PREVALENCE OF BODY INJURIES AND HANDLING PRACTICES FOR SLAUGHTER PIGS AND THEIR ASSOCIATION WITH MEAT QUALITY IN KIAMBU COUNTY, KENYA

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR MASTER'S DEGREE OF UNIVERSITY OF NAIROBI (VETERINARY PUBLIC HEALTH)

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DEDICATION

To my mother, Aidah Kaggwa Namazzi. To family and friends.

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ACRONYMS / ABBREVIATIONS

AU-IBAR	African Union Inter-African Bureau for Animal Resources
CGIAR	Consortium of International Agricultural Research Centers
DFD	Dark Firm and Dry
EC	European Commission
EFSA	European Food Safety Authority
FAO	Food and Agricultural Organization
GoK	Government of Kenya
IACUC	Institutional Animal Care and Use Committee.
IFPRI	International Food Policy Research Institute
ILRI	International Livestock Research Institute.
IREC	Institutional Research Ethics Committee
KSPCA	Kenya Society for Protection and Care of Animals
NACOSTI	National Commission for Science, Technology & Innovation
OIE	World Animal Health Organization
PFN	Pale Firm and Non – exudative
PSE	Pale Soft and Exudative
RFN	Red Firm and Non – exudative
RSE	Red Soft and Exudative
WAP	World Animal Protection

ABSTRACT

The demand for pork in Kenya is expected to increase by 268% by 2050, based on data on demand for the year 2010. The government of Kenya has legislation in place demanding for humane treatment of pigs from the farm to the slaughterhouse, but no study on pig welfare has ever been done along the pork value chain in the country. The study hypothesis was that handling practices of pigs before slaughter and the resultant body injuries has an association with the quality of pork harvested. The specific objectives of this study were to; 1) determine prevalence of body injuries on pigs and handling practices which hampers welfare status of pigs for slaughter. 2) Analyze the relationship between body injuries on pigs, the handling practices and meat quality. Data on body injuries and handling practices were collected from 529 pigs, and meat samples of *biceps femoris* obtained for a total of 387 pigs previously selected for the study. The meat samples were placed in cool boxes and then transported to the laboratory at the Department of Public Health Pharmacology and Toxicology, University of Nairobi for further analysis. These meat samples were subjected to various tests to determine meat $pH_{24,}$ meat color and drip loss, and a published criterion was used to categorize meat into four different meat quality categories: Pale Soft and Exudate (PSE), Dark Firm and Dry (DFD), Red Soft and Exudative (RSE) and Red Firm and Non-Exudative (RFN). Data were analyzed by computing frequencies and other measures of central tendencies and dispersions. Further analysis was done to determine the relationship between the body injuries and handling practices with the various meat categories using multinomial logistic regression. The results showed that about 97% of pigs were not well stunned based on signs of consciousness post-stunning, 83% had one or more body injuries with the most prevalent being laceration to the ears (ear marks' used as identification markers). About 5% of the pigs were transported to slaughterhouses when tied on motor bikes and bicycles while 27% were transported under conditions of high loading density. Approximately 48% of pork leaving the abattoir were classified as Red Firm and Non-exudative (RFN) which is considered ‘normal’ quality with the rest of the pork falling within the ‘poor’ quality classification categories of Red Soft Exudative (RSE) (11.4%), Pale Soft Exudative (PSE) (3%,) Dark Firm Dry (DFD) (3%,) while 36% were unclassified. There was a strong association between purchase-slaughter interval and high loading density with reduction in quality of meat, where for every one-hour increase in purchase slaughter interval the relative odds of obtaining PSE and DFD pork increased by a factor of 1.02 and 1.04 respectively, while high loading density increased the likelihood of harvesting PSE, RSE and DFD meat. These findings call for the need for education of various stakeholders along the pork value chain to improve on pig handling practices and the welfare of pigs because they are sentient-beings and are capable of suffering pain, besides the resultant loss in quality of pork harvested. Therefore, policy makers and other pig practitioners should consider these findings to change legislation on pig welfare and husbandry practices under similar settings.

CHAPTER ONE

1.1 BACKGROUND

Pork is a growing source of animal protein globally, the main producers being China and the European Union, with a steep upward trend in other regions of the World (Szűcs & Vida, 2017). In Africa, pigs are increasingly contributing to improved nutrition and household incomes (Nantima et al., 2015). The sub-Saharan African region particularly Nigeria, Uganda, Malawi, Democratic Republic of Congo, Rwanda, Burundi, Ghana and Kenya has seen a rapid increase in the production and consumption of pork over the recent past (FAO, 2011). The demand for pork in Kenya has been increasing, driven by an expanding and urbanizing human population with increasing disposable incomes. In 2012, approximately 129,450 tons of pork were produced in Kenya (Mburugu Mosoti, 2014), with the demand for pork consumption predicted to increase by 268% between 2012 and 2050 (FAO, 2017). The largest pig slaughter facility in Kenya produces approximately 80% of the country's processed pork products and exports approximately 2000 tonnes per year, while three independent slaughter facilities located within Nairobi and multiple local slaughter slabs, all supply pork for the local markets (Murungi et al., 2020). The growth in the pig sector in the country is ongoing, yet with little attention to pig welfare in Kenya (Mutua et al., 2020)

Animal welfare refers to the physical and mental state of an animal in relation to the conditions in which it lives and dies. One construct of welfare considers the provision of five freedoms; the freedom from hunger and thirst, freedom from discomfort, freedom from pain, injury, or disease, freedom to express normal behavior and the freedom from fear and distress (OIE, 2019; OIE, 2013). On this basis, Kenyan Prevention of Cruelty to Animals Act (1983) clearly outlines the regulations to be followed in animal slaughter, and the penalties that have to be faced in contravention of this law. Efforts have further been made in enforcement of awareness about animal welfare through incorporation of animal welfare learning in higher institutions like Universities and Technical schools offering animal sciences courses (AU-IBAR, 2017). This in turn has provided a platform for non-governmental organizations (NGOs) and other bodies to join the welfare campaign.

As well as being an ethical issue with implicit importance to the individual sentient animal, welfare has important impacts on the safety and economics of meat production. Mal-treatment of animals from the farm all the way through transportation to the abattoir and pre-handling before slaughter causes distress (negative stress) to these animals (Stajković et al., 2017). Stress is defined as the physiological, behavioral and psychological state of the animal when confronted with, from the animal's point of view, a potentially threatening situation (Terlouw, 2005). This triggers the Sympathetic Nervous System and the Hypothalamic Pituitary Adrenal Axis to modify and release hormones that lead to physiological and metabolic responses (Trevisi & Bertoni, 2009). These responses can produce meat defects that include exudative pork: Pale Soft and Exudative (PSE) and Red, Soft and Exudative (RSE) pork; where the glucagon hormone released leads to anaerobic break down of glucose, producing lactic acid that lowers muscle pH, decreasing the ability of muscles to hold water. Metabolic responses can also lead to Dark, Firm and Dry (DFD) pork where there is aerobic breakdown of glucose with no production of lactic acid, leading to high muscle pH and no breakdown of muscle fibers hence a lot of water is retained in the carcass postmortem (Feiner, 2006). Several studies have reported associations between different welfare practices and these pork qualities, for example; prolonged fasting leading to PSE meat, unsuitable loading densities increasing incidences of PSE and DFD pork, increased lairage time leading to DFD pork, electrical stunned pigs producing higher incidences of PSE pork relative to pigs stunned with Carbon dioxide and a review reporting how other stunning methods are likely to produce particular meat quality defects (Čobanović et al., 2016; Guàrdia et al., 2005; Gregory, 1987; Trevisan & Brum, 2020; Velarde et al., 2000)

There appears to be an increasing awareness by Kenyan consumers of animal welfare issues and a stated willingness to pay for improved welfare (AU-IBAR, 2017.; Otieno & Ogutu, 2020). With an increasing middle-class with disposable income, demanding higher-quality animal source products, this indicates that pig welfare can no longer be ignored by the value chain stake holders because consumers have been documented to be diverse and dynamic in their purchase behavior (Clemons & Gao, 2008) and may boycott products which do not adhere to their demands.

Animal welfare is a relatively new field in Africa, with scare data therefore available on welfare issues across the continent (Mutua et al., 2020; Tan, 2021). No studies have been carried out to date on the influence of animal welfare practices on meat quality in the Kenyan context. Science has an important role in underpinning societal decisions around animal welfare (Hemsworth et al., 2015) and welfare assessments provide an evidence base as recommended by Blokhuis et al.,(2008) for enhancing compliance with and enforcement of animal welfare legislation. As slaughterhouses provide important points for the assessment of animal welfare (AU-IBAR, 2017), this research, determining the prevalence of welfare associated lesions and handling practices for pigs at the point of slaughter and their relationship with technological meat quality provides such an evidence base for the pork value chain in Nairobi.

1.2 Objectives

1.2.1 General Objective.

To investigate prevalence of body injuries on pigs destined for slaughter, pig handling practices and their relationship with meat quality at a non-integrated pig abattoir in Kenya

1.2.2 Specific objectives.

- Estimate the prevalence of body injuries and handling practices for pigs taken for slaughter
- Determine the relationships between body injuries and handling practices with meat quality from slaughtered pigs

CHAPTER TWO

LITERATURE REVIEW

2.1 Animal Welfare Frameworks

Different analytical tools have been developed overtime to assist in the assessment of animal welfare at all levels of production for farm animals. In this section these frameworks i.e biological and affective states, the 5 freedoms and one welfare are going to be described. These frameworks approach assessment of animal welfare under different perspectives as explained below. A few of them overlap but debates on differences persist.

2.1.1 ***The 5 freedoms of animal welfare***

This framework was formulated from the basis of the Brambell report of 1965 for assessment of animal welfare from which the 5 freedoms of animals were later developed in 1979. Each freedom comprises of two parts: the freedom and the provision (Webster, 2016). These include:

1. Freedom from hunger or thirst – by ready access to water and a diet to maintain health and vigour.
2. Freedom from discomfort – by providing an appropriate environment including shelter and a comfortable resting area.
3. Freedom from pain, injury or disease – by prevention or rapid diagnosis and treatment
4. Freedom from fear and distress – by ensuring conditions and treatment which avoid mental suffering
5. Freedom to express normal behaviour – by providing sufficient space, proper facilities and appropriate company of the animal's own kind.

Four of these five principles reflect the largely accepted need to assess freedom from poor welfare conditions and the fifth freedom introduces a whole new dimension on what acceptable animal welfare means and how it can or should be assessed (Hughes, 1976).

This framework is extensively known in farming, academia and policy making, and forms the foundation of most animal welfare laws, codes for recommendations and farm animal welfare accreditation strategies, and was used to develop the Welfare Quality® assessment scheme (McCulloch, 2013). It's widely used in education of veterinary and animal welfare science (McCulloch, 2013). Despite all these benefits, some have argued that the use of "freedoms" for assessment of animal welfare is a concept that should be left to non – specialists because advances in animal welfare science have since exposed their limitations, which have become particularly evident when trying to use them as the basis to determine whether or not farming practices are acceptable for purposes of developing standards (Hughes, 1976). Broom, (2019) argues that freedoms aren't accurate enough to be employed in assessment of the welfare of given species or group of species because they are not logical in places if the wording is considered exactly. He further explains that all freedoms, whether for humans or animals should have limitations therefore making them not fully achievable. McCulloch (2013), argues about the ambiguousness and interconnectedness of the terms used in these freedoms while Webster, (2005), describes them as ideal but unattainable states of animals. However, the Five Freedoms have withstood strong criticism to achieve cosmopolitan public acknowledgement and are easily found in national laws, marketing and farm assurance programs, occasionally with a few modifications (FAWC, 2009).

This framework was used by Lukovic *et al*. (2017) to obtain differences between the different production systems in the European union where they found that alternative production systems assured better welfare of pigs related to freedom to express natural behavior in comparison to intensive production systems. Freedom from hunger and thirst was infringed upon especially in the outdoor pig production systems. Expression of normal behavior during transportation as an indicator of stress has been investigated by Kim *et al*. (2004) who reported that at high stocking densities animals usually stood and couldn't express their normal behavior of standing or sitting. The freedom from hunger has also been used as a yardstick by Driessen *et al*.(2020) that concluded that pre-slaughter withdrawal of food for more than 18 hours is detrimental to pig health and welfare. In South Africa, based on the freedom from distress, Spencer & Veary (2010) found that there were no specialized trucks for transportation of pigs and this led to fighting and heat stress. In his study in Kenya about designs for trucks used to transport animals Wambui *et al*., (2016), reported that there were no appropriately designed trucks for the transportation of cattle and this often led to injuries and fractures, thus infringing on the freedom from pain and injury.

2.1.2 The concept of One Welfare

Another somewhat new conceptual framework for assessment of Animal welfare is "One Welfare" that recognizes the interconnections between animal welfare, human wellbeing and the environment. (Garcia *et al*,.2016). This concept has its root on the already infamous concept of One Health. (Broom *et al*, 2019) adds "One Biology" to this concept arguing that from a biological point of view, humans are animals and that human activities degrading the environment have far reaching consequences not only to the environment and animals but also to man. Colonius & Earley (2013) add social welfare, the balance of welfare across societies and generations, to this concept.

