UNIVERSITY FOR DEVELOPMENT STUDIES, TAMALE

VALIDATION OF HERBAL MEDICINE (LUWINE) FOR THE CONTROL OF AFRICAN SWINE FEVER IN UPPER EAST REGION OF GHANA

GODFRED ADAGPANGA AWELIGIYA

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BY

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DECLARATION

CANDIDATE'S DECLARATION

I, Godfred Adagpanga Aweligiya hereby declare that this thesis is the result of my own original work and that no part of it has been presented for another degree in this University or elsewhere:

Candidate's Signature: ……………...……………. Date: …………………….………

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I hereby declare that the preparation and presentation of the thesis was supervised in accordance with the guidelines on supervision of thesis laid down by the University for Development Studies.

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ABSTRACT

African swine fever (ASF) is a highly contagious viral disease that affect domestic pigs and it is characterized by fever, blotching of skin, and haemorrhage of the lymph nodes, internal organs and the gastrointestinal tract. The prevention and cure of ASF will depend on management practices by farmers, observance of biosecurity measures, the immune system of the pig, and the control of secondary infections. This study was therefore, carried out to determine the knowledge and management of African swine fever by farmers in the Upper East Region (UER) of Ghana. The study also assessed the effects of 'Luwine' (a local herbal medicine prepared from the root of *Sarcocephalus latifolius* and dry bark peels of *Pseudocedrela kotschyi*) to control ASF and the secondary infectious associated with ASF. A semi-structured questionnaire was used to determine the knowledge and management of ASF among 250 pig farmers. Experiments were conducted using 'Luwine' and/or standard antibiotics to control ASF and bacteria (non-fastidious and fastidious bacteria) associated with ASF secondary infections. Pig farmers were mostly males (83.52%), between 30-35years (63%), had non-formal education (30%) and have kept pigs for less than 5 years (45.05%). Pig farmers also engaged in other economic activities (81.62%), used own labour on the farm (42.12%), obtained feed from the local market (94.14%) and provided their pigs with pipe borne water (92.62%). An average of 20 pigs per farm suffered and died from ASF outbreak in the study area and the mortalities were more in piglets (36.28%) than other age groups. Most farmers (67.14%) reported and sort veterinary advice during ASF attack on their farms, and the veterinary officers confined diseased pigs (67.59%). The survey revealed that outbreaks of ASF occurred most in poor pig farmers' farms than the well-resourced farmers. ASF pigs treated with 'Luwine' recorded less mortality than the control group (difference of means in terms of mortality was up to 5 pigs). The non-fastidious and fastidious bacteria were all resistant to 'Luwine'. The non-fastidious bacteria were highly susceptible to azithromycin (100%), gentamicin (100%) and amoxycillin/clavulanic acid (80%), but resistant to teicoplanin (70%). The fastidious bacteria were highly susceptible to gentamicin (70%) and suphamethoxazole/trimethoprim (70%), but resistant to ceftriaxone (100%), teicoplanin (100%) and chloramphenicol (80%). Multidrug resistant occurred between the non-fastidious (50%) and fastidious (90%) bacteria. The administration of 'Luwine' could not cure ASF since mortality was increased with days. The non-fastidious bacteria were generally more resistant than the fastidious bacteria. 'Luwine' was not effective against the bacteria associated with secondary infections in ASF pigs. Among the antibiotics, gentamicin was the best for controlling bacteria associated with ASF pigs. Strict biosecurity should be observed among farmers and stakeholders should compensate farmers whose farm experience ASF outbreaks.

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DEDICATION

This work is dedicated to my family, especially my wife Gloria Anyesom Adazebra and children Mechtildis Awinaabono Abokoringo and Macanisius Alowine Abokoringo.

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ACRONYMS/ABBREVIATION

AIBP---Agro-industrial By-products

AMC----Amoxycillin/clavulanic acid

AR---Atrophic Rhinitis

ASF---African swine fever

ASFV--- African swine fever Virus

AU----African Union

AZM----Azithromycin

BVG---- Bishopton Veterinary Group

C----Chloramphenicol

CN---Gentamicin

CRO----Ceftriaxone

CTA-----Technical Centre for Agriculture

DFID---- Department for International Development

DNA---- Deoxyribonucleic Acid

FAO---Food and Agricultural Organisation

FASDEP----Food and Agriculture Sector Development Policy

GDP---Gross Domestic Product

GPRS--- General Packet Radio Service

GSS----Ghana Statistical Service

IICAB---- Institute for International Cooperation in Animal Biologist

KNWDA---- Kassena-Nankana West District Assembly

MAR----Multiple Antibiotic Resistance

MHA----Müller Hinton Agar

MMA----Mastitis-metritis-agalactia

MOFA—Ministry of Food and Agriculture

NCI--- National Cancer Institute

NTFPs-- Non-Timber Forest Products

PMWS---Post-Weaning Multi-Systemic Wasting Syndrome

RNA--- Ribonucleic Acid

SXT---Suphamethoxazole/trimethoprim

TEC---Teicoplanin

TE---Tetracycline

TSB----Trypticase Soy Broth

WOAH--- World Organization for Animal Health

YBP---- Years Before Present

CHAPTER ONE

INTRODUCTION

1.1 Background

The livestock subsector is a significant element of Ghana's agriculture and plays a multi-faceted role in supporting the rural population with livelihoods. Livestock development in the nation is a significant contributor to improving food security, intensifying farming and reducing poverty, especially among the rural poor (Falvey, 2015). Livestock production has a special importance in economic development in most instances as it serves as the prime driver of growth in the agricultural sector. The subsector adds an approximately 1.2% to agricultural Gross Domestic Product (GDP), and in 2015 the cattle subsector reported the greatest development of 9.3% of all industrial operations (Ghana Statistical Service (GSS), 2015). Studies have shown that the subsector's primary contribution to the domestic economy is reflected in its food and environmental safety as it offers animal protein to improve the human population's dietary status (MOFA, 2016).

Livestock plays a key role for farmers in their socio-economic and cultural identity and is a source of food, jobs, food safety, as well as store or trade assets (Banson *et al*, 2014). In times of pressing economic requirements, it functions as a bank and insurance because it produces money (Holness *et al.*, 2005). It also provides us with manure to improve soil fertility and composition. Furthermore, cattle offer draught energy in particular, enabling bullock-owning families to farm 60% more land than their neighbours without bullocks (Amu, 2005). In the particular case of northern Ghana, cattle, sheep, goats, horses, donkeys, pigs are the main animal species kept. Roger and Mallam (2007) noted that intensive animal production systems do not exist in the regions, however, small stock are allowed to forage freely in the dry season and confined in the wet reason. Government agencies, many non-governmental organizations and other stakeholders in the animal sector are continually providing farmers with education, incentives and other types of assistance to enhance and boost their input and production (Adzitey, 2016). Ghana's commitment to the development of the livestock sector, for example, is the formulation of the Ghana Livestock Development Policy and Strategy aimed at developing a competitive and more effective livestock industry that improves national output, decreases the import of meat and livestock products and helps to improve the livelihoods of the entire livestock value chain.

