not explored.

According to farmers' perception, 51.6 percent of the pigs were heat stressed implying that heat stress is very rampant in the study area. Ability of the farmers to identify pigs with heat stress is vital for triggering action towards curbing heat stress. As adaptation options to this heat stress, farmers preferred constructing a well-designed pigsty, providing shade, allowing pigs to rest when it is hot, providing water for drinking, allowing pigs to wallow and pouring water to the pigs. There may be a need for improvement of the existing adaptation options and innovating new ones. Massive awareness of any new or improved adaptation option is needed since awareness about the adaptation options correlated to their use by farmers. Female members of the households were the frequent decision makers and labor providers for the adaptation options implying that female pig farmers are the major actors towards adapting to heat stress in Lira district, Uganda and other areas with similar farming system.

The recommendations include:

- Further research is needed to assess the productivity effects of heat stress in pigs, and the cost implication and the effectiveness of each heat stress adaptation option.
- The extension workers should be equipped with knowledge about heat stress and techniques to identify prevent or manage heat stress in pigs.
- Pigs should be provided with adequate water or preferably adlib especially during periods of potential heat stress. Pig swimming/wallowing and pouring water on the pigskin are some of the interventions farmers may use. Pigsty should be designed to minimize overcrowding while incorporating ways to improve air flow and evaporative cooling.

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HH ID:

APPENDIX 1: RESULTS TABLES AND FIGURES

Table 9: Household and pig farm characteristics

Characteristics	Overall
Age (years) of pig farmer	39.24 ± 12.76
SEX	
Male	36.54
Female	63.46
Other	
Relationship of respondent to household head	
Household head	45.19
Wife/spouse	40.38
Other family member	14.42
Pig keeper laborer (paid)	
Other non-family member	
Name of sub-county	
Barr	55.77
Ojwina	44.23
Topography of the pig farm	
plain	73.08
sloping	17.31
mixed	9.62
Education level of pig farmer	
No formal and illiterate	12.50
No formal but literate	1.92
Primary school	45.19
High/Secondary school	26.92
College	7.69
University	3.85
Religion based school	1.92
Other	
Main household religion	
No religion	0
Christian	100
Muslim	0
Traditional	0
Pig enterprise type	
Farrow to wean	0.96
Farrow to finish	2.88
Both farrow to wean and farrow to finish	88.46

APPENDIX 2: PHOTOS

Plate 1: Data collection team- from left; restrainer, veterinary doctor, translator, and student

Plate 2: Respondent during an interview by the student

Plate 3: Student measuring the rectal temperature

Plate 4: Focus group discussions for male and female participants going on

Plate 5: Pigs under a tree shade

Plate 6: Pig wallowing in mud during period of heat stress

Plate 7: Pigs in the pigsty; This pigsty has a high roof to allow airflow

Plate 8: A child pouring water on the pig skin as a cooling intervention during the period of heat stress

Plate 9: A pig wallowing in the deliberately constructed wallowing pond

Plate 10: One of the research feedback sessions in the urban areas

Plate 11: Research feedback session in the rural area. Participants holding translated brochures with message on how to identify and manage heat stress in pigs

Plate 12: Phenotypic guide for the common pig breeds

Source: Karen Marshall, (2017)