Given the breadth encompassed by the vision of One Welfare, an interdisciplinary approach is required in fostering its reality where we are cognizant of the fact that concentrating efforts on improving a single aspect could lead to inefficiencies in another. Several studies show how well functional livestock production systems without environmental consideration could have dire effects on environmental health. Animal production systems have significant water, carbon and nitrous oxide footprints and are noted among the largest factors accounting for climate change. The need for attentiveness on the influence of animal production upon the environment has been greatly emphasized and research providing solutions to such challenges falls directly into the concept of one welfare ((Rojas-Downing et al., 2017; Steinfeld *et al*, 2006). One Welfare is a paradigm aimed at complementing initiatives set up to remedy these problems.

The one welfare framework is described in great detail, with befitting experiences and cases explained under each by (Garcia *et al*, 2015), the framework comprises of the following tenets in no particular order of priority:

1. The connections between animal and human abuse and neglect.
2. The social implications of improved animal welfare.
3. Animal health and welfare, human well-being, food security and sustainability.
4. Assisted interventions involving animals, humans and the environment.
5. Sustainability: Connections between biodiversity, the environment, animal welfare and human well-being.

The above One Welfare framework makes it clear that Initiatives to improve animal welfare cannot be isolated in nature but ought to be multilateral. International and domestic public policies ought to take responsibility of not only scientific, ethical, and economic affairs but additionally religious, cultural and international trade policy consideration (Garcia *et al*, 2016). One Welfare provides a stable policy drafting platform that considers man, animals and the environment. There are already approaches and research in practice as explained by Garcia (2017) but the concept still needs more development in regards to assessment tools of these tenets before its more integrated into policy, education, national and international development projects as for the case of the five freedoms of animals.

2.1.3 Concept of biological functioning and affective states

This approach is explained by basic health and normal body functioning, stress responses, and various behavioral responses like indicators of welfare of animals. This approach has the capacity to be largely evidence-based and objectively measurable, as there is a good scientific understanding of, and accepted methods for the measurement of, biological function and physiological responses to stress. Biological function may be measured by clinical, behavioral and physiological parameters (Hemsworth and Coleman, 2010)

This framework is most closely aligned with early but enduring public policy because it is an appropriate framework to support the development of acceptable minimum welfare standards, particularly those mandated under legislation. Many farm animal welfare research studies have employed this framework, though a focus on biological function alone has been questioned as insufficient to truly assess welfare when animal sentience is considered (Hughes, 1976; Hemsworth *et al*, 1998)

The concept of animal sentience leads to a second conceptual framework that of affective states, based on the idea that welfare of an animal is acquired from its ability for, and experience of, positive and negative states, experiences and/or emotions. The negative comprise; pain, fear, frustration, thirst, and hunger, and the positive comprise comfort and contentment. Thus, this framework emphasizes that the welfare state of an animal is a balance between positive and negative experiences. This concept more thoroughly encompasses animal behaviors, including the notion that positive affective states result from an animal's ability to carry out a range of innate or normal behaviors, and/or that denial of an opportunity to carry out some behaviors may lead to negative affective states (Duncan, 2006).

Affective experiences in animals, like emotions, are subjective states and can't be assessed directly, but there exists informative indirect physiological and behavioral indices that can cautiously be employed to attempt interpretation of these experiences. Methods that have been used to assess affective states are explained in detail in (Duncan, 2006). As some negative states are likely to have an impact on biological functioning, they may be indirectly measurable through those scientific methods, which highlights the overlapping of these frameworks. However, scientific methods for measurement of some positive affective states are still being developed.

The affective states framework for animal welfare introduces more values-based elements, compared to the biological functioning approach, but research towards improving the evidence base is underway (Hughes, 1976). Although initially seen as competing, the biological functioning and affective state frameworks effectively overlap therefore they are not entirely self-sufficient that single-mindedly pursuing one may cause poor welfare from the other. The two approaches are more unified with biological functioning known to include affective states and affective states known as a product of biological function (Hemsworth *et al*, 1998)

The biological functioning framework was used by Hemsworth *et al*. (2015) to assess grouped sow welfare. The study showed that reduction of the space of the floor for gilts and sows increased aggressiveness and stress, it reduced immunity and performance in reproduction, it also showed that a inadequate dieting of pregnant sows led to hunger.

2.2 Regional and local studies on animal welfare

A few animal welfare studies have been carried out in Africa around pre and during slaughter of animals, Omotosho *et al*. (2016) carried out a research to investigate and create a better understanding of pig slaughtering practices and the animal welfare and hygiene situation in the process in Southwestern Nigeria where he reported animal welfare issues that included inhumane transport , restraint, lairaging, and stunning. These lead to a lot of stress and detriment to animal welfare. Spencer & Veary (2010) carried out a study in South Africa to understand the significance of the welfare impacts in relation to the way pigs are handled before slaughter, stunning induction requirements for accurate electrical stunning, and the methods used to stun and stick where they found that the welfare of pigs before slaughter was affected by the origin and type of pig slaughtered, the daily throughput range of pigs and which abattoir. They observed deficiencies animal welfare in offloading animals, they found that none of the abattoirs had a properly designed stunning place, increased pig pre-slaughter stress followed. They also reported that stunning was done a number of times on a given animal.

A few animal welfare studies have been carried out in the East African region mainly in assessment of set systems and how they relate in the protection of the welfare of animals. Grönvall (2013) evaluated animal welfare in Ethiopia during slaughter and to investigate chain activities between animal markets and Kera abattoir in Addis Ababa where he found a significant correlation between abusive handling and aggressive animal behavior, he also noted that animals trek for very long distances during this process. Lemma *et al*. (2019) carried out a Knowledge, Attitude and Practice (KAP) around animal welfare study in Ethiopian communities and they found that respondents had a good amount of knowledge about animal welfare but however scarcity of resources led to undermining of animal welfare.

2.3 Economic and health impacts of poor animal welfare

Economic Impacts of Poor Animal Welfare

Livestock keeping, at almost all scales, is a business where economics are of profound importance (Sinclair *et al*, 2019). Therefore, introducing changes that improve animal welfare can be expensive and momentarily increase production costs (Grandin, 2015) but in the long run, cost-benefit analysis show total income potential increases (Burgess & Hutchinson, 2005; Sinclair *et al*, 2019). A study in Burkina Faso and Mali showed training of farmers in principles around animal drug usage was costly but with more revenues (Liebenehm *et al*. 2011)

From an economic perspective the benefits to improved animal welfare include; improved product quality, reduced animal losses due to mortalities (Grandin, 2015), improved productivity like live births and milk production per animal (Aguayo-Ulloa et al., 2014) reproduction and thrift in livestock. Intensive animal production systems like caging layers, force feeding broilers, sow stalling among others most often compromise animal welfare leading to stress that has serious consequences on the whole stock, given reproduction rates go down, production indices reduce, and costs of production go up.

Some statistics on healthcare of animals show that a big portion of losses of animal production are not caused by pathogens in isolation but by poor animal breeding, feeding and raising and other management related factors (Vetter et al., 2014). Market opportunities are obtained from good welfare. Willingness to pay studies show that consumers in the United States of America could pay higher to buy meat that made them feel contented about animal welfare of the animal through its life and at slaughter (Fearing & Matheny, 2007).

Animal welfare has traditionally been seen as a 'luxury' in Lower and Middle Income Countries (LMICs) because consumers purchase food as cheaply as they can because the situations in the nations don't allow them to be strict in their food choices. However, a change in subject to meat exporting enterprises in these same countries could prioritise improved animal welfare as a relevant benefit to continue exporting, animal products to western nations and also expanding wider to other markets. Improved animal welfare makes the animals safer and easier to handle, which results in improved slaughter line speeds (Gibson & Jackson, 2017) and requires less staff, that are satisfied, likely to be with less time off and less medical expenses (Sinclair *et al*, 2019)

(Gibson & Jackson, 2017) discuss pleurisy in pigs in the United Kingdom (UK). Pleurisy is a chronic condition that can arise due to negligence in proper management of pigs and can lead to post harvest losses arising from pleural stripping or, in the most extreme cases, excessive trimming of the chest cavity. They explain that the losses incurred due to this disease at slaughter amounted to 226 pence per pig at the production end while at the processing end, a reduction of in-line speed and associated staff costs were calculated at 29 pence per pig. (Harley *et al*., 2012) losses can also happen because of poor quality meat. As much as (PSE) and (DFD) meat is fit for human consumption, it has decreased retail potential and profitability because of its abnormal texture, appearance and odour and has cost up to £12,660,000 annually, estimated losses to the UK pig industry

In Africa, very few studies have been done to show this link, however, a study by Jaja *et al*.(2018) in South Africa to quantify the amount of food lost to condemnation and factors' contributing to these losses and monetary loss due to condemnation, they cited bruises, abscesses and cysts among the major causes of condemnation and that monetary losses for all condemnations in the study were over 34,000 United States Dollars USD. Post-harvest losses have also been reported to happen in Africa due to inhumane slaughter of pregnant animals, Njoga *et al*. (2021) in Nigeria carried out a study in cattle to examine the slaughtering conditions and slaughter of pregnant cows, and the impacts on meat quality, food safety, and food security and found that an estimated loss of about 44,000 kg of beef, equivalent to $186,400 was lost in foetal wastages in the 6 month period of the study. Another longitudinal study by Adebowale *et al*. (2020) still on bovine foetal wastages in Nigeria reported an estimated loss of up to $ 2,943,886.22 in the 9 year period. In Tanga abattoir in Tanzania, Swai *et al*. (2015) reported a foetal wastage of 29.1% in a period of 3 months.

Transport stress is an issue in animal welfare and can lead to economic losses, a study by Adeyemi *et al*. (2010) in Nigeria on the effect of transportation stress on slaughter cattle documented employment of unfit vehicles, cattle tied to each other in lying positions, overloading, absence of rest, and lack of water for cattle in transit, brutality to cattle during loading and unloading as the stressors experienced by cattle during transport the economic losses incurred from these suboptimal transportation conditions amounted to USD 7,692 and USD 4,086 respectively for cattle that died in transit and moribund cattle respectively. A similar study by Ibironke *et al*. (2010)

in Nigeria that did not quantify monetarily revealed a loss of 1197 cattle and 27 camels due to deaths resulting from inhumane transportation for a period of 3 years.

In Kenya, due to use of trucks not designed for the transport of cattle Wambui *et al*. (2016) reported a cattle mortality rate of 6.16% in the duration of his study. No such studies have been carried out in the pig value chain in Kenya.

2.4 Human and environmental health impacts of poor animal welfare

As explained earlier on in the "One Welfare" framework, treating animals humanely has a ripple effect on the environmental and human health, conversely poor animal welfare also has its effects on the health of man and the environment. Therefore, this section will throw light on the latter, in contexts of both industrial and small holder farming systems.

Globally, industrial farm animal food production is about 50% of all food animal production. There are ethical challenges to these systems given the practices there in that barely meet international regulations of the five freedoms. (Goldberg, 2016)

As explained earlier, in industrial systems, pigs are confined in tiny group pens or standalone stalls with no space for any kind of movement. Such intensification systems pose health risks not only to animals but to humans and the environment as well. For example, large masses of swine waste are released in these housing systems and it finds its way as a soil fertilizer or into runoff and waterways (Devereux, 2014). The resultant contaminants have crucial negative environmental effects on water hygiene effects and even climate change.

To maximize profits, livestock enterprises rely on heavily feeding animals to attain market weight in the shortest time possible. Use of small quantities of antibiotics in feed is known to increase the weight gained by an animal in a given period of time. This non therapeutic antibiotic usage raises animal welfare concerns that have far reaching impacts on human health in the form of anti-microbial resistance. For example, in America, 80% of all manufactures antibiotics find use in farm animals, for non-therapeutic uses (Goldberg, 2016).

Welfare concerns in such systems are a source of stress to the animals which leads to the release of catecholamines that decrease relsease of gastric acid, delay gastric emptying and accelerate motility of intestines and transit of the colon (Tache *et al*., 1999; Monnikes *et al*., 2001). Consequently, rise of stomach pH increases probability of foodborne pathogens surviving gastric passage and colonizing the Gastro Intestinal Tract (GIT). (Rostagno, 2009)

Stress related released hormones act on the intestinal mucosa to change interactions between luminal microorganisms and epithelial cells (Wang & Wu, 2005). leading to high microbial invasion ability in the GIT. As a consequence, stressed animals are more susceptible to emerging (and more severe) infections, and could carry higher pathogens in the GIT and associated lymphoid tissue. Also, animals that already excrete bacteria can shed more with their higher defecation frequency, because of higher motility of intestines (Lenz *et al*., 1988; Williams *et al*., 1988; Barone *et al*., 1990). The total sum of all this leads to increased shedding of pathogens that find their way in the human food chain.