Pig rearing in the Upper East Region of Ghana has become a common task among many individuals. Due to the ever-changing nutritional patterns and the rapidly increasing demand for animal protein, especially pork, this has become progressively essential. Pork is the most frequently consumed meat in the world (Food and Agriculture Organisation (FAO), 2014). Many distinct pork products are eaten by people, including bacon, sausage, pork chops, and ham. In addition to meat, several precious goods or by-products come from swine. In order to satisfy the rapidly increasing market demand for meat, small holder peri-urban rearing systems have switched to short-cycle species, namely poultry and pigs. This phenomenon has more or less given rise to many peri-urban commercial pig-producing units, rearing improved and often pure exotic breeds.

Ghana has a pig population of approximately three hundred and fifty-four thousand, six hundred and seventy-eight (354, 678), dispersed throughout the nation, (EMPRES, 2002). According to Adzitey (2016), between 2001 and 2010 the production of pork in Ghana increased by 67 percent, while in 2010, to stand at 17,506 tonnes. Native Ashanti

Black (Local Black), Large White, Landrace, and crosses between exotic and local races are the nation's primary pig kinds. Free-range, semi-intensive and intensive technologies are the most prevalent pig production systems in Ghana. These animals are scattered throughout the country's agro-ecological areas. The indigenous Ashanti Black pig is found nationwide and has the largest concentration in the Northern, Upper West and Upper East regions (MOFA, 2008; Aboagye *et al.*, 2014).

According to Collins (1993), the main function of pig rearing is to provide food (fresh, healed or processed) for humans. The sector is therefore concerned with meat quality and the effective production of meat. Wiseman (1992) said the pig is one of the oldest animals to be domesticated and plays an essential part in peasant economies including African continent. Pigs also provide a ready and regular source of cash to meet the daily needs of rural families, such as paying college fees and expenses, spending on health and farm inputs. Because of the heavy losses in their pig herds in many affected areas, parents were unable to send their kids to school (Babalobi *et al*., 2007).

Many limitations impeded production as well as development in the pig sector. Banson *et al*. (2014) noted that the absence of enhanced breeding stock and sector rearing data resulted in the import of subsidized meat. Food and Agriculture Sector Development Policy (FASDEP) II described inadequate availability of quality feed, low implementation of good agricultural practices in the manufacturing, handling and transport of livestock/livestock goods, low genetic material of livestock species, bad management practices and low productivity as main problems facing the livestock subsector, including the pig sector. The reality is that illnesses are the most significant factor in the pig sector that hinders progress. Whenever they happen, they play a key role of enormous financial losses.

The African swine fever virus (ASFV) is a serious disease of pigs that can lead to approximately 100% death, generally leading to catastrophic impacts on the economy, agriculture and food safety of a country (Vapnek, 1999). It is probably the most severe restriction for pig production wherever it happens and in many African nations it presents a severe issue. African swine fever virus (ASFV) is the cause of African swine fever (ASF), a significant disease affecting all races and ages of wild and domestic swine (Marisa *et al*., 2017). The virus is a double stranded DNA virus of the genus Asfarviridae (King, 2012). ASF has a number of clinical manifestations, including elevated mortality rates of hyper-acute or acute illness (Blome *et al*., 2013). Transmission occurs in domestic pigs and wild boars when healthy animals are in direct contact with sick or infected pigs or through infectious excretion and secretion contact. In most sub-Saharan Africa, the illness is regarded endemic (Dietze *et al*., 2012). Changes in rearing methods and growing globalization have also raised the danger of their introduction into other areas, according to Spickler (2015). ASF's overall upsurge in many fields is fuel by the huge development in Africa's pig industry (Dietze *et al*., 2012). Due to its notable potential for transboundary spread, which was amply proved in the second half of the last century when it fled from Africa to impact several nations in Western Europe and other Asian nations, ASF is said to be of great significance (World Organization for Animal Health (WOAH, 2008). Recent outbreaks have resulted in important losses and in some nations have endangered entire populations of pigs (EMPRES, 2002).

In Ghana, there is a severe danger to the pig sector from the emergence and spread of the disease with its related financial losses. In 1999, the first recorded manifestation of ASF in Ghana affected domestic pigs. According to Babalobi *et al*. (2007), more than 200,000 pigs were scheduled for mandatory slaughter to contain the outbreak of ASF in Accra and Central region where 700 pigs were originally killed by the outbreak in 1999. An approximately 7,061 pigs were recorded dead as a consequence of the disease, while an estimated 1,743 were killed and eaten by their owners in Ghana (EMPRES, 2002).

Efforts to create a cure have not yielded positive results after the emergence of the illness. Dietze (2012) stated that no known vaccine is available yet, so prevention and control initiatives should concentrate on reducing the burden of disease in domestic pigs through enhanced husbandry practices, protecting regions not impacted by the disease through regulated trade and development programs in the swine industry that emphasize awareness and prevention.

Plants serve as prospective medicinal products to cure multiple human and animal diseases. The use of herbal and natural remedies has been long advocated in the delivery of healthcare for both humans and animals. Ethno-veterinary medicine, a traditional animal health care that includes the understanding, abilities, techniques, procedures and beliefs discovered among community members about animal health care (McCorkle, 1986).

In most developing countries, ethno-veterinary medicine is particularly crucial where convectional veterinary medicine is beyond farmers ' reach. Many indigenous veterinary beliefs and practices persist in a wide majority of livestock breeders and farmers particularly in developing countries (Moreki, 2013). Commercial or large-scale pig producers may be prepared to take proactive long-term steps to address certain difficulties, but on the other hand, often, smallholders cannot protect themselves from heavy and repeated losses. These resource-poor pig farmers use ethno-method medicine mostly in rural regions.

African peach and dry zone cedar are well-known locally accessible plants that are usually used by pig farmers in the Upper East region to prevent and treat human and livestock illnesses. There is, however, a little documented data about these plants used in the region's ethno-veterinary medicine. This research seeks to validate the use of these herbs for the prevention of African swine fever.

1.2 Study Objectives

The primary goal of this study is to validate herbal medicine (Luwine) in the Upper East region of Ghana to control African swine fever (ASF). In particular, the study is aimed to:

1. Assess the level of farmers' knowledge on ASF
2. Determine the prevalence of ASF in the area
3. Assess the average losses experienced due to ASF
4. Evaluate the herbal medicine ability to control mortality in pigs infected by ASF
5. Assess the effectiveness of the herbal medicine to reduce secondary infection in ASF pigs
6. Determine the standard antibiotic that can control secondary infections associated with ASF pigs.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of Agriculture and Livestock Production

Agriculture is the main pillar of most economies in Western African nations. The industry derived its significance from providing livelihood for most families, foreign exchange earnings as well as local agro-industrial raw materials. As an agrarian nation, Ghana occupies a land area of 238,537 square kilometres characterized by broad biodiversity and climatic conditions appropriate for various agricultural manufacturing, (Ghana Statistical Service (GSS, 2013). The nation has agricultural resources that make a significant contribution to the foreign exchange earnings necessary for growth and economic development. The financial contributions of the sector are also linked to their GDP contributions. The agricultural sector's performance has lagged behind that of utilities and industry in latest times. The sector's delayed performance has become a major problem for policymakers and scientists. More than half (51.8%) of the economically active 28 million individuals in the country are employed by the industry (GSS, 2013).