The alternative small holder systems used broadly in African settings also come with their own animal welfare concerns. Given the scarcity of monetary resources and the changes in weather conditions, feeding, housing, treatment and transportation are faced with a litany of challenges (Devereux, 2014). For example, Banda et al., (2012) explains that animal nutrition in small holder systems is usually characterized by under nourishment as scarce land provides limited space for foraging of animals. Environmental implications then arise as foraging pressure from animals combines with subsistence farming by humans on limited pieces of land.

This same pattern of scarcity is also seen in the housing systems that are usually built very close to human settlements leading to very high risks of exposure to zoonotic pathogens because of poor waste disposal and poor structural designs. (Devereux, 2014)

2.5 The pork value chain in Kenya

Pig production in Kenya consists of large integrated commercial farms, medium scale commercial farms and small scale commercial farms. The latter is done in small holding units, as conventional free range systems as well as scavenging systems in urban slums and garbage disposal areas. It makes up to 70% of Kenyan pig producers, usually characterized by 5-100 pigs (Mutua *et al*, 2010). A study in western Kenya where the traditional systems are popular recorded pig production constraints that included; insufficient feeding (Mutua *et al*., 2012), less established marketing strategies (Kagira *et al*., 2010), poor breeding (Mutua *et al*., 2011), inadequate time to attend to the pigs, tether wounds (Mutua *et al*., 2010).

Medium scale commercial pig farmers keep 100 - 5000 pigs and large integrated commercial farms have over 5,000 pigs, Farmers' Choice (FC) falls under this last category with approximately 30,000 pigs with farms in Uplands, Kamiti and Eldoret.

Feed is responsible for close to 80% of the costs in producing pork (Mburugu Mosoti, 2014). Millers, in general can be categorized as: Fully automated, semi- automated millers with manual feed mixers; and non-automated millers mixing rations with spades, however, farmers also make their own feed from raw materials that they buy and mix at their farms supplementing this feed with the compounded feeds, this helps to reduce costs. (FAO, 2012)

Other inputs in this business are; technical extension and training. Veterinary drugs and vaccines which can be obtained specially from the veterinary stores (Mburugu Mosoti, 2014)

There are 5 main pig abattoirs in Kenya as mentioned below with their normal throughput; Farmers' Choice; 400 pigs a day, Kenol-Kabati slaughter house in Thika; 30 pigs per day; Ndumboini Slaughterhouse in Kabete; 50 pigs per day; Lyntano slaughter house in Nairobi; 8 pigs per day; and London slaughter house in Nakuru; 8 pigs per day. Pig slaughtering in other areas regions, such as western Kenya is mostly executed in localized slaughter-slabs (Cook *et al*., 2017). Currently, only Farmers' Choice is subscribed to international quality standards like Hazard Analysis Critical Control Point (HACCP), BVQI (Bureau VERITAS Quality International), ISO and Total Quality Management standards and is the only abattoir that can export pork and pork products from Kenya. (FAO, 2012)

The large pork processors are mostly Nairobi area and big cities. The main pork processors are Farmers' Choice, with other smaller processors in Nairobi, Nakuru, Njoro and Eldoret. Most of them get carcasses from Ndumboini and Kabati abattoirs besides Farmers' Choice. Large pork butcheries like Gilani's in Nairobi and Nakuru and Prime cuts in Village market can be termed as processors given that they deal with both fresh and processed pork products. Advanced technology is used by processors including cold rooms, refrigerated transport trucks and processing equipment in differentiating cuts for optimum prices.

Pork marketing is done at 4 levels; at the farm gate for live pigs, at the slaughterhouses for slaughtered pigs, at the butcheries for fresh meat, specialized pork eateries for cooked pork and as processed products from retail outlets. Most pork products have sale through butcheries as well as eateries, these constitute the informal market (Murungi *et al*., 2020)

In Kenya, the distances between the livestock production areas and terminal markets can be large, making livestock movement a necessity (Wambui *et al*., 2016). Depending on distance, Animals are transported on foot, motor bikes and in trucks for delivery to the slaughterhouses (Heinz & Srusivan, 2001). Similar to a report from Ethiopia by Asebe (2016) in Kenya there are often no appropriate vehicles for transport or loading facilities and animal handling is generally poor during the process. Poor transport and loading/offloading practices lead to common cases of lameness, muscle injuries and sickness (Hellstrom, 2013).

The government of Kenya is aware of this and hence drafted animal welfare into law. The Prevention of Cruelty to Animals Act Cap360 (2012) which describes in detail the protection of animals in transit where clear instructions are given to the animal transporters about how animals, including pigs, should be loaded and offloaded onto the trucks, how they should be transported and advises against health states of animals that wouldn't be suitable for animal transport. It further goes on to detail the best means of travel to be used and guides on the general design of the vehicles in relation to the floor and surfaces of the car. This law does not only offer guidance to transporters but also clearly outlines the roles of government officials in relation to transportation and when and which penalties should be given to individuals in contravention to these laws.

In spite of all this documentation, a study by Wambui *et al*. (2016) still concluded that there were no dedicated trucks for long distance transportation of animals but improvision with locally available trucks to do the job, this poses a risk of falling, trampling and fighting. Cleaning these trucks is also difficult making them hosts for disease pathogens, which is a food safety concern. Wambui *et al*. (2016) also reported wear and tear of material used that contained no modifications of hard wood as recommended/advised by veterinary authorities for use on the side of the body of the trucks and poor ventilation. The total sum of this according to his study led to animal mortalities.

2.6 Pig Welfare issues and their assessment

Various factors determine the welfare of animals at farm level and these fall in the categories of; housing and environment; nutritional and health programs; handling and caretaker interactions; animal group dynamics; and common management practices (Devereux, 2014). However, in this section we are going to elaborate on those experienced by animals subsequent to leaving the farm premises.

Welfare of pigs at slaughter involves aspects of pig handling from the transport process, through unloading the pigs from the truck, moving them to the Lairage and subsequently to the stunning point and exsanguination. The major pig welfare issues during transportation include: loading density, duration, animal size and condition, management factors on the truck and vehicle design. Pigs from different farms may be transported together and this leads to fights among them in establishment of hierarchical dominance (Faucitano & Geverink, 2008). On arrival at the slaughterhouse animals are often not immediately offloaded. The total sum of all this is pain, injuries, fatigue, prolonged hunger and thirst, heat stress, mortalities and morbidities (Schwartzkopf-Genswein *et al*.,2012).

During offloading of pigs, ramps are supposed to be used in the process to prevent slipping and falling that might lead to fractures and injuries. The animals are then moved to the Lairage preferably by use of boards and not electric goads to prevent injury to the animals. (Rabaste *et al*., 2007; Faucitano & Geverink, 2008)

Pigs require rest in the Lairage for at least 2 hours to enable them to recover from the stressful process of transportation, this in turn improves the quality of meat that will be harvested. Combining pigs from different farms into the same spaces and inefficient facility designs, contribute to aggression for dominance hierarchy and subsequent injuries and stress (Terlouw et al., 2008). Pigs should then be moved from the Lairage to the stunning area by use of boards and not electric goads to avoid injuries. Grandin (1997) further advises that its best to slowly and calmly move pigs in small groups rather than individually as pigs naturally follow other pigs, or in large groups since they may be more difficult to drive. He advises that the race set up to the stunning point should be well lit and preferably made of solid walls to keep the animal's focus in front.

It's prudent that pigs are rendered unconscious before slaughter to eliminate pain, discomfort and stress due to this procedure. Whatever the stunning method, the animal has to get rendered unconscious long enough for bleeding to result in enough blood loss to cause death from shortage of oxygen to the brain (cerebral anoxia) (Channon *et al.*, 2002). This means that, death has to happen before the animal is able to regain consciousness and should be bled before it regains its consciousness. However, this is not always the case due to inefficiencies in the stunning process and equipment as described by (Faucitano & Geverink, 2008). Commonly practiced in Kenyan non – integrated abattoirs is head only electrical stunning because of easy access to electricity and ability to locally produce/improvise the tools used. However, the convenient access to this method should be coupled with the recommended specific instructions for efficient stunning, these mainly include the position of placement of the tongs and the voltage used. Hoenderken (1978) and Anil (1991) advise that when the tongs are placed in the right position, a current of 0.5 A delivered using a 50 Hz sine wave alternating current (AC) is adequate but when the tongs are positioned behind the ears, 1.3 A is required to stun pigs, with a stun duration of 3 seconds (Faucitano & Geverink, 2008)

Lack of observation of these specific instructions demeans the function of head only electrical stunning because as much as the animal may be immobilized, it will still be conscious and therefore sticking would happen in the absence of unconsciousness. Stocchi *et al.* (2014) observed 84.13% of animals showed one or more signs of consciousness during bleeding, therefore this welfare concern is not alien and education to slaughterhouse operators could go a long way in remediation. EFSA *et al*. (2020) clearly describes animal based measures that could be observed in the presence or absence of consciousness, these include; apnea which can be recognized from observing the flank and/or mouth and nostril for movement, vocalizations, spontaneous blinking, movement of mouth and nostrils. The other welfare concerns to look out for during this period is the stun to stick interval. This is important because stunning only renders the animal unconscious for a given time before the animal displays signs of consciousness again. A study by Anil (1991) reported that this interval is 37s. This means that if the animal is stunned, but bled beyond 37s, then the bleeding will have been done in the presence of consciousness.

Another less commonly used stunning method in East African pig abattoirs is the use of head on blunt force with a wooden or metal plank is used to deliver a blow to the pig skull to render it unconscious. Frequently, more blows are required in absence of proper execution and therefore blunt force has risks of high failure rate. These multiple blows are painful to the animal and elicit fear (FAO, 2001)

Finally, it's important to ensure that sticking of the pig is done right. In Kenya, the thoracic stick is commonly used where a long blade is used to sever the brachiocephalic trunk. Its pertinent that this is done accurately to ensure that the pig doesn't regain consciousness. The animal should also be left long enough to bleed out to death so that subsequent procedures, i.e scalding, dehairing and evisceration are done when the animal is dead. Anything short of this would mean that all these subsequent procedures were done while the animal is still alive exposing it to a substantial amount of pain and fear before its death (Faucitano & Geverink, 2008)

2.6.1 Welfare assessment at farm level

OIE lists animal outcome-based criteria that can be useful indices of animal welfare. These are considered as tools for monitoring efficiency of design and management, since they influence animal welfare. (OIE, 2019). Below are descriptions of some of the criteria used to assess pig welfare at farm level.

Behavior

Pigs have strong motivational systems to meet their essential needs. These include basic needs for eating and drinking, but also for exploring the surroundings and expressing their natural behavior. (Godyń *et al*, 2019). Normal behavior in pigs are those observed under natural conditions (Wallgren *et al*, 2016). Therefore, indoor raised pigs do not display the entire repertoire of behaviors they perform under natural conditions. Abnormal behaviors on the other hand refer to behaviors in pigs that have not been seen under natural conditions. They indicate of poor welfare in pigs under production conditions. Management and environmental deficiencies can cause changes in behavioral patterns, and can lead to abnormal behaviors. (Li, 2015).

Environmental enrichment

The attention to animal enrichment was introduced for the first time in the 1940s for laboratory animals (Godyń *et al*, 2019). Animals should be provided with an environment that provides complexity, manipulability and cognitive stimulation to foster normal behavior, improve their physical and mental state and reduce abnormal behavior. For pigs this calls for enrichment of their environment (OIE, 2019). Domesticated pigs still express very similar behaviour to their wild ancestors and this has implications for pigs in our farming systems and the behaviours we try to satisfy with the provision of enrichment. Enrichment can manage and prevent escalation of undesired and damaging behaviours, like tail biting. Examples of materials used for this include salt and mineral lick stones, substrates such as Lucerne/alfalfa straw, green fodder, miscanthus (pressed or chopped), root vegetables, peanut shells, fresh wood, corn cobs, natural ropes, compressed straw cylinders, shredded paper, pellets, larger space, fragrance or even music. Furthermore, enrichment for pigs should be done considering the fact that pigs may lose attention towards an object in a few days, and therefore their environments should be frequently renewed (Godyń *et al*, 2019).

Painful procedures

Pain in animals is an aversive sensory and emotional experience that represents the animal's notion of damage or threat to the integrity of its tissues (Molony *et al*, 1997). Procedures such as surgical castration, tail docking, teeth clipping or grinding, tusk trimming, identification, and nose ringing may be performed on pigs but have the potential to cause pain (Van Beirendonck *et al*, 2011). They require to be performed ways that minimize pain, distress and suffering animals. Options for improving animal welfare during these procedures include the internationally recognized 'three Rs: replacement (of painful procedures with less painful ones), reduction (such procedures done only when necessary) and refinement (e.g. providing analgesia or anesthesia under the recommendation of a veterinarian) (OIE, 2019).

Provision of feed and water

Pigs ought to be supplied with sufficient quantity and quality of *feed* and nutrients every day to enable each pig to keep healthy, meet its physiological foraging and feeding requirements. Feed and water need to be provided in such a way as to prevent injurious competition with adequate supply of drinkable water free from contaminants available at all times. In outdoor systems where pigs have some autonomy over diet selection, stocking density should match the available natural feed supply (OIE, 2019). They can also utilize by-products and human food waste (FAO, 2011).

Transportation of pigs

Numerous reasons exist for movement of animals like marketing, slaughter, re-stocking, from drought areas to better grazing and change of ownership. Known methods of animal movement include; by hoof, by road, rail, air and on ship. This activity is very stressful to animals and is an avenue for poor animal welfare and decreased production (Heinz & Srisuvan, 2001). During transportation animals can get bruised, trampled, suffocated, heart failure, heat stroke, sun burn, dehydrated, exhausted and injured.

Vehicles for pig transportation should have good ventilation, a non-slipping floor, proper drainage and adequate protection from the sun and rain. The sides surfaces should be smooth and with no protrusions. Vehicles should be fitted with a portable ramp to facilitate offloading (Averós *et al*, 2008)

Avoid feeding of pigs before transport because the feed ferments and the gas leads to pressure on the heart in the thoracic cavity, risking heart failure and death. They should not be transported with other species unless separated by a partition

High environment temperatures raise heat stress risk and mortality during transportation therefore it's of importance to move animals during mornings, evenings or even at night. High humidity combined with high temperatures is lethal to pigs, this can happen in stationary vehicles. Pigs can therefore be kept cool by wetting them and allowing them access to frequent drinks of water during long journeys, especially in hot and humid conditions (Heinz & Srisuvan, 2001)

Most developed countries use loading densities of 0.35 – 0.46m^2/100kgs for the transport of pigs (Warriss, 1995a). This offers appropriate space required for sternal recumbence and ensuring enough area for all animals to rest and to not fatigue during transportation. High densities could reduce the risk of pigs being thrown around by the vehicle's motion. At maximum pigs should be journeyed for 3 hrs (Warriss, 1995a). Warriss *et al*. (1998) demonstrated that, between the range of stocking density of 201 to 321 kg/m^2, densities on the higher end led to increased physical stress to pigs transported for 3 hr.

2.6.2 Welfare assessment at abattoir level

In most conventional abattoir systems unfamiliar pigs are handled together in pens during lairage leading to fighting. Lairage pens may be poorly designed with slick floors or long holding times which increase stress levels. Pigs are usually moved in large groups from the lairage pens to the stunning area by use of electric goads, both these practices are against the natural behavior of pigs and very stressful (Støier *et al.*, 2001).

Over recent years, in developed countries, many scientific opinions and guidelines on pig welfare at slaughter have been advanced, mostly focusing on specific monitoring indicators to evaluate how effective stunning methods are (EFSA, 2013a). Therefore, an establishment can choose to develop and enforce a written animal handling scheme that sufficiently addresses the most crucial attributes of animal welfare. (Nastasijevic *et al.*, 2018).

Increased stress during transport, Lairage and prior to stunning, increases the shedding of food borne pathogens in feces by animals meant to be slaughtered (Martínez-Miró *et al.,* 2016; Massacci *et al*., 2020; Nastasijevic *et al.*, 2018; Rostagno, 2009; Verbrugghe *et al*., 2011). This increased shedding, alongside poor food hygiene practices can subsequently introduce increased amounts of microbial load (including pathogens) into the slaughter line and consequently onto food for human, affecting the process hygiene at slaughter/dressing and increase the public health risk for the consumer because of high exposure to foodborne pathogens (Nastasijevic *et al*., 2018). Therefore there is a need for revision of abattoir inspection structures to incorporate strict animal welfare monitoring.

2.6.3 Lesion and Non-Lesion assessments of Pig welfare

The abattoir is an important multi-purpose area for monitoring animal diseases, zoonoses and food safety however (Harley *et al* 2012). Bottacini *et al*. (2018) further recommend the abattoir as an important site for assessment of animal welfare. There is a general consensus that animal based lesions are the best parameters for assessing the level of welfare an animal (Main *et al* 2007). This study is going to look at loin bruising, tether lesions, hind limb bursitis and tail biting.

Loin bruising refer to patches of hemorrhage on the skin that can either be localized or of a diffuse nature. This may be due to mounting or fights during transportation. These injuries are suggestive of poor welfare (Harley *et al*., 2014). These lesions together with tail biting are some of the highly cited animal-based indices of pig welfare and expert panels recommended their utilization in assessment (EFSA, 2012; Van Staaveren *et al*., 2017). Tail biting is for the most part due to modern pig management systems characterized by high stocking rates with no opportunities for normal foraging or exploration behaviors (Sonoda *et al*., 2013) and competition for insufficient feeder space (Zonderland, 2010). Causes of tail biting are multifactorial, coming from interaction of various environmental factors of the animals.

Bursitis is a lesion found on the metatarsal region of the hind limbs of pigs (Gillman *et al.*,2008). Bursae are naturally occurring fluid-filled sacs that reduce friction at points where muscles and tendons glide over bones (McFarland *et al*., 2000). Bursitis is a pathological response to trauma, the prevalence and severity of which is influenced by the degree of pressure exerted on the limbs by pig floorings (Mouttotou *et al*., 1999). Bursitis has implications for animal welfare, not least due to its associations with lameness, which can infringe all of the five freedoms (Harley *et al*., 2014). Bursae come about when pigs are housed on hard floors, and the prevalence may go higher when the stocking density is increased. Mouttotou *et al*.(1998) found a significant association between decreased carcass quality and prevalence of hock adventitious bursitis.

2.7 Quality aspects of pork.

Pork quality can be considered from technological, nutritional, and sensory point of view. Technological quality are the utility attributes of meat in ongoing production processes, which consist of technological and physicochemical properties such as: water holding capacity, pH, intensity and homogeneity of colour, firmness and processing yield. Nutritional quality of meat is about microbiological analysis, fatty acids profile and content of cholesterol, fat, conjugated linoleic acid, vitamins and minerals. Sensory quality of pork is measured instrumentally as well as in sensory panel evaluation, and involves such elements as colour, marbling, tenderness, juiciness and flavor (Rostagno, 2009)

Animal welfare is a salient factor of overall 'food quality' concept. There has been increase in awareness and interest by main stakeholders in developing countries in animal welfare and its effects on food safety (EFSA, 2012). There is an indirect effect of animal welfare on food safety due to the close links to animal health and food borne diseases (Nastasijevic *et al*, 2018)

Fresh pork has been commonly categorised based on Ph, colour & driploss percentage into: PSE (pale, soft, exudative), RFN (reddish-pink, firm, non-exudative) and DFD (dark, firm, dry). RFN meat is the ideal pork quality (Kauffman *et al*. 1992, Joo *et al*. 2000a).

However, two more defect classes have been recently introduced: RSE (reddish-pink, soft, exudative) and PFN (pale, firm, non-exudative). RSE pork has normal color, but a soft texture and is exudative like PSE pork. PFN pork has the texture of meat of good quality, but the color is pale like that in PSE. (Joo *et al*, 2000a)

Below is a description of the 3 key technological quality attributes of pork this study will cover;

2.7.1 Drip loss from meat

Drip loss refers to the fluid lost from fresh, non-cooked meat via passive exudation usually expressed as a percentage of the initial weight of the product. It's the ability of meat to retain its inherent moisture even though external pressures (like gravity, heating, centrifugation, pressing) are applied to it (Lonergan, 2012). It's calculated as the loss in the meat sample weight (due to drip and evaporation) divided by the original sample weight, multiplied by 100, therefore recorded as percentage drip (NPPC, 2000). Drip loss if of importance because of its economic impacts. Water is responsible for upto 75% of meat weight therefore increased drip losses result in losses in terms of appearance, texture, nutritional value, and attractiveness, hence a compromise to the quality of fresh meat and its processing (Watanabe *et al*, 2018). Water lubricates between muscle fibers, is a means of metabolite transport and is important in determining the plasticity, rigidity and gelatinization of the insoluble proteins (Hughes, 1976). Due to its structure and mobility, three classes of water are regularly recognized in intact muscle. Bound water which is water attracted to polar or ionic groups of macromolecules such as proteins. Entrapped/immobilized water that is water retained by steric effects and/or by attraction to bound water and comprises 80% of the total myowater in living muscle or pre-rigor muscle, and has no free flow in muscle (Lonergan, 2012). Lastly is the free water which is water unimpeded and is held by weak intermolecular forces between the liquid and the surrounding matrix and makes up less than 10% of the total myowater found in pre-rigor meat (Lonergan, 2012), but these amounts increase with structural muscle changes and entrapped water flows out. (Zhu, 2016)

Given the importance of drip loss, several studies have been carried out for example Støier *et al*. (2001) investigated a low stress handling system during lairage and in the minutes before stunning and how it improved the meat quality, especially drip loss, compared with a traditional stunning system under commercial conditions. Many other similar studies have been carried out monitoring drip as a meat quality attribute that can be affected due to poor quality. There are several methods of measuring drip loss including; 1) bag method which is acknowledged at international level as the standard method, but needs expansive space and careful sample handling (Torres *et al.*, 2017). 2) filter paper wetness method which is more rapid with reduced accuracy. This method is the simplest and fastest technique and reported as being highly correlated with the bag method (Torres *et al.*, 2017), 3) centrifugation, where a weighed meat sample is centrifuged at 100,000 x g for 1 h in a stainless steel tube, dried and re-weighed to determine liquid loss (Torres *et al.*, 2017) and 4) Absorption, this technique is the quickest among all in this list but necessitates skilled operators for repeatable incisions as well as measurements (Mason *et al.*, 2016).

In order to balance accuracy with resource and space availability the EZ-Driploss method has been chosen for the current study. The EZ-DripLoss method has been reported to have high sensitivity and reproducibility (Zhu, 2016). It also uses less space and is less sensitive to sample handling than the bag method which it is highly correlated with. (Torres *et al*, 2017)

2.7.2 pH of meat

The pH refers to the measure of the amount of hydrogen ions (H+) in a solution (Warriss, 2001). pH affects behavior of proteins in fresh and processed pork. pH is the negative log of hydrogen ion concentration. It's increase as a result of lactic acid dissociation in pork leads to a pH decline. pH is in essence relative acidity. Pure water has a pH of 7.0 (neutral), the pH of lemon juice is round about 2-3, and the pH of milk is around 6.8. pH affects the solubility of proteins, their functioning and also ability to bind water. Low pH generally has disastrous effects on these attributes. (Tomovic *et al*., 2014)

Muscle pH of a living pig is neutral, 7.0 - 7.2. During processing to meat, the processing means can result in incomplete oxidation due to lack of oxygen, as a resulting in accumulating of lactic acid within muscles leading to acidification hence pH reduction (Pearce *et al*., 2012). The decline rate of postmortem pH is an important determinant of meat color and drip loss. The ideal ranges for initial and ultimate pH were 6.3-6.7 and 5.7-6.1, respectively. Postmortem pH is measured within one hour of slaughter (initial pH or pH45min) or at 24 h (ultimate pH or pH24h). (Kim *et al*. 2016a).

Given $pH_{ultimate} > 6.1$ created high possibilities of inducing DFD pork which isn't preferred by consumers, it's presumed that pH 5.7 ~ 6.1 would be most suited for consumers (Kim *et al*, 2016b). PSE is due to a rapid fall in pH, inducing substantial denatureing of proteins (Nastasijevic *et al*, 2018).

Unlike drip loss, methods for measuring pH in meats are limited. The pH of solutions can be measured using indicator dyes that change colour with different pH values. For example, litmus, which is red in acid and blue in alkaline solution (pH values 5 and 8). However, they aren't reliable for measuring minute pH alterations that happen in meat. The second method is by use of glass electrodes that have a special glass sensitive to hydrogen ions. pH electrodes require calibration by use of solutions whose pH is known (buffers) and the meter adjusted as required. Meters should ideally be calibrated over ranges within which they are to be used. Temperature affects pH therefore it's of great importance to calibrate the pH electrode at the temperature it is to be used / sample temperature (Warriss, 2001)

pH measurements can be destructive or non-destructive in nature where these procedures are where in the non-destructive method, a hole is pierced in the sample with a knife or a sharp pin and the meter electrode inserted and in the destructive method, the sample is first homogenized and then the pH measured (ISO, 2004).

2.7.3 Colour of meat

Colour is a cardinal aspect of meat quality that can determine the choice of consumers because it determines appearance(Cannon *et al*, 1995 ; NPPC, 2000). Appearance is key given that its only by this criterion that the consumer judges acceptability of meat as they purchase (Warriss, 2000). Determination of pork colour can be performed in several ways that include subjective human analysis, use of computerized vision systems and objective analysis of light reflectance (Berg, 2001). In the latter instruments such as spectrophotometers and colorimeters are used for measuring of color. For this study I am going to use a colorimeter, an instrument that conveniently employs the use of the CIELAB system of color measurement that was established by the The Commission Internationale de l'Eclairage (CIE), where *L** is the *lightness* component or *value*; *a** and *b** are chromaticity coordinates. The *a** coordinate measures red–greenness, the *b** coordinate yellow–blueness (Warriss, 2000). Commonly used in the categorization of pork is the Lightness (L*) value where according to (van Laack et al., 1994) CIE LAB L*-value >58 0 is PSE, CIE LAB L*-value 52.0-58-0 is RSE, CIE LAB L*-value >58.0 is PFN, CIE LAB L*-value 52.0-58-0 is

RFN and CIE LAB L*-value < 52.0 is DFD, all in combination with specific values of drip loss and pH.