Agricultural performance in Africa has greatly benefited from livestock sector production. The cattle sector makes a significant contribution to rural people's livelihoods. According to Williams and Okike (2007), as part of their livelihood policy, at least 100 million poor individuals in West Africa depend on livestock. In 2016, the contribution of the livestock sector to the gross domestic agricultural product was 1.2% (Ghana Statistical Service, 2013). In Ghana, ruminants as well as non-ruminants are reared. Cattle, goats and sheep are the prevalent ruminants produced in Ghana, while pigs and poultry (national fowl, guinea fowl and ducks) are the non-ruminants bred. Small animal production, however, dominates the country's ruminant production. In the poultry industry, large-scale production is presently prominent. Traditional animal production such as rabbits, grass-cutters, bees, snail and fish farming has earned a great deal of advocacy and support from both the private and public sectors. The production of animals in Ghana is carried out under three primary schemes, the intensive, semi-intensive and extensive systems (Adzitey, 2016). The intensive system is primarily performed by business farmers, whereas in rural societies the extensive system is usually practiced. Farm labour is derived from household sources, but mostly under large-scale production is complemented by hired labour.

As much of the meat and food produced is purchased in the raw form, the agro-processing industry is underdeveloped (Al-Hassan and Jatoe, 2014). Meat processing is carried out on a small scale, using traditional technology, like food crops. Animals are usually killed in their homes by people or authorized persons in community, government slaughter slabs and by authorized persons in government-owned slaughterhouses or abattoirs (Adzitey, 2016). Livestock production is a significant source of livelihood in many rural groups in the three northern regions of Ghana, particularly during the dry season.

2.2 History of Pigs

One of the most important occurrences in human history was livestock domestication (Amills *et al*., 2010). While people were given continuous access to food supplies from animals, national species were protected from prospective predators, their numbers and geographical distribution enhanced far beyond their wild ancestors (Zeder *et al*., 2006). Pigs are usually docile and easy to grow. They form one of the early creatures that have been domesticated. All zoo archaeological surveys available indicate that pig domestication happened from distinct wild populations at distinct times and in many distinct fields. This suggests that there was in fact independent domestication of pigs in these fields. In the case of European pigs, McGlone (2009) recorded that pig domestication began 9000 years ago when human hunting for pigs in caves coincided with the establishment of settlements and the change from the solely hunter-gatherer manner of life to primitive farming and pastoralism. Recent zoological surveys have also found that the first pig domestication happened around 9000 Years Before Present (YBP) in the Near East and may have happened constantly from local wild boar communities (Bokonyi, 1974). Ekesbo (2011) said one point worth noting is that it was a gradual method to domesticate all forms**.** Changes in the morphology and behaviour of domesticated pigs have been gradual and cumulative, according to Zeder *et al*. (2006). According to Kindon (1979), only one species, S. scrofa, has been domesticated, however, the other species, in particular the African species, have excellent domestication potential. Jones (1998) noted that babyrusa (*Babyrousa babyrussa* from Indonesia) and popular warthog (*Phacochoerus africanus*), bushpig (*Potamochoerus larvatus*) and African giant forest hog (*Hylochoerus meintzbageni*) are closely related to scrofa. Darwin (1868) also acknowledged two significant domestic pig types, one European (*Sus scrofa*) and one Asian (*Sus indicus*). The former was supposed to come from the European wild boar, although there is no proof of the origin of the *Sus indicus*

(Giuffra *et al*., 1999). Larson *et al.* (2005) claimed that *Sus scrofa* originated as other suid species in South East Asia and moved westwards to India and East Asia until it reached Europe. Studies by Larson *et al.* (2010) have shown that *Sus scrofa* has distinctive genetic backgrounds in India, South East Asia and Japan that suggest extra domestication sites.

The rearing of pigs became a significant component of the culture of the Persians, Egyptians and Chinese where they ate pork by 3000–4000 BC, (McGlone, 2009). Pigs spread to the west and north of Eurasia after this era. For example, Henan (5000–6800 YBP) reported that pig bones and swine paintings were found at remote Neolithic locations situated at Yangshao in China, (McGlone, 2009). Observations by Amills *et al*. (2010) indicated that Western African pigs do not display far-off Eastern alleles suggesting that they derive from the admixture with European heritage of indigenous populations and exotic races. Blench (2000) research suggests that pigs distributed across North Africa play an important part in the economy of Tangier's Neolithic communities. Pigs were grown in North Africa from remote times, especially in Egyptian and Berber cultures, according to Blench (2000), until they were effectively eliminated by the spread of Islam. In sub-Saharan Africa, in West-Central Africa (from the Ethiopian borderlands to central Nigeria), Angola (from southern Cameroon to Angola), important ancestral pig-keeping areas were acknowledged (Blench 2000). However, pig breeds in the continent are poorly defined at the level of morphology, manufacturing and genetics, and as such very few conservation programs are undertaken to maintain them (Amills *et al*., 2012).

2.3 Breeds of Pig

2.3.1 Indigenous Breeds

The origin of these pig breeds is traced back to Iberian. They are discovered with different names in nearly every country on the African continent. They are referred to as Ghana's Ashanti Dwarf pig, South Africa's Kolbroek, Mali's Somo, Gabon's Bakosi, Nigeria's West African Dwarf pig, Togo's Bush pig, and Zimbabwe's Mukota pigs (African Union (AU), 2015). With a short forehead and legs, they are generally small in size. Their straight tail and an elongated snout with horizontally or slightly erect, medium, semi-erect, swept-back small ears also recognize them. Compared to the exotic races of relatively long legs, they also have a narrow body. The skin is often dark, pie at times, grey, red at times, usually white.

The coat is different; sometimes long, coarse hairs are developed along the spine that almost covers the skin with a strip of longer hair. Local African Pigs are usually tiny in size, with adolescents reaching a maximum weight of 100 kg but rarely weighing more than 60 kg at 12 years of age, even under the best rearing conditions (AU, 2015).

Studies have shown that they mature sexually soon and the female may display first oestrus at the age of three months (AU, 2015). Local African Pig is capable of tolerating food shortages, it is heat tolerant and prolific.

2.3.2 Large White

The Large White breed (Plate 2), also known as the Yorkshire, was bred in the York County of England. Graeme and Greg (2005) stated that in the late 1700s this swine breed was created and in 1981 nearly 4000 Large Whites were recorded in England, ranking them as the top breed in the nation. The Large Whites are coloured white and free of black hair. They are exceptionally lengthy, high carcass quality deep-sided hogs and are known to be very prolific and great mothering capacity. The characteristics of the head are a slightly dished face and erect ears. They have sound feet and legs, allowing long productive live. The sows were observed for their heavy milk production and big litter size. The Large White is generally believed to have a high ability to be compatible with a broad spectrum of weather conditions. They are a big breed and have been commonly used in programs for crossbreeding. Large White and Landrace are the most common crosses. This cross is often used in commercial herds as the maternal row.