2.7.4 Animal welfare and meat quality

Using the above three technological quality pork attributes, pork can be classified as Dark Firm and Dry (DFD); this resulting due to lack of muscle acid production because of low levels of glycogen. Increased acidity of the muscle increases water-holding capacity in the lean, tightly binding water to muscle proteins, and contributes to firm textures. Muscle cells swollen with retained water and tightly packed together absorb more light (darker color), and also restrict how deeply oxygen can penetrate into the tissue to "brighten" muscle pigment (Węglarz, 2010). Pale Soft and Exudative PSE; this is caused by excess denaturing of proteins because of a combination of a low pH and increased muscle temperature post mortem. This combination leads to denaturation of muscle proteins, decreasing their capability to bind water (Joo *et al*., 2000). Red Soft and Exudative (RSE); this is a relatively new category of meat in comparison to all the others Red Soft and Exudative (RSE); this is a relatively new category of meat in comparison to all the others and has a Red normal color albeit with soft texture as well as the exudative aspect of PSE (Tomović *et al*., 2014). All the above are suboptimal meat categories. The desired meat category is Red soft and Non – Exudative (RFN) meat that is ideal pork for consumers this pork has a reddish-pink color and its firm with no exudation, this is because RFN pork has an optimal pHn therefore there is no denaturing of proteins as muscle is converted to meat. It's color is reddish-pink color because of the presence of myoglobin in the muscle leading to firmer texture given that the muscle fibers are more evenly spaced with contractile proteins not binding an excess amounts of water (Newman, 2017). Several schemers/criteria have been used to classify this pork and these were summarized by (Cazedey *et al*., 2016). Development of these categorization criteria has enabled research into animal welfare and its effects on meat quality.

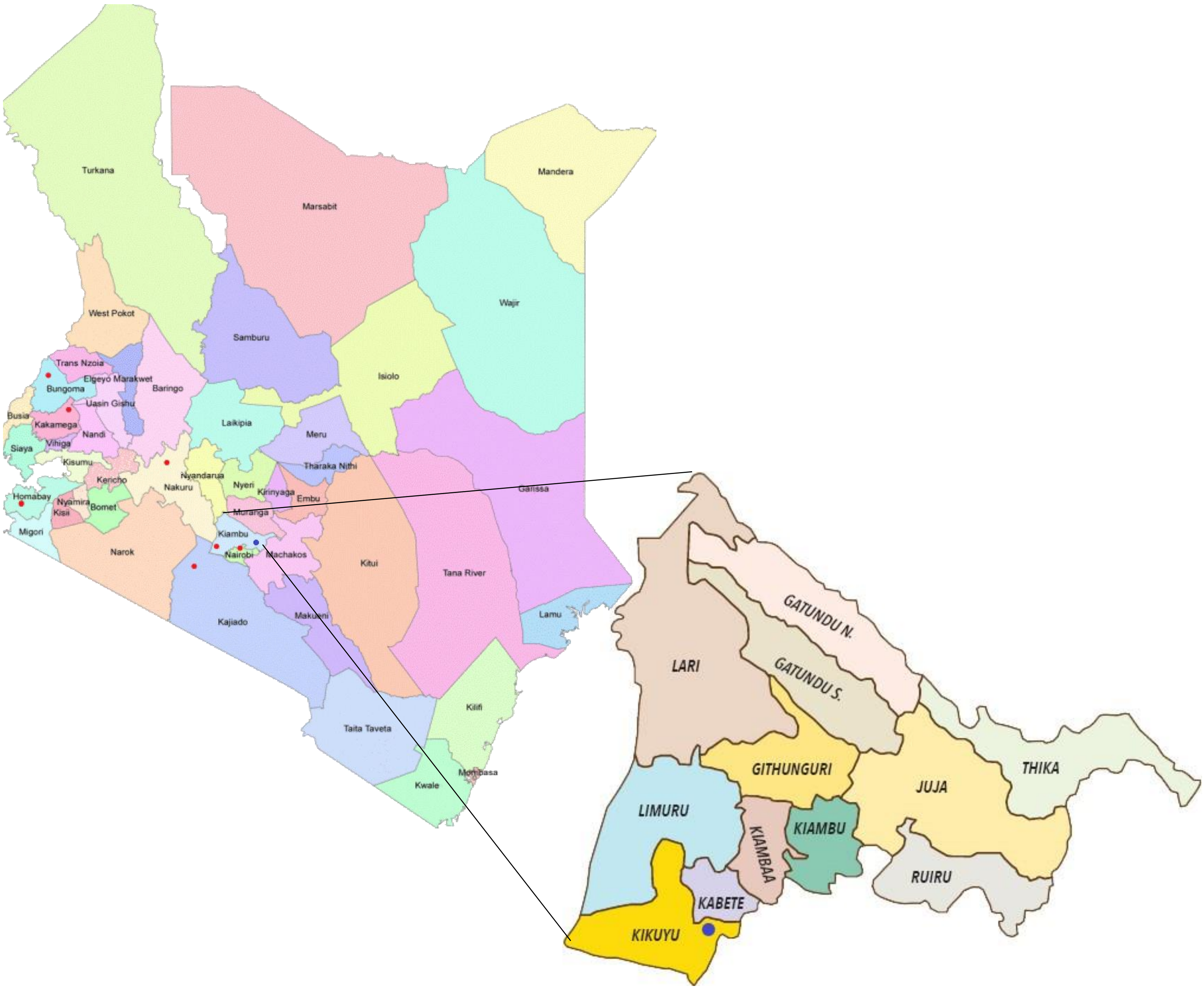
Pre-handling of animals before slaughter has been studied to affect the quality of meat harvested. Longer transport times were found to be associated with harvesting of DFD meat (HSUS, 2010b), in a study that investigated the effects of transportion on meat quality. In his research determining the effect of stocking density and Lairage time on carcass and meat quality Čobanović *et al*. (2016) found that high stocking density was associated with PSE meat, long Lairaging was associated with a high incidence of DFD meat. Season of slaughter of pigs has also been studied by Correa *et al*. (2013) who found an increased incidence of DFD meat in winter seasons in comparison to the summer. No studies have been done in the African context exploring the relationship between animal welfare and technological meat quality harvested in any species.

CHAPTER THREE

MATERIALS AND METHODS

3. 1 Study Area

The study was carried out at a non-integrated pig abattoir in Nairobi, called Ndumbuini abattoir. This abattoir is located in Kabete Sub-county in Kiambu County. This county covers a total land area of 2,543.5 Km^2 (Kenya National Bureau of Statistics, 2009) and is the second most populous (over 2.4 million people) according to Kenya National Bureau of Statistics (2019). Kiambu County borders Nairobi and Kajiado Counties to the South, Machakos to the East, Murang‘a to the North and North East, Nyandarua to the North West, and Nakuru to the West. The county lies between latitudes 00 25‘ and 10 20‘ South of the Equator and Longitude 360 31‘ and 370 15‘ East. (County Government of Kiambu, 2013). The facility has been reported to slaughter between 90 to 120 pigs by FAO (2012) that are majorly received from Homabay, Kajiado, Nakuru, Bungoma, Kakamega, Nairobi and Kiambu Counties (Murungi *et al*., 2020).



- Counties that supply pigs to Ndumbuini abattoir

- Location of Ndumbuini abattoir

Figure 1; A map showing the location of Ndumbuini abattoir and the various counties from which pigs are supplied (Photo Credit; Wikipedia, (County Government of Kiambu, 2013))

3.2 Study Design

A cross sectional study was conducted. This is an observational study which was carried out at a specific point in time and with a purpose of finding prevalence of outcome of interest within study population.

3. 3 Study Population

All pigs presented to Ndumbuini abattoir for slaughter, under the assumption that these were representative of the target population. The target population comprises of pigs raised for the urban terminus market (Nairobi) of which the majority (75%) are raised in Nairobi and Kiambu, 20% from other central counties and (5%) Western, not including those pigs raised under contract for the large integrated company ‘Farmers Choice Ltd’. The estimated total pig population in Kenya is 335, 301 with estimates of individual populations from the above regions being 29,976 for Nairobi, 91,977 pigs from central counties and 87,838 pigs for Western counties (KNBS, 2009). These are raised mainly under intensive semi-intensive and free range production systems (FAO, 2012).

3. 4 Sample size determination

The formula below by Dohoo *et al*.(2009) was used to calculate the sample size required for the study;

$n = (Z^2PQ)/L^2$

Where

n = required sample size

Z = CL of 95% (standard value 1.96)

P = Prevalence 50% (hypothetical given there are no studies done before in the study area concerning the objectives of study)

Q = (1 – P)

L = level of precision at (5%)

Therefore;

$$n = (1.96^2 \times 0.5 \times 0.5)/0.05^2 = 384$$

A minimum sample size of 384 pigs will be required for this study.

3.5 Selection of study units

For all pigs, whether walk-ins or from the Lairage, presented for slaughter, I recruited every 2nd pig into the study for the purpose of systematic random sampling. The trader/butcher presenting the animal for slaughter was approached to request their informed consent to participate in the study.

If the next pig to be selected according to the systemic random sampling originated from the same farm as a previously recruited animal, then this animal was ineligible for sampling and the next 'independent' pig was recruited and we returned to every 2nd pig from there forward.

3. 6 Field data collection

After collection of informed consent (see Appendix 2) for sampling of animals from the trader/butcher presenting the pig to slaughter. The pig was restrained using a humane pig snare over snout behind canine teeth and led for weighing into the weighing crate to obtain its live weight. The pig was then driven into the stunning box by the abattoir operators where it would be ear-tagged after it was stunned for easy follow up. Pig welfare data below was then collected and entered into an Open Data Kit (ODK) form as described.

3.6.1 Pig Live – Weight, Origin And Transport Data

The weight observed on weighing the live recruited pig was entered into the ODK form and the trader/owner of the pig interviewed for origin and transportation means for pig to the abattoir. The details of the questionnaire used is presented Appendix 4

3.6.2 Stunning and Observation for Welfare lesions.

The method used to stun (render unconscious) the pig was observed and noted down. Presence/absence of signs of consciousness (vocalizations, blinking, heavy breathing and bodily movements) at the point of bleeding the pig was observed and recorded. The method used to bleed the animal was also recorded. On suspension of the carcass, I observed and digitally recorded all the internal and external welfare lesions. All this data was recorded in Open Data Kit (ODK) form.

3.6.3. Muscle Sample Collection.

Muscle samples were collected from each carcass according to the EZ-Drip Loss meat sampling procedure (DMRI, 2018). With the carcass hung on gambrels, immediately after splitting, a (9 x 7 x 2) cm meat sample was collected from the left-side silverside (Biceps femoris) for determination of Drip Loss, pH and color. The meat sample was placed in a zip lock bag and kept in the cooling box for transportation to the laboratory at University of Nairobi for analysis as shown in (figure 2)

Data collection was followed up with specific observation of the electrodes and amperage measurement that was done using 376 True-rms AC/DC Clamp Meter with iFlex™ (Fluke Corporation, 2010)

3.7 Laboratory procedures

3.7.1. Measuring ultimate pH

Ultimate pH (pH_{24}) was obtained after 24hr storage of the samples at 4^0C with the use of a pH meter (pH Meter FP20). The direct method for measurement of pH as described by Warriss, (2000) was used where the electrode sensor of the meter was inserted into the muscle tissue at different sites and the duplicate pH readings recorded in an ODK form. The average reading was recorded as the final pH of the meat.

3.7.2. Measuring drip Loss

The drip loss from the meat was obtained following the procedure outlined in the EZ Drip loss manual (DMRI, 2018). On the day of sample collection (within 6hrs of collection), two cylindrical samples (25ø × 25 mm) were bored into the collected muscle sample using the cylindrical knife provided in the kit. A drip loss container was weighed and the weight recorded (W_C). The bored cylindrical sample was then placed in the drip loss container, ensuring the meat doesn't come into contact with the lid, and the combined weight of the meat and the container measured and recorded (W_T). This was done in duplicates for all samples. The EZ-DripLoss containers were then placed in the holder in the plastic box in the order they have been sampled. Then the EZ-DripLoss samples were kept at 4°C for 24 hours. The meat sample was then removed from the drip loss container and the combined weight of the container and the meat juice measured and recorded (W_1). The drip loss was then calculated using the formula below.

$EZ-DripLoss = (W_1 - W_C) * 100 / (W_T - W_C)$

3.7.3. Color detection

The color of meat samples was obtained using a PCE – CSM 2 colorimeter with an aperture size of 8mm, a measuring angle of 45^0 and a D_{65} illuminant. The device was calibrated every day before use as instructed by the manufacturer (Park & Kingdom, n.d.). The muscle samples of not less than 15mm, collected, were allowed to bloom for an average of an hour as recommended by Association, (2012) and Warriss, (2000). One at a time the meat samples were placed on a white background and the colorimeter measuring aperture placed on each to read in triplicates. The average L* value obtained was recorded and saved in an ODK form.