Plate 1: A Large White Pig

2.3.3 Duroc

Durocs are identified with the color of their red body. Durocs can range from a golden, nearly yellow color to a very dark red color. Duroc race was first named Duroc-Jersey, originating from New Jersey's Jersey Reds, New York's Red Durocs, and Connecticut's Red Berkshires (Vickie *et al*., 2001). The Duroc's distinctive feature is drooping ears. The sows of Duroc are prolific and have a strong capacity to mother. They have great ability to feed and generate big amounts of milk. Generally, the Durocs are preferred for their rapidly increasing capacity. They are a big breed that has been commonly chosen for desirable muscle, meat production and elevated female prolificity. Durocs are regarded as a big breed in size. Durocs were recognized as a superior source of genetics for quality improvement. Plate 3 shows a picture of a Duroc.

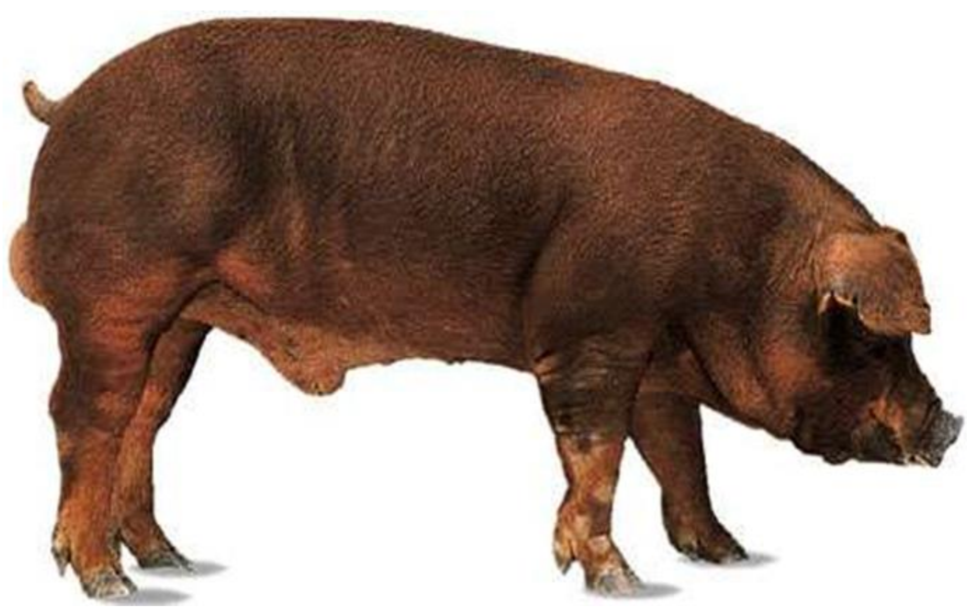

Plate 2: A Duroc Pig

2.3.4 Hampshire

In Boone County, Kentucky, the Hampshire races were created from the New England foundation stock, known as the Thin Rinds and Belted Hogs (Vickie *et al.*, 2001). The breed of the Hampshire (Plate 4) is black with a white belt around the fore shoulders and front legs. Hampshire have erect ears and are known to be heavy muscular, lean, aggressive hogs with big regions of the distant eye and have less back fat. Hampshire are praised for their capacity to forage and exceptional quality of carcass. Hampshire boars therefore create excellent terminal sires. Hampshire sows are very prolific, extra longevity and great mothers. They are comparatively lower than certain races. The requirements of the Hampshire breed state that Hampshire must have at least six functional teats on each side of their body, must be black in colour with a white belt, including both the front legs and the feet (Hybrid Earth Station (HES), 2007). Due to their excellent carcass quality, they were used widely in crossbreeding. Modern Hampshire is the leader in high-quality carcass production.

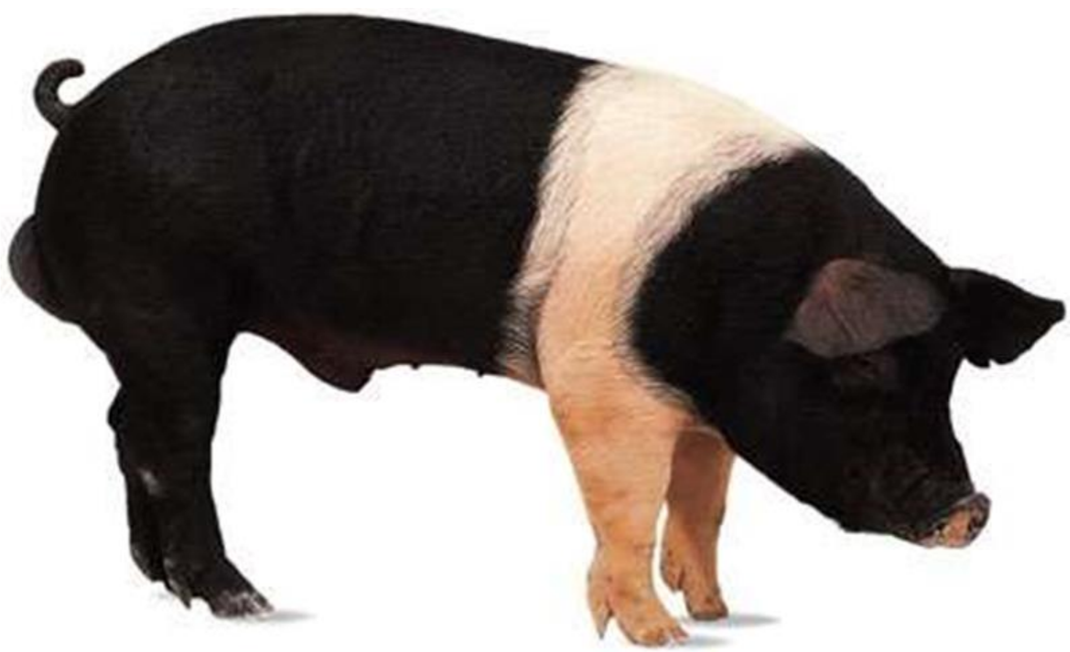

Plate 3: Hampshire Pig

2.3.5 Berkshire

Berkshires are hardy and can be adapted to outdoor production as well as confinement. Berkshire sows are very docile and have an outstanding disposition. Berkshire boars have great libido and superior semen quality. A Berkshire pig is shown in Plate 5.

Plate 4: A Berkshire Pig

2.4 Pig Production in Ghana

The process and factors that constitute pig production in Ghana need to be delved into. Pig production, also referred to as swine production, is a profitable financial undertaking conducted at the farm level by low-income farmers. Also recently, swine rearing and pork production has attracted the growing interest of Ghanaian farmers seeking enterprise diversification after a period of low profitability (Banson, 2014). Managing and producing pigs in Ghana includes a series of operations that are more focused on offering adequate production methods such as accommodation, feeding and other extra activities of husbandry that are very crucial in swine production.

2.4.1 Housing

Housing is a key element of pig farming that is healthy and effective. More importantly, pig farmers need to construct pig houses so that their animals do not go into peoples ' farms to vandalize their plants, avoid theft of pigs, decrease disease outbreaks and avoid wallowing them in the mud to decrease the public appetite for pork (Osei and Adu, 2015). Furthermore, pigs are heat sensitive and may die as a result of heat stress (St-Pierre, 2003) and therefore need to be housed in a favourable environment. Sites intended for pig housing should be located at an elevated location that cannot be flooded with rainwater and should be shielded from the sun (tree shade) and have sufficient fresh air (FAO, 2009). Indoor housing requires well-regulated and controlled temperature circumstances to assist maximize the productivity of pigs (Ewur-Banson *et al*., 2014). Campos- Labbe, (2003) stated that climate circumstances have a direct effect on the health of pigs and that their output may result in insufficient housing circumstances leading to disease, enhanced feed consumption, and weight gains that directly affect farmers ' profit.

Pigs can be housed indoors in individual stalls, pens (in groups or batches) or in barns, but if the pigs are raised outdoors they would need a refuge during cold and warm weather conditions (Ewur-Banson *et al*., 2014). There should be room for feeding, drinking and bedding in the accommodation. In Ghana, in the building of homes for swine, many distinct housing materials are used with the rationale of offering the animals with secure surroundings. A typical pig housing in Ghana is built from mostly accessible and less costly timber, bamboo or mud. Most pig farmers have recently made progress with the use of concrete and bricks or a mixture of them. Despite the costly nature of these products, they are more durable than the former. Studies undertaken by Osei and Adu (2015) discovered that two kinds of infrastructure were prevalent throughout the Ashanti region of Ghana, made from wooden constructions with concrete floors sloping into drains.

According to their research, owing to the enormous financial capital engaged in contemporary housing units, 24.1% of farmers surveyed used very easy and cheap housing for their pigs. The writers noted that most farms with wooden constructions (61.5%) belonged to the category of tiny scale. Only two (7.7%) and eight (30.8%) farms in the large and medium-sized farms used wooden structures, respectively. They also reported that, farmers who adopted the simpler residential system claimed that the wooden walls and the palm-covered roof were better suited to pigs in tropical conditions because it allowed more air circulation and improved heat and odour reduction, while wealthier farmers were of the opinion that enhanced and contemporary infrastructure provided better safety from harsher environmental circumstances. The suggested ground spacing for pigs is: 1.5-2.0 sqm for pregnant sowing, 4-6 sqm for lactating sowing, 0.3-0.5 sqm per piglet and 6-8 sqm for boars, according to the FAO (2009). In such circumstances, however, the farmer must keep the environment clean and provide good hygiene practices. Because illness plays a key role in producing pigs that provide a clean atmosphere, it will assist to reduce the appearance of illnesses and the hazards of infections.

2.4.2 Feeding

McDonald *et al.* (1998) described food as the material that can be digested, absorbed and used after animal ingestion. Feeds must contain adequate energy, protein, minerals and vitamins to satisfy the maintenance, development and reproduction needs of the animal (FAO, 2009). Feed consumption plays an important role in determining the output that may also represent pigs ' health status (Bruininx *et al*., 2001). To attain maximum development, at each phase and manufacturing form, pigs need to consume feed that fits their future appetite (Murray, 2006). The formulation of feed for pigs should be based on the motivation to achieve highest animal efficiency and therefore maximum profit. However, consideration is also given to a number of variables such as genetic differences in pigs (gender and genotypes), alternative feed ingredients, variability, nutrient accessibility and stability in feed components, nutrient and non-nutrient interactions, voluntary feed consumption, physical and social environment, and other dietary formulations and feeding strategies. Furthermore, each farmer must notice the feed requirement of their livestock in order to guarantee economic efficiency. However, owing to the elevated price associated with swine feeds, many farmers are challenged to satisfy the feed requirements of pigs. According to available information, the main cost element for swine production in Ghana is the cost of feeding and feeding, on the other hand, has floated between 60 and 75% of complete production costs (Okai *et al.*, 2001). Due to the elevated feed expenses, correctly formulated and compounded feeds tend to be used in study stations, colleges and large-scale business farms, while small-scale manufacturers are compelled to use agro-industrial by-products (AIBP) and what is referred to as non-conventional feed assets (NCFR) (Montsho and Moreki, 2012;

Okai *et al*., 2001). Table 2.1 shows examples of some AIBP and NCFR used for pigs in Ghana.

Table 2.1: Some AIBP and NCFR Used for Pigs in Ghana

Agro-industrial By-products	Non-conventional Feed Assets
Brewers spent rain	Mucuna (raw, cooked, processed
Cassava (foliage, peels and tuber)	Oil palm sludge
Citrus pulp	Pawpaw (peels and foliage)
Cocoa pod husk	Rice bran
Copra cake	Rubber seed
Groundnut (cake and skin)	Sheanut cake
Maize bran	Sorghum or guinea corn
Mango kernel meal	Watermelon rind
Molasses	Wheat bran
Plantain peels	

Source: Okai *et al*. (2001)

Umesh *et al*. (2014) argued that agro-industrial by-products are end-products of manufacturing and consumption that have not been used, primarily organic, and that their economic value is often very small. Furthermore, fruit waste such as banana rejects and pineapple pulp by contrast has sugars that are helpful for energy supply. The bulk of plant feeds are bulky poor-quality cellulosic roughages with elevated crude fibre and low nitrogen content, appropriate for ruminant feeding (Umesh *et al*., 2014). The ingredients in Table 2.2 must be included in a typical diet of pigs. Other accessible feeds such as cassava products and sorghum are frequently used in the case of Ghana.

Table 2.2: Feed composition for pigs

Ingredients	Pig Weight		
	15-30 kg	30-60 kg	Over 60 kg
Soya beans	25	20	15
Rice bran	25	30	35
Maize	20	25	30
Broken rice	5	5	5
Wheat bran	20	15	10
Leucaena tress leaves	5	5	5
Total	100	100	100
Crude protein	16	15	14

Source: FAO (2009).