Drip loss, pH and colour were combined to determine the quality category the meat belonged to based on the criteria by Warner *et al*. (1997) as shown in Table 3.1

Table 3 1; Classification of Pork Quality

Quality Categories	pH24h	*Drip Loss %*	*Color (L*)*
1. PSE	< 6.0	> 5	>50
2. RSE	< 6.0	> 5	42 – 50
3. PFN & RFN	< 6.0	< 5	42 – 50
4. DFD	$\geq$ 6.0	< 5	<42

Figure 2;An image showing samples being processed in the laboratory at University of Nairobi.

3.8 Data Analysis

Data were collected using an Open Data Kit form (https://opendatakit.org/) and uploaded to the servers every day. The datasets were later downloaded as .csv files, cleaned and merged for statistical analysis in the R environment for statistical computing version 3.6.0 (2019-04-26)(R Core Team, 2018). Descriptive statistics including the prevalence of welfare associated lesions and practices together with their 95% confidence intervals was calculated using the DescTools and gmodels package (Signorell, 2020)(Warnes et al., 2018). Recommended pig space requirements are dependent on the weight and hence size of the pig, therefore loading density was calculated according to recommendations by Spoolder, (2017). Both univariable and multivariable analyses were done using the glmer function of the lme4 package (Bates, 2010).

Multinomial logistic regression was further performed on the dataset using the multinom() function from {nnet} package. Since the multinom() function does not include p-value calculation for the regression coefficients, p-values were calculated using z-tests and variables with a p-value less than 0.05 will be considered significant (Assuming 5% significance level). The model was built backwards by gradually removing the less significant variables until a set of variables that produces the highest model accuracy, according to the lowest Akaike Information Criterion (AIC) value was obtained. Possible model inaccuracy due to overfitting was addressed through cross validation.

3.9 Consent for the Study

This study under the broader study "Identifying food safety hazards and animal welfare issues in pork supplied to Nairobi through a large non-integrated abattoir" sought and obtained consent from the International Livestock Research Institute, Institutional Animal Care And Use Committee (Ref no. 2019-36) and the Institutional Ethical Review Committee (ILRI-IREC2020-14). The PI, Dr. Lian Thomas holds a NACOSTI permit (NACOSTI/P/20/4847) and permission was sought from both the DVS and the county DVS prior to fieldwork commencing. See Appendix 1 for all approvals and permissions.

Further still, upon arrival at the slaughterhouse each sampling day I sought out the slaughterhouse owner and the meat inspector on duty for permission to commence work.

Consent was obtained for recruiting each pig from the person responsible for presenting the pig to slaughter. The Informed Consent Document (Appendix 2) was explained to the presenting individual and their signature or thumb-print registered before data collection begun.

CHAPTER FOUR

RESULTS

Five hundred and twenty-nine pigs were sampled between 5th January and 5th March 2021, of which 53.8% (95% C.I. 49.43 – 58.11%) were female. Pigs were mainly presented for slaughter by traders 86.32% (95% C.I. 82.99 – 89.10 %), followed by farmers 10.21% (95% C.I. 7.81 – 13.22 %). Half the pigs, 52.02% (95% C.I. 47.63 – 56.39), had a resting interval of 24hrs or more between the time from purchase and slaughter.

The majority of pigs were obtained from Kiambu County 79.58% (95% C.I. 75.79 – 82.91%) and Nairobi county 12.72% (95% C.I. 10.04 – 15.96 %) with the rest from pig keeping counties in central and western Kenya (Homabay, Kajiado, Makueni, Muranga and Nakuru counties). The majority of pigs originated from housed systems 97.68% (95% C.I. 95.87 – 98.74 %) and others came from outdoor systems. 52.02% (95% C.I. 47.63 – 77.07) of the pigs were kept for 24hrs or more after purchase, before being presented for slaughter. The transport means to the slaughterhouse was mostly by pickups, with 85.30% (95% C.I. 81.88 – 88.18%) transporting an average of 6 pigs, followed by motor bikes and bicycles, 7.54% (95% C.I. 5.48 – 10.26), with other means of transport being pro-boxes, sedans, tuk tuks and walking. The mean loading density was 1.13 pigs/m^2 (95% C.I. 1.02 – 1.23) with 27.44% (95% C.I. 23.59 – 31.65) transported at high loading densities. The mean transport time for the sampled pigs was 1.23hrs (95% C.I. 1.15 – 1.31hrs) as estimated by those presenting the pigs to slaughter (range 0.5 – 10hours). 20.16% (95% C.I. 16.82 – 23.95 %) of the pigs were transported together as a mixed batch with other pigs not from the same farm.

Figure 3;An image showing a pig presented to the abattoir on a bike

A high proportion of pigs, 82.97% (95% C.I. 79.34 – 86.09 %) had one or more welfare lesions with the most prevalent 77.07% (95% C.I. 73.00 – 80.69) being lacerations to the ears ‘ear marks’, utilized by traders to identify their pigs. Other gross lesions included; pleuropneumonia 27.33% (95% C.I. 22.75 – 32.42) and tail bites 7.28% (95% C.I 5.19 – 10.07%). Electrical, head-only, stunning was utilized on all pigs 100% (95% C.I. 99.07 – 100.00), but about 99.61% (95% C.I. 98.43 – 99.93%) of all pigs were not well stunned as evidenced by post-stunning consciousness signs. The stunning device used was old, corroded and never washed as seen in Figure 2, it was connected to direct current that fluctuated between 0.3 – 0.4 A. (Table 4.1) shows a summary of lesions and practices.

Figure 4; An image showing ear marks on a pig.

Table 4 1; Prevalence of welfare lesions and pig handling practices by traders and at slaughter

Lesions	**n/N***	**Prevalence (%)**	**95% C.I.**
Ear marks	373/484	77.07	73.00 – 80.69
Pleuro-pneumonia	94/344	27.33	22.75 – 32.42
Tail biting	35/484	7.23	5.16 – 10.00
Liver Milk spots	22/459	4.79	3.10 – 7.28
Loin Bruising	20/484	4.13	2.61 – 6.42
Hind limb Bursitis	16/484	3.33	1.97 – 5.46
Tether Lesions	11/484	2.27	0.01 – 4.15
Lacerations	6/484	1.23	0.50 – 2.82
Practices			
Incomplete stunning	510/512	99.61	98.43 - 99.93
Transported as mixed batch	103/511	20.16	16.82 - 23.95
Transported at high loading density	135/492	27.44	23.59 - 31.65
Purchase-slaughter interval > 24hrs	270/519	52.02	47.63 - 56.39

*due to the rapid nature of the slaughter process we were not able to complete all observations for every pig hence N is variable for each observation

From the recruited pigs, we were able to obtain 387 meat samples for analysis of technological qualities of meat where the mean pH_{24} was 5.61 (95% C.I. 5.59 – 5.64, range 5.17 – 6.92), the mean L* value was 44.28 (95% C.I. 43.90 – 44.67, range 35.23 – 59.48) and the mean drip loss was 3.10% (95% C.I. 2.89 – 3.30, range 0 – 11.98).

Of the 387 pork samples evaluated, 2.6% were classified as DFD, 2.6% as PSE, 47.5% as RFN, 11.4% as RSE. The remaining samples (35.9%) could not be classified according to the quality criteria set for this study. Univariate association between the classification and lesions and practices demonstrated several statistically significant associations as illustrated in (Table 4.2).

Table 4 2; Univariate Analysis Between Predictor Variables and Meat Quality showing varialbles with a P-value < 0.05.

	DFD (N=10)	Other (N=139)	PFN_RFN (N=184)	PSE (N=10)	RSE (N=44)	Total (N=387)	p value
originate_same_farm							0.031
- N-Miss	1	5	3	0	0	9	
- no	3 (33.3%)	24 (17.9%)	33 (18.2%)	5 (50.0%)	14 (31.8%)	79 (20.9%)	
- yes	6 (66.7%)	110 (82.1%)	148 (81.8%)	5 (50.0%)	30 (68.2%)	299 (79.1%)	
Time between Purchase and slaughter							0.003
- N-Miss	0	3	1	0	0	4	
- Mean (SD)	19.200 (18.931)	13.941 (12.239)	14.557 (13.274)	14.400 (12.394)	6.545 (10.812)	13.535 (13.006)	
- Range	0.000 - 48.000	0.000 - 48.000	0.000 - 48.000	0.000 - 24.000	0.000 - 24.000	0.000 - 48.000	
Live_Weight_kg							0.023
- N-Miss	1	12	6	0	2	21	
- Mean (SD)	64.222 (28.084)	64.748 (31.224)	54.899 (21.141)	59.000 (12.623)	58.095 (25.015)	59.025 (25.793)	
- Range	34.000 - 130.000	13.000 - 230.000	25.000 - 186.000	30.000 - 78.000	27.000 - 160.000	13.000 - 230.000	
loading_density							<0.001
- N-Miss	1	16	8	0	1	26	

- high	7 (77.8%)	23 (18.7%)	43 (24.4%)	5 (50.0%)	12 (27.9%)	90 (24.9%)
- recommended	2 (22.2%)	100 (81.3%)	133 (75.6%)	5 (50.0%)	31 (72.1%)	271 (75.1%)

Variables with ($p < 0.05$) from the above table were further subjected to multinomial logistic regression, with backward selection. (Table 4.3) shows the stepwise selection procedure from the initial model to the final one while (Table 4.4) shows the final variables included in the parsimonious polychotomous logistic model their p-values and the estimates of their coefficients and standard errors.

Table 4 3; Stepwise Selection Procedure from Initial Model to Final Model

Step	**df**	**Residual.Df**	**Residual.Dev**	**AIC**
1	3	15	232.5494	262.5494
2 - Transported as mixed	3	12	235.5898	259.5898

Table 4 4;Multinomial logistic regression on meat quality and their relationships with body injuries and pig handling practices

Meat category	Variables	Coefficient	Standard error	Z	Odds ratio
PSE					
	Interval	0.011	-0.052	-0.219	1.011
	Loading density	-1.435	0.862	-1.664	0.238
	Live weight	0.007	0.015	0.459	1.007
DFD					
	Interval	0.057	0.033	1.715	1.058
	Loading density	-2.288	0.873	-2.621	0.101
	Live weight	0.006	0.013	0.474	1.006
RSE					
	Interval	-0.052	0.020	-2.619	0.950
	Loading density	-0.481	0.512	-0.939	0.618
	Live weight	-0.002	0.010	-0.163	0.998
Uncategorized					
	Interval	0.001	0.012	0.101	1.001
	Loading density	-0.190	0.355	-0.536	0.827
	Live weight	0.011	0.006	1.986	1.011

CHAPTER FIVE

DISCUSSION

This study found that half the pigs, 52.02% were held for 24hrs or more before being presented for slaughter. This is a subtle phase that exists in the pork value chain in the region and was accurately described in Uganda by Sanni (2017) and Tatwangire (2014) as "hoarding/bulking" of live pigs. Animal hoarding was defined by Mogbo *et al*. (2014) as the accumulation of a large number of animals with failure to provide minimal standards of nutrition, sanitation and veterinary care. In the region, this practice involves traders sourcing for pigs from different farms to make a certain number, in this process some pigs are in the buyers' custody, before they are transported to the abattoir for slaughter(Mutua *et al*., 2020; Mutua *et al*., 2011).

Similar practices have been reported by Omotosho *et al*. (2016) in Nigeria and Roesel *et al*. (2016) in Uganda. According to Tatwangire (2014), gross margins are a major explanatory aspect behind hoarding. 10.37% of the pigs held for 24hrs or more were being held together with pigs that originated from different farms, this is a major stressor to these pigs as described by Death et al. (2010). Incidence of fighting bouts were influenced by formation of travelling groups by mixing unfamiliar animals according to Gerritzen *et al*. (2013). Suffice to say that break down in social structures is not the only stress these animals are subjected to in this phase, in a study of truck design for animal transportation in Kenya, Wambui *et al*. (2016) concluded that there were no vehicles dedicated to the transport of livestock, this implies that prolonged periods of confinement of pigs on such vehicles with designs that do not meet the standards as those recommended by FAO (2001) and Mitchell & Kettlewell (2008) not only exposes pigs to long fasting periods but also to potentially harsh environmental conditions.

This kind of treatment of animals is prohibited by Kenyan legislature in Regulation 4 of the Prevention of Cruelty to Animals Act (Transport of Animals) Regulations (1984) that states "*A person who transports an animal by sea, air, road or rail, or who causes or permits an animal to be so transported, in a way likely to cause injury or unnecessary suffering to that animal, shall be guilty of an offence*". Transport by its nature is an unfamiliar and threatening event in the life of an animal (Tarrant & Grandin, 2014), experiments by Verbrugghe *et al*. (2011) showed that social stress and starvation result in elevated serum cortisol levels and starvation can result in hypoglycemia. This in turn increases the risks in meat quality defects of PSE and DFD especially when feed is withdrawn for over 18hrs(Adzitey & Nurul, 2011; Bidner & McKeith, 1998). This is in agreement with my study which found a significant association ($p < 0.05$) between the purchase – slaughter interval and meat quality.