2.4.3 Marketing

Livestock production in rural regions is usually regarded unproductive (Shackleton *et al*., 2001), since the pricing of pork and pork products was a disincentive for the fast marketing of pigs (Okai, 2007). Similarly, poor management practices and low or no inputs investment in the swine business by most rural farmers largely contributes to the situation. As a consequence, the marketing of pigs from most rural regions is difficult because customers are already biased against rural pigs, which are believed to be of bad quality and therefore one would not receive enough cash from them (Chimonyo *et al*., 2005). Furthermore, intermediaries and processors cannot give a realistic cost to small-scale producers who happen to be the bulk of pig production (Okai, 2007). For example, Chimonyo *et al*. (2005) discovered that there is bias in rural regions in Zimbabwe against indigenous Mukota pig breed. Buyers prefer exotic races because they are better and therefore more appropriate for generating revenue. Kagira *et al.* (2010) reported that 62.5% of pigs were purchased within the community in the village of Ramotswa in Botswana and 95%in the district of Busia in Kenya. Osei Sekyere and Adu (2015) believed that the comparatively reduced cost of meat is a significant problem facing the swine company. They stated that Ghana's pig market is not regularly stable owing to frequent outbreaks of African swine fever in some parts of the country. They discovered that the Ashanti region sold a nice 40 kg boar for 500 cedis. In addition to coping with the geographical sector where pigs are sold and their prices, the majority of farmers are less specialized in pig production as most farmers sell pigs of all ages (Mbuza *et al*., 2016). By contrast, Ouma *et al*. (2014) revealed that some farmers were highly specialized in production, with 25.1% of piglets sold for breeding, 36.1% of pigs reared for slaughter, and 42.2% of farmers sold piglets to farmers. Studies conducted by Mbuza *et al*. (2016) found the farm gate (68%) to be the most common way of selling, while others sold the eggs in the nearest public markets (20%).

2.5 Pig Management Systems in Ghana

Swine production takes place in Ghana in many kinds of systems. These management systems are classified based on the rate of intensification. These vary from the extensive or traditional system to commercial producers' intensive system where pigs are completely restricted. The semi-intensive system is another management system recognized among the country's farmers (Dick and Geert, 2004).

2.5.1 The Extensive or Traditional Production System

This system is characteristic of small farmers in rural fields. The primary aim of this system is to secure the family emergency fallback funds while providing them with a little meat from time to time, without any significant investment of time or money. The main feature of this system is that the pigs are allowed to move around the house and surroundings freely, scavenging and finding a large part of their food for themselves (Dick and Geert, 2004). Often kitchen refuse or agricultural waste products are added to the food they collect. During the cropping season, the animals are generally housed to keep the animals from destroying the sown plants. In accommodation, machinery, food and medical facilities there is nearly no investment. There is generally no effort by selective breeding or any other means to enhance production. The pigs are not grown on the farm in some instances. Piglets are carried in and fattened for sale at a later date during a season when food is abundant. But under this production system, the development rate of pigs is slow as much energy is spent on roaming. Moreover, under this scheme, there is a high incidence of worm in livestock. Improvement could be accomplished in this traditional production system by enclosing pigs in pens or yards. This will decrease piglet mortality, decrease energy loss through scavenging, and enhan ce theanimals ' health status by ensuring a regular vaccination program and control of p arasites (Awuni, 2013).

2.5.2 Semi-intensive System

This production system is based solely on containment and feeding levels. Pigs are restricted to a confined space in semi-intensive systems. Animals are totally dependent on their owners for food under this system. It is necessary to bring fresh water and fodder to the pigs once or twice a day. This pig-keeping scheme opens up opportunities for enhanced feeding and disease control, which can lead to quicker growing and healthier pigs and/or bigger litters. This system's benefits were ascribed to reducing the probability of stolen livestock. Moreover, keeping the animals tied or enclosed prevents disease contraction and infestation of pests. Furthermore, this system protects pigs from damaging plants. Despite these benefits of this pig production system, it is quite time consuming because it needs considerable time for health management procedures and herd feeding (Dick and Geert, 2004).

2.5.3 The Intensive System

This system is mostly performed in peri-urban regions and is characterized throughout the year by complete confinement. Commercial pig production companies are spread in towns and villages with a profitable market for pork and appropriate facilities (Chabo *et al*., 2010). Mostly exotic races of Large White and Landrace and their crosses are used, especially in the southern sector of the country (Barnes, 1994). Feed, water and protection from extreme weather are constantly given to pigs (Mutetikka, 2009). The intensive production system is defined by high labour requirements, inputs, high capital requirements and an extremely functional marketing arrangement. Such producers ' motive is to produce lean meat to meet consumer demand (Fowler and Livingstone, 1984). Pigs raised by higher learning institutions and other governmental and non-governmental organisations are doing much better because animal welfare is at the top of their leadership procedures (Barnes, 1994). Ouma *et al*. (2013) categorize this scheme into the peri-urban intensive in their research categories, which is most frequently practiced in peri-urban regions while rural intensive is found in all fields. Due to the unique place of the majority of intensive structures in peri-urban and urban regions, the restricted property holdings and the need for rapid development of pigs to match investment with yields, the use of forages in this system is restricted.

2.6 Pig Diseases

Pigs are susceptible to many illnesses and can be one of the biggest single limiting factors preventing pigs from growing successfully. Because of its financial effect, these diseases are of great significance to pork producers. Moreover, as many of these diseases are damaging to customers, disease also presents a danger to human life. Most pig producers are likely to be unaware of the manifestation and cure of these diseases and, if they happen, may experience financial losses. Bacterial, viral, dietary and genetic deficiencies cause several of the prevalent swine illnesses (Lawhorn, 2008)

2.6.1 Atrophic Rhinitis (AR)

All illnesses causing turbinate atrophy in swine are referred to as atrophic rhinitis (AR), but not all instances of AR are economically important (Turnquist, 1995). Rhinitis is an upper respiratory tract inflammation that occurs to some extent in almost every commercial swine herd (Lawhorn, 2008). Atrophic on the other hand happens by shrinking and distorting the turbinate bones inside the snout. It is now accepted quite well that most of the atrophic rhinitis is caused by *Bordetella brochiseptica*) (bacterial infection). More lately, the prevalent causes of AR have been recognized as type D and type A *Pasteurella multocida*, particularly those producing Type D and A toxin. Other causes of this inflammation are acknowledged as bacteria, chemicals (manure gas), dust, pollen, temperature changes, and other irritants to the environment, and may adversely affect feed conversion effectiveness and pig gain rate (Lawhorn, 2008). Atrophic rhinitis is characterized by sneezing, pig with a crooked, bleeding nose and tear-stained face. Atrophic rhinitis symptoms are noticeable and can be readily recognized. Rhinitis sicca, dry rhinitis, ozena, open nose syndrome, and empty nose syndrome are frequently connected with atrophic rhinitis. Epistaxis and shortening or lateral deviation of the snout may occur in serious instances (Turnquist, 1995). In instances where the snout has been shortened, the snout skin may be wrinkled.

It is essential to remember that it is neither cost-effective nor realistic to eliminate or prevent anyatrophy and/or AR turbinates in a commercial herd. However, antibacterial were used individually or together in feed or water, antibiotic injections, vaccination, and environmental modification to manage the clinical signs of AR. Another prominent control of AR is vaccination. According to Lawhorn (2008), vaccines containing *B. bronchioseptica*, *P. multocida* type D and type A, plus toxoids to *P. multocida* type D toxin or *P. multocida* types D and A toxin may be used. Nasal irrigation is once again recognized as one of the medicines most commonly used to treat the disease. This can be used for healing purposes or as maintenance therapy. Irrigation is used to avoid comprehensive crusting of the hallmark. Irrigation often has to be done numerous times in a day to accomplish this outcome (Cowan, 2005).

Rhinitis, AR, and/or turbinate atrophy vary economically. Pigs or feeder pigs lose business or get reduced prices when pigs have AR snouts crooked or shortened. The author points out that moderate to severe turbinate atrophy can result in an increased number of days for the hog to reach market weight (from several days to several weeks). The efficacy of transformation of feed in the affected pigs also varies. Efficiency in feed conversion tends to worsen as the degree of severity increases. Atrophic rhinitis animals are not discriminated against in slaughter costs, but in terms of feed conversion efficiency and pig growth efficiency, any economic loss has already occurred (Lawhorn, 2008).

2.6.2 African Swine Fever

African swine fever is one of the most complicated and economically destructive viral diseases in swine herds, with a significant socio-economic effect in the nations affected. It is a significant disease that affects all breeds and ages, both domestic and wild pigs. ASF was first describe in Kenya in 1921 (Sánchez-Vizcaíno et al. 2012). Subsequent reports indicate that many African, European and American nations have been affected by the disease. It is currently prevalent in much of Sub-Saharan Africa, Russia, and Sardinia, with sporadic outbreaks occurring in the rest of the world (Backlund, 2013). According to OIE (2009), African swine fever is a highly contagious disease among household pigs and has a high mortality rate of around 100%.

African swine fever is caused by African swine fever virus (ASFV). The African swine fever virus (ASFV) is a large, enveloped DNA virus that belongs to the genus *Asfivirus* and family *Asfarviridae* (Salas and Andrés, 2012). ASFV is its only genus member and the only known arbovirus of DNA (Pagani and Rijks, 2017). The natural hosts of ASFV are African wild pigs; however, wild boars and domestic pigs of all breeds and ages are also susceptible to the infection by ASFV. Domestic swine infection can be implicated in several types of illness, ranging from extremely lethal (up to 100%) to subclinical) (depending on viral and host variables).

Research into the disease indicates that ASF can be transferred between household and intake of infected meat products by wild boars or by direct contact with infectious excretions and secretions (Costard *et al*., 2013: Sargsyan1 *et al*., 2018). It is also noted that ASF can be transmitted through ticks that act as vectors that spread the disease from one species to another. According to Institute for International Cooperation in Animal Biologics (IICAB, 2015), this virus can become endemic in wild suids and can complicate or even stop eradication in transmission cycles between these livestock and Ornithodoros ticks.

Studies indicate that sudden fatalities with few lesions may be the first indication of a herd infection (IICAB, 2015) in clinical signs of ASF disease. The infected animal exhibit signs of anorexia, elevated fever, lethargy, weakness, and recumbences in critical instances. It is possible to see the incidence of erythema and is most evident in white pigs. Some pigs, particularly on the ears, tail, reduced legs or hams, create cyanotic skin blotching. Diarrhoea, constipation and/or signs of abdominal pain may also occur in pigs; diarrhoea is originally mucoid and may later become aggravated.

Also noted were respiratory signs (including dyspnoea), nasal and connective discharges, and neurological signs. Pregnant pets often abort; the first signs of an epidemic may be abortions in some instances (IICAB, 2015).

ASF is not treated, and all efforts to create a vaccine have so far failed. Strategies for controlling the disease were to kill all infected animals in Ghana and other areas of Africa in order to contain the disease. In infected nations or territories, control of disease is mainly through rigorous application of measures for bio-security (Pagani and Rijks, 2017). Other control measures suggested include separation of domestic pigs and wild suids, and appropriate disposal of carcasses and offal hunted and domestic livestock (Beltrán-Alcrudo *et al.*, 2008). Farmers can also guarantee that household pigs and wild suids do not have direct contact. For instance, pig producers whose premises are surrounded by a pig-proof double fencing barrier and who enforce bio-safety measures have not encountered ASF for over 60 years in endemic areas of South Africa (Pagani and Rijks, 2017).

The origin of African swine fever is traced back to Africa where the disease was first recognized as an entity distinct from classical swine fever introduced in Kenya in the 1920s when foreign explorers brought domestic pigs to the nation. The incidence of the disease in other areas of West Africa was later recorded. In 1973 and early 1990s, sporadic occurrence of the illness was recorded in Nigeria, causing 100% mortality. Soon after the disease was recorded in Senegal in 1978 and retrospective studies in Casamance and Guinea Bissau indicated the presence of ASF (Babalobi *et al.*, 2007). Further outbreaks appeared in Cameroon in the mid-and late-1980s. In 1996, other studies confirmed the resurgence of the disease in Côte d'Ivoire, while in 1997, it occurred in Togo and Benin**.** The African continent's economic evaluation and evaluation of the ASF epidemic was very catastrophic. In 1999, the occurrence of ASF in Ghana led to the obligatory killing of more than 200,000 pigs to contain the outbreak of ASF in greater Accra and Central regions where 700 pigs were initially killed following the outbreak of October 1999. (Babalobi *et al.*, 2007).

2.6.3 Swine Dysentery

Swine dysentery is one of the most frequent infectious diseases affecting the pig digestive tract. Swine Dysentery has long been acknowledged worldwide as a significant pig disease and can be seen in all kinds of pig-keeping activities (White, 2018). *Brachyspira hyodysenteriae* is a renowned bacterial disease triggered by swine dysentery. The bacterial is usually present in manure and occurs when an infected manure is ingested by a healthy pig. According to Bishopton Veterinary Group (BVG, 2014), humans cannot be infected with the bacterium of Swine Dysentery, but can spread through contaminated shoes, as a whole, and machinery. Rodents and birds can carry it as well. The disease usually spread slowly but steadily in a barn where there are big numbers of pigs raised together (Radostits, 2012).

Bloody diarrhoea and dehydration are common clinical indications of the disease. The disease runs over a number of days, with rectal temperatures initially rising to 41°C, but this will drop over a few days (White, 2018). Manure (stool or faeces) becomes smooth, sometimes jelly-like, and its colour differs from a grey cement in mild instances to a bright red in serious instances where the large intestine is haemorrhaged (Radostits, 2012). Death may occur soon or later. Treatment of swine dysentery can be accomplished by administering suggested drugs. Radostits (2012) reported that arsanilic acid in drinking water has been the preferred therapy for swine dysentery for 6 days. Arsanilic acid will not be efficient in some instances and may require additional particular antibiotics such as tyrosine (Radostits, 2012).

2.6.4 Mastitis

Mastitis in sow is often associated with inflammation in the udder after farrowing leading to failure in milk production. The infected glands show typical signs of inflammation, such as severe oedema and skin congestion. It is a complex disease of financial significance in sows that impacts the piglets ' health, welfare, and efficiency. Martin *et al.* (1990) describe mastitis as a syndrome of disease that leads to death of baby pigs by starvation and increased susceptibility to other new-born deadly illnesses. This inflammation is often caused by various microorganisms, most frequently bacterial infection. Mastitis-induced bacteria are mostly coliforms.