The positive coefficients for this predictor under PSE and DFD meat, with their respective odds ratios >1 suggest that with all other variables maintained constant, increase in the purchase – slaughter interval is more likely to produce DFD and PSE meat. For every hour increase in the purchase – slaughter interval, the odds of obtaining PSE and DFD meat increase by a factor of 1.01 and 1.06 respectively. We hypothesize that this is due to the stresses subjected to the pigs during this period which may include fasting, being mixed with unfamiliar pigs, unsuitable climatic elements as described by Pietrosemoli & Tang (2020), noise among others.

This study found that 27.44% of pigs were transported under conditions of high loading densities. Several publications exist with suggestions for space requirements for pig transportation

(Commission, 2002; Panel & Ahaw, 2011; Spoolder, 2017), however the loading densities for pigs in this study were defined and calculated according to the recommendations by Spoolder (2017). Similar to observations by Omotosho *et al*. (2016) in Southwestern Nigeria and Kagira *et al*. (2010) and Thomas (2014) in Western Kenya, there was transportation of pigs to the abattoir by use of motor bikes and bicycles as shown in Figure 2. albeit at a lower prevalence (7.54%) than reported in rural western Kenya where this mode of transportation is the norm (Kagira *et al*., 2010).

Dependency on motorbikes for pig transportation (see figure 3) to this abattoir was reported as a challenge to pig traders Murungi *et al*. (2020), but is a solution to the high cost of transportation. As much as use of such means may be cost effective, it undermines the welfare of pigs by exposing them to fractures (see figure 4) and even mortalities. The study also found that 29% of pigs carried by pickups were under high loading densities, over loading of pigs was reported by Spencer & Veary (2010) in South Africa. Ideally pigs should be able to stand or lie down in their natural position during transportation (Panel & Ahaw, 2011). Arndt *et al*. (2019) sheds more light on what these different rest positions can be and their space requirements.

Figure 5;An image showing a fracture on a carcass..

Over loading of pigs is against the Kenyan Prevention of Cruelty to Animals (Transport of Animals) Regulations (1984) Cap 360, Regulation 8 which states that "*The transporter or other person in charge of animals transported in vessel, aircraft or vehicle, or any pen therein, shall ensure that the animals are not overcrowded and are so accommodated as to avoid any risk of injury or unnecessary suffering. A person who fails to comply with this Regulation shall be guilty of an offence.*" These inhumane methods could be as a result of lack of awareness/knowledge that pigs are sentient beings and generally about animal welfare as deducted by Descovich *et al*. (2019) in China, but also the trend of livestock intensification in Africa comes with commercial pressures that lead to tradeoffs in animal welfare (Devereux, 2014). High loading density propagates vices like fights in the pigs but it is also increases incidence of PSE meat (Gerritzen *et al*., 2013; Kim *et al*., 2004). In contrast to (Warriss *et al*., 1998), the study found a significant association ($p < 0.05$) between a high loading density and meat quality.

The negative coefficients for the recommended loading density under PSE, DFD and RSE meat with their respective odds ratios being <1 suggests that with all other variables maintained constant, the recommended loading density is less likely to produce these categories of meat. This is indicative of the fact that a high loading density risks harvesting defective meat.

The study also found out that 77.07% of the pigs were ear marked with knives by slaughterhouse workers (see figure 5), where initials of the names of the owners were inscribed deep into one or both of the ears and this was done for easy identification and follow up by their owners from the Lairage to the point of dispatch. This kind of identification method causes injury to the animal and according to the description of Sanni (2017) this is intentional abuse of animals but due to ignorance, similar practices have been reported in Uganda (Roesel *et al*., 2016). Such an identification method is probably used because the dearth of well-established identification systems in the nation, with less technical solutions being more feasible (Mutua *et al*., 2020).

Ear notching in piglets is most similar to this practice (HSUS, 2010a) but even in this case OIE (2019) recommends that it is carried out by a trained professional, and the practice still raises welfare concerns as concluded by Numberger *et al*. (2016). Therefore this practice not only violates OIE recommendations but also the freedom from injury and pain as stipulated by World Organisation for Animal Health (2011) and the national Prevention of Cruelty to Animals Act , (2012) Cap 360 which states that "*Any person who, for the purpose of capturing or killing an animal, uses, or causes or procures to be used, any net, snare, trap or other device so designed as to cause unnecessary suffering to an animal captured or killed thereby is guilty of an offense and is liable to a fine*". Omotosho *et al*. (2016) reports scrapping off bristles of pigs still with sharp blades to form signs unique to each owner, this is a less invasive practice that could be used for identification.

Almost all animals (99%) showed signs of consciousness, several factors exist which may have contributed to this observation; Head only electrical stunning on unrestrained animals, poorly made electrode set (see figure 6) and fluctuating electrical current was used in the abattoir, risking improper placement of electrodes as evidenced by the high proportion of animals demonstrating post-stunning signs of consciousness. Such practices elicit pain and fear and undermine welfare (Anil & McKinstry, 1998). Ideally, stunning should render the pig instantaneously unconscious, long enough until bleeding results in enough loss of blood to cause death from lack of oxygen to the brain (Channon *et al*., 2002; Rosenvold & Andersen, 2003). The stunning was executed using a V – shaped handheld device, with electrodes on each side, similar to that described by Spencer & Veary (2010) in South Africa, however these electrodes were tied together on either side of a piece of wood (which was then used as a handle) and connected to direct current, therefore the current was always on in the electrodes throughout the stunning process, also posing a serious human health hazard.

Figure 6; An image showing the electrode set that was used for stunning.

Contrary to recommendations on tong maintenance by FAO (2001), the electrodes were old, corroded and never cleaned (see figure 7) which is a potential cause for ineffective stunning through electrical impedance (EFSA, 2004). There was no fixed position of the tongs on the animal while stunning and these were placed anywhere between the base of the neck and behind the ears, (see figure 8)), a similar finding to Stocchi *et al.* (2014), this is contrary to the ideal placement of electrodes recommended by Anil & McKinstry (1998) under field conditions. Wrong placement of electrodes was further aggravated by a low amperage system that delivered an electric current that fluctuated between 0.3 – 0.4 A, different from the 1.3A recommended by Nielsen *et al.* (2020) when tongs are placed behind the ears.

Figure 7; An image showing the stunning device.

Using such low electric current risks the pigs experiencing a painful electric shock before onset of consciousness (EFSA, 2004). The total sum of all this is ultimate contravention with Section 8 of the Kenyan Prevention of Cruelty Act (1983) Cap 360 that states *"Any person who, whether in any slaughterhouse or abattoir or in any place than a slaughterhouse or abattoir, and whether for human consumption or not, slaughters an animal— (a) in such a manner as to cause it more suffering than is necessary; or (b) in the sight of any another animal awaiting slaughter, shall be guilty of an offence and liable to a fine not exceeding two thousand shillings or to a term of imprisonment not exceeding three months or to both."*

Figure 8; An image showing electrode placement during stunning.

We observed a substantial amount of meat categorized as RSE. The most prevalent category of poor quality meat was Reddish – pink Soft and Exudative (RSE). RSE, like Pale Soft and Exudative (PSE) meat, readily gives up moisture due to defective water-holding capability of muscle proteins, this is the fluid often seen accumulating in retail packages and also leads to less juicy pork after cooking (Buege & Griffin, 2015). Packaged products with these exudates affect quality as perceived by the consumer (Renerre *et al*., 1993) and according to Blakeney (2019) consumer surveys by supermarkets, he reported that consumers rarely bought food with the wrong appearance. These excessive exudates from meat have also been associated with microbial spoilage (Kim *et al*., 2013), Faucitano *et al*. (2010) found that RSE meat has a higher susceptibility to spoilage in comparison to the other pork classes.

Drip loss can also be a major source of food wastage and financial losses (Juliet *et al*., 2019). According to my study, the mean drip loss for the exudative categories of pork were 6.79% and 6.86% for PSE and RSE respectively in comparison to the 2.54% for normal meat. This means that 68.6g are lost for every kg of RSE pork in 24hrs, equating to a daily loss of Kshs 21.76 (0.2 USD) per kg. With the multiplier effect, these are substantial losses to stakeholders in this pork value chain. This is in agreement with a study by Juliet *et al*. (2019) in Uganda where drip loss was found to be the second major cause of beef losses, together with meat wastage (drops of meat and bones that fall off during cutting of beef for sale) where the two factors led to losses of up to 787.50 USD daily per district of study.

Furthermore, consumers are known to be the final and important stakeholders in the pork value chain, Weng (2017) concluded that consumers show a willingness to pay more for safe pork, this stresses the importance of businesses to observe animal welfare due to the underlying benefits that exist there in, improvement of perceived product quality is a benefit to businesses (Fernandes *et al*., 2021). With the steadily emerging global trend of consumer requirements dictating product qualities and specifications (Asmare, 2014) it would be catastrophic for pork producers to ignore the finding by (AU-IBAR, n.d.) that Kenyan pork consumers made inquiries to pig slaughter – houses on good animal welfare products. This shows that consumers in the country are more aware about the sentience of animals and expect their animal – related products to be processed with more respect for animal welfare (Asmare, 2014).

The study reported 35.9% of the meat as unclassified according to the criteria used by Warner *et al*. (1997). Joo *et al.* (1995) argues that unclassified pork should exist because the classificatory parameter values of technological quality attributes were determined apriori, this means that the processes that set the ranges of the individual attributes that define the different classes of meat were set before these classes were known to exist. Peres *et al*., (2018) explains that these samples are not capable to fit into a standard created by rigid crisp range of values proposed for each parameter and traditionally are discarded. Pospiech (2016) goes further to emphasize that naturally, the known standard categories do not exclude the possibility of occurrence of other quality groups.

A review by Torres Filho *et al*. (2017) for pork quality studies shows that for all schemers used to categorize pork there was reporting of uncategorized meat in all papers. Some of the studies that highlighted presence of unclassified meat include; (Cazedey *et al*., 2016; Faucitano *et al*., 2010). Peres *et al*. (2018) tried to solve this problem by employing alternative means of classification of pork which he defined as "fuzzy approaches" where modelling and computer algorithms were used to try and classify these unclassified meat samples into given classes but however there was no significant difference between use of these approaches and use of the traditional classificatory schemers. Therefore, presence of this meat presents an important opportunity for research on its ultimate classification.

The findings from this study emphasize that there are welfare concerns to address in the pork value chain at the abattoir of study. All animals including pigs are sentient beings that have enormous capacity to feel a huge range of emotions, learn from their experiences, adapt to challenges and to suffer when their needs are ignored or disrespected (Asebe & Gelayenew, 2015; OIE, 2013). Blokhuis *et al*. (2008) and Sanni (2017) emphasize the revered and convenient platform held by legislation and government systems in the protection of animal welfare. From the general discussion we can see that Kenya has the (Prevention of Cruelty to Animals Act, 1983) that is dedicated and has a bias towards animal welfare (Muigua, 2020).

Kenya is also in a unique position with the currently tabled Animal Welfare and Protection Bill (2019) that has detail on observation of animal welfare in the nation and the Draft National Livestock Policy (2019) that acknowledges animal welfare as an important concept. However, with this legal arsenal in place, it leaves a lingering question on why there is inadequate enforcement and implementation, a challenge/weakness also acknowledged by (AU-IBAR, n.d.) in their assessment of animal welfare in the East African nation. This is a challenge that undermines all animal welfare related progressive legislative efforts but also inputs by non – governmental organizations, and therefore means of addressing this challenge need to be developed. There is also a need for change in public opinion about the importance of good animal welfare (Asebe & Gelayenew, 2015).

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This study found that:

- Over half of the pigs were kept for 24hrs or more from the time they were purchased and before they were presented for slaughter.
- A third of the pigs were transported to the abattoir at high loading densities.
- There was a very high prevalence of pigs with ear lacerations due to use of ear markings to label pigs for easy follow up in the abattoir.
- Nearly all the pigs were poorly stunned, this was observed by presence of post stunning consciousness signs. The poor stunning was hypothesized to be due to poor design and maintenance of the stunning device, lack of restraint of pigs before stunning and poor electrode placement of the pigs during stunning.
- There was a considerable percentage (11.4%) of Reddish – pink Soft and Exudative pork.
- If traders transport pigs at recommended loading densities, there will be reduction of the risk for obtaining PSE, DFD and RSE defected pork.
- Increase in the time between purchase and slaughter of pigs increases the risk of obtaining PSE and DFD defective pork.

6.2 Recommendations

From this study, we recommend;

- Education and increase of awareness to traders to reduce the time between the purchase of pigs and the time they present them to slaughter and to transport pigs at recommended loading densities.
- Education and increasing awareness to slaughterhouse workers that ear marking of pigs with sharp objects causes pain and injury to the pigs and also teaching them the practices around proper and effective stunning.
- Further studies for example; on – farm welfare assessment animals, consumer preference and willingness to pay as influenced by technological quality attributes of harvested meat, knowledge, attitude and practices concerning animal welfare legislation.

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APPENDICES

Appendix 1; Approvals and Permissions.

ILRI INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE   CGIAR

9th April 2020

Our Ref: ILRI-IREC2020-14

International Livestock Research Institute
P.O. Box 30709 00100
Nairobi, Kenya.

Dear Lian Thomas,

Ref: Food-safety in rapidly changing food-systems: Food-safety hazards, animal welfare and the regulatory environment in the pork value chains of Nairobi

Thank you for submitting your request for ethical approval to the International Livestock Research Institute (ILRI) Institutional Research Ethics Committee (IREC). ILRI IREC is accredited by the National Commission for Science, Technology and Innovation (NACOSTI) in Kenya, and approved by the Federalwide Assurance (FWA) for the Protection of Human Subjects in the United States of America.

This is to inform you that ILRI IREC has reviewed and granted final approval for your study titled *'Food-safety in rapidly changing food-systems: Food-safety hazards, animal welfare and the regulatory environment in the pork value chains of Nairobi'*. The approval period is 9th April 2020 to 8th April 2021 and is subject to the following requirements:

- Only approved documents including (informed consents, study instruments) will be used.
- All changes including amendments, deviations, and violations are submitted for review and approval by ILRI IREC.
- Death and life-threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to ILRI IREC within 72 hours of notification.
- Any changes anticipated or otherwise that may increase the risks or affect safety or welfare of study participants and others or affect the integrity of the research must be reported to ILRI IREC within 72 hours.

Patron: Professor Peter C Doherty AC, FAA, FRS

Animal scientist, Nobel Prize Laureate for Physiology or Medicine–1996

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Appendix 2;Consent from Institutional Animal Care And Use Committee.

ILRI

INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE

CGIAR

23rd January 2020

Our Ref: ILRI-IACUC2019-36

International Livestock Research Institute
P.O. Box 30709 00100
Nairobi, Kenya.

Dear Lian Thomas,

Ref: Identifying food safety hazards and animal welfare issues in pork supplied to Nairobi through a large non-integrated abattoir

This is to inform you that ILRI IACUC has reviewed and approved your request to use animals in your research activity titled *'Identifying food safety hazards and animal welfare issues in pork supplied to Nairobi through a large non-integrated abattoir'* as per the IACUC - ANIMAL USE FORM approved on 23rd January 2020. Note that the approval is subject to compliance with the following:

- Compliance with all regulatory requirements as applicable to this research activity;
- Only approved standard operating procedures (SOPs) are used.
- Any changes anticipated or otherwise are submitted to ILRI IACUC for review and approval before they are implemented;
- Only persons named on the approved IACUC - ANIMAL USE FROM (section 3 – 5) can handle and/or carry out sampling of the animals;
- Submission of completed PI Report Back Form upon completion of this activity to the ILRI IACUC; and
- Reporting of any adverse events to ILRI IACUC immediately.

Should you need aby further clarification and or information, please call on ILRI IACUC on ILRIResearchcompliance@cgiar.org for any assistance you may require.

Patron: Professor Peter C Doherty AC, FAA, FRS

Animal scientist, Nobel Prize Laureate for Physiology or Medicine–1996

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Appendix 3; Informed Consent Form

INFORMED CONSENT FORM (ICF) FOR PORK VALUE CHAIN STAKEHOLDERS IN NAIROBI

Principal Investigator;

Dr Lian Thomas, Institute of Infection and Global Health, University of Liverpool, UK and International Livestock Research Institute, Nairobi, Kenya lian.thomas@liverpool.ac.uk

Name of Project: Identification of food-safety hazards and welfare lesions in the pork value chain, Nairobi, Kenya

This Informed Consent Form has two parts:

- **Information Sheet (to share information about the study with you)**
- **Certificate of Consent (for signatures if you choose to participate)**

You will be given a copy of the Information Sheet

Part I: Information Sheet

Introduction

We are a group of researchers from ILRI, the University of Nairobi and University of Liverpool. We do not represent any government or regulatory body.

Purpose of the research

Pork is rapidly increasing in popularity, but there are various foodborne diseases which can be associated with its' consumption if correct handling practises are not used. Such problems are not only a public health issue, but can also cause economic losses if pork requires condemnation by the meat inspector. There are also concerns about the way animals are handled before being slaughtered which as well as being detrimental to the animal can also lead to economic losses from trimmed or condemned carcasses.

We wish to study the presence of some diseases in pork and the presence of lesions (bruises, tether wounds, lacerations etc) which may indicate sub-optimal animal welfare. The results of this evaluation will be used to help us develop interventions which may help the development of an economically viable and safe value chain.

Funding Sources

This study is funded through the Wellcome Trust – University of Liverpool Institutional Strategic Support Fund, The Soulsby Foundation, The University of Liverpool Early Career Researcher Fund and World Animal Protection (WAP). WAP have been consulted on the design of the study, all other funders had no influence on the design and implementation of the research.

Type of Research Intervention

Should you agree to participate the following things will happen: the selected pig(s) will be weighed and examined by a veterinarian for signs of disease or injury. They will be identified using a simple band around one ear and one forelimb. After the pig(s) have been killed one of our team will collect blood from the animal. At different parts of the slaughtering process other team members will examine the carcass and internal organs for signs of disease or injury. We may take photographs of any lesions we find. One of our team will be stationed with the meat-inspector and will record any parts of the animal which are condemned, they will also take a small (25g) sample of the liver to test for chemicals including heavy metals.

Once the carcass is ready to dispatch we would like to purchase from you the following organs which we will examine for the presence of disease, we will pay you the following prices:
Full head including brain, cheek and tongue @ 100/kg
Pluck (Heart & lungs) @ 150 (total)

Participant Selection

We will be selecting every 2nd pig slaughtered on each day we spend at the slaughter house, you are being requested to participate in this research as the trader presenting an eligible pig to slaughter

Voluntary Participation

Your participation in this exercise is entirely voluntary. If you choose not to participate there are no adverse consequences to you or your animal.

Photography

Photographs may be taken of your pigs, no details identifying them as belonging to you will be captured on these photographs.

Benefits & Risks

There will be no direct benefit to you, but your participation will help us find out more about the safety of pork and the welfare of pigs.

Reimbursements

You will not be provided any incentive to take part in the research.

Confidentiality

Any information about you will have a number on it instead of your name. Only the researchers will know what your number is and there will be no record of your name kept by the team

Sharing the Results; We will produce a feedback leaflet and provide it to the slaughterhouse manager for dissemination to interested parties. We will also publish the results in scientific journals so that other interested people may learn from the study.

Who to Contact

If you have any questions, you can ask them now or later. If you wish to ask questions later, you may contact any of the following:

Principal Investigator;

Dr Lian Thomas, Institute of Infection and Global Health, University of Liverpool, UK and ILRI, lian.thomas@liverpool.ac.uk

Research Supervisor

Prof. Eric Fèvre, Institute of Infection and Global Health, University of Liverpool, UK and ILRI, Eric.Fevre@liverpool.ac.uk

This proposal has been reviewed and approved by *ILRI IREC***, which is a committee whose task it is to make sure that research participants are protected from harm. If you wish to find out more about the ILRI IREC, contact (ilrikenyaeohs@cgiar.org) or visit website (www.ilri.org/researchcompliance).**

You can ask me any more questions about any part of the evaluation exercise, if you wish to. Do you have any questions?

Part II: Certificate of Consent

I have been invited to participate in an exercise to investigate food-safety and animal welfare in the pork value chain of Nairobi

I have read the foregoing information, or it has been read to me. I have had the opportunity to ask questions about it and any questions I have been asked have been answered to my satisfaction. I consent voluntarily to be a participant in this study.

Print Name of Participant__________________

Signature of Participant ___________________

Date ___________________________

Statement by the evaluator/person taking consent

I confirm that the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

A copy of the information sheet has been provided to the participant.

Print Name of Researcher/person taking the consent________________________

Signature of Researcher /person taking the consent__________________________

Date ___________________________

Appendix 4; Data Collected from the Abattoir.

Information from the traders.

1. Type of truck used for transportation. (Model and space specifications.)

   …………………………………………………………………………………………………

2. Number of pigs transported in the truck.

   …………………………………………………………………………………………………

3. Origin of these animals.

   …………………………………………………………………………………………………

4. Are they from one farm or they are a mixed batch?

   …………………………………………………………………………………………………

5. Live weight of the pig

   …………………………………………………………………………………………………

Animal Information.

Welfare Lesions

Animal I D

……………………………………………………………………………………………….

What method was used to stun the animal

……………………………………………………………………………………………….

Is the animal showing any signs of consciousness?

……………………………………………………………………………………………….

If yes, list them.

……………………………………………………………………………………………….

Write down the external welfare lesions observed on the carcass.

……………………………………………………………………………………………….

Write down the internal lesions observed in the carcass.

……………………………………………………………………………………………….

Antiplagiarism report

14/7/2021 (1)

INVESTIGATION OF PREVALENCE OF BODY INJURIES AND HANDLING PRACTICES FOR SLAUGHTER PIGS AND THEIR ASSOCIATION WITH MEAT QUALITY

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While every care will be taken to preserve the submitted work, the University of Nairobi is not liable for loss or damage to the work(s) or associated data while it is stored within the digital repository.

Work(s) to be deposited:

Title: PREVALENCE OF BODY INJURIES AND HANDLING PRACTICES FOR SLAUGHTER PIGS AND THEIR ASSOCIATION WITH MEAT QUALITY IN KIAMBU COUNTY, KENYA

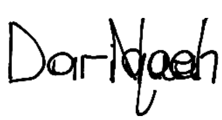
Author: Sentamu Derrick Noah

Depositor's Declaration

I Sentamu Derrick Noah
hereby grant to the University of Nairobi Digital Repository, a non-exclusive license on the terms outlined above.

Name; Sentamu Derrick Noah

College; College of Agriculture and Veterinary Sciences

Sign; 

Date; 19/10/2021

Student ID

University of Nairobi

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Change Password · My profile · Year 1 Registration · Student ID · Academic Tracking · Inter Faculty · Clearance Status · Caution Refund

J56/21910/2019 DERRICK NOAH SENTAMU (Regular/Integrated)

ID/PP No. ______ **Type :** New (First Time) [Make Request]

Previous Requests

	Request Date	Status	Receipt No.	Validity	Remarks	
1.	15-FEB-2019	PRINTED 21-MAR-2019 04:40		21-MAR-2019 - 20-MAR-2020	ID Already Printed	1.
2.	04-JAN-2021	PENDING			ID Card Available for Printing.	2.

Procedure for getting the new generation Student ID Card

1. Ensure that your fees (including that of Student ID) is paid and receipted before making the ID card request.
2. Fees for Re-Issue of lost ID card must be paid and receipted separately.
3. Place your request for the Student ID through the Student Portal.
4. Request for renewal of expired ID card should be made **NOT MORE THAN ONE MONTH BEFORE EXPIRY OF THE CURRENT ONE** .
5. Ensure that your photo has been taken and uploaded into the System.The University Photographer is located at JKML Library.
6. Allow at least two working days for the processing of your ID card.
7. Keep checking the status of your ID request through the Student Portal.
8. Collect your printed Student ID from your Faculty / School / Institute Office once the STATUS of your request is reflected as PRINTED.

Note:

1. Validity for Re-Issued ID Card will be the same as that of previously Issued (Lost) ID.
2. Validity for Replacement / ID Re-New will start after expiry of current Issued ID.

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Financial Statement

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Fee Statement · Detailed Fee Statement · Pay Fees Online

J56/21910/2019 DERRICK NOAH SENTAMU (Regular/Integrated)

Fees Statement

Academic Year : 2019/2020 **Billing Currency :** KES

Transaction/ Receipt Number	Date	Description	Debits DR	Credits CR	Balance	Cur.Rate
2180357292	2019-02-15	FEES PAYMENTS	0.00	205,000.00	-205,000.00	KES=1
2180524696	2020-10-30	FEES PAYMENTS	0.00	40,000.00	-245,000.00	KES=1
J56/21910/2019-2019/2020-SEM1	2021-10-18	FEES PAYABLE FOR SEM1	122,000.00	0.00	-123,000.00	KES=1
J56/21910/2019-2019/2020-SEM2	2021-10-18	FEES PAYABLE FOR SEM2	100,000.00	0.00	-23,000.00	KES=1
		Academic Year Totals :	**222,000.00**	**245,000.00**	**-23,000.00**	

Closing Balance : -23,000.00

Academic Year : 2020/2021

Transaction/ Receipt Number	Date	Description	Debits DR	Credits CR	Balance	Cur.Rate
Opening Balance			0.00	23,000.00	**-23,000.00**	
J56/21910/2019-2020/2021-SEM1	2021-10-18	FEES PAYABLE FOR SEM3	117,000.00	0.00	94,000.00	KES=1
		Academic Year Totals :	**117,000.00**	**23,000.00**	**94,000.00**	

Closing Balance : 94,000.00

Academic Year : 2021/2022

Transaction/ Receipt Number	Date	Description	Debits DR	Credits CR	Balance	Cur.Rate
Opening Balance			94,000.00	0.00	**94,000.00**	
2200042554	2021-06-07	FEES PAYMENTS	0.00	93,000.00	1,000.00	KES=1
2200101018	2021-10-19	FEES PAYMENTS	0.00	1,000.00	0.00	KES=1
		Academic Year Totals :	**94,000.00**	**94,000.00**	**0.00**	

Closing Balance : 0.00