Attempts to classify the broad range of clinical syndromes that affect the periportally diagnosed mammary gland of the sow, but no classification has been commonly accepted (Gerjets and Kemper, 2009). However, classifications were based on the amount of impacted organs, including uni-glandular or multi-glandular mastitis, or mastitis was split into acute and chronic mastitis (Waldmann*et al.*, 2001) in terms of length and state of inflammation.

Mastitis symptoms can differ. Fever exceeding 39.5 ° C is often the first symptom of mastitis (Scuka *et al.*, 2006). The sow may lactate usually during the first few hours after parturition, but later the teats may only contain a few drops of or no milk (Scuka *et al*., 2006). There are no noticeable changes in the milk, udder or overall condition of the animal in subclinical mastitis. Instead, milk laboratory assessment is used to diagnose it (Björk, 2013). The sows have apathy, they generally lie on the stomach, and constipation affects them. Coliform mastitis is distributed globally. An average incidence is 12.8% postpartum agalactia, with a difference from 0.5 to 50% between individual herds (Hermansson *et al.*, 1987). Milk production is changed and piglet development may be insufficient when many glands are impacted. It was noted that piglets from mastitis sows had a reduced weight, but the distinction was not substantial (Ross *et al*., 1975). It is not always evident in many research on the significance of mastitis as a pathological entity whether the sows were chosen for the existence of mastitis or because the litter had delayed development and elevated mortality (Ross *et al*., 1975; Ross *et al*., 1981). Piglet mortality may lead from prolonged farrowing moment, sowing crushing, starvation and impaired immunity to infectious agents due to inadequate immunoglobulin intake of colostrum (Bertschinger, 1999).

2.6.5 Coccidiosis

Coccidiosis happens in adult swine from time to time. Coccidiosis is the condition induced by organisms of coccidia. Coccidiosis is generally introduced to the herd without any indications through the incoming inventory. Coccidia may infect pigs with no discernible disease or clinical impact (Radostits and Senior, 2012). First mentioned in 1934, coccidiosis was not regarded significant because most infections were not associated with any illness. The emergence of constant farrowing in confinement circumstances in the 1970s resulted in real disease occurring and being acknowledged as both prevalent and serious. Coccidia in suckling pigs are powerful and primary pathogens. Several species in elderly pigs were also associated with serious enteritis outbreaks. The severity of the disease is immediately linked to the ingested dose of the offending organism. Baby pig diarrhoea connected with coccidian's accounts for 10 to 36% of instances of baby pig diarrhoea from the South-eastern states and parts of the Midwest (Radostits and Senior, 2012).

In suckling piglets, this illness is very prevalent and is caused by three kinds of intracellular coccidian parasite. It creates diarrhoea, often between the ages of 10 and 21 and up to 15 weeks of age, which can be bloody. Fluid therapy and coccidiostats are used to treat acute situations. Secondary infections can be caused by wall harm. Preventive treatment of sows with coccidiostats may be suitable depending on the rate of incidence on the farm. To end the cycle of infection, hygiene should be enhanced; sow faeces are a significant cause and infection can spread by flies. It will assist to decrease the parasite load and the probability of coccidial infection by providing a hot, dry, clean creep region.

2.7 Ethno-veterinary Concept

The introduction of organic farming in advanced nations is pushing for more environmentally friendly and humane techniques of animal husbandry, which provides much hope for the use of traditional knowledge and ethno-method medicine in Africa (Adedeji *et al.*, 2012). This knowledge may originate either from scientific or traditional sources (Santos García-Alvarado *et al.*, 2001). Over time, ethno-method medicinal practice and abilities have evolved primarily through trial and error, and sometimes through experimentation and innovation (Viegi *et al*., 2003). Worldwide, traditional medicine depends heavily on locally available plant species and plant-based products and capitalizes on traditional knowledge-repository (Awas and Demissew, 2009). Ethno-veterinary medicine relates to the understanding, abilities, techniques, procedures and values of the people regarding the care of their livestock (McCorkle, 1986). Cultural acceptability, economic affordability and efficacy against certain diseases could be attributed to extensive use of traditional medicine compared to modern drugs (Vijayakumar *et al*., 2015). As such, most smallholders have embraced this technique of disease control in their animal husbandry for efficient therapy.

Due to its apparent significance, studies on the use of traditional medicine for the therapy of diseases in the livestock industry have been extensively reported. Plant components used to treat different ailments by most traditional animal manufacturers were primarily leaves, fruits, tubers and seeds. According to Williams (1990), *Elaeis guineensis* oil is used among all Ghana poultry species to heal fowl pox. The use of *Agave americana* leaves with Capsicum spp fruits and roots for the therapy of Newcastle disease was recorded by Technical Centre for Agriculture (CTA, 1996). A combination of *Colocasia esculenta* washed and grounded tuber added to 2 litres of water and sieved can be used to relieve cough, colds and pneumonia in Chickens, according to CTA (1996). Broken *Adansonia digitata* fruit brought into poultry potable water is used in all poultry to treat cholera (Nwude and Ibrahim, 1980). Unfortunately, ethno veterinary documentation in the porcine sector is restricted.

2.8 Medicinal Plants

Plants have been empirically chosen and used as drugs for centuries in the history of all cultures as traditional preparations. Traditions of plant-collecting and plant-based drugs were handed down from generation to generation (Maydell, 1996) and for disease prevention and treatment males were completely dependent on medicinal herbs. Only in the 19th century did man start to isolate the active principal compounds of medicinal plants and the discovery of *Cinchona pubescens* bark quinine for the treatment of tuberculosis was a particular landmark (Phillipson, 2001). A series of natural products isolated from flowering plants became medicine before the Second World War and a number are still used today (*Cinchona pubescens* bark quinine, papaver latex morphine, *Digitalis lanata* leaves digoxin, Solanaceae species atropine, etc.) (Phillipson, 2001). In the post-war years, fresh drugs from flowering crops (*Taxus brevifolia* bark taxol, *Rauvolfia serpentine* roots reserpine as tranquillisers and *Catharanthus roseus* vinblastine for cancer chemotherapy) were discovered. Despite these results, the impact of phytochemistry on new drug development has diminished and the pharmaceutical industry has started to concentrate its research on synthetic chemicals. At the end of the 1980s, with the renewed interest of Western countries in herbal remedies and th increasingly urgent need to produce new, effective drugs, pharmaceutical and scientific societies focused on traditionally used medicinal plants (Taylor *et al*., 2001). This attention has been much more essential and urgent in Africa as it is well known that the transfer of oral information is prone to disruption and may lead to the loss of valuable ethno-medical information (Fyhrquist, 2007). Moreover, owing to the rapid loss of natural habitats and thus the loss of medicinal preparation ingredients, traditional medicinal plants and remedies are becoming increasingly vital (Iwu. 1993). Of the 250,000 flowering plant species, there was no detailed examination of the majority for their pharmacological features (Phillipson, 1997). It is difficult to estimate the exact quantity of plants at the origin of medicinal medicines. An evaluation of plant-derived products used in prescription drugs found that only 40 flowering plant species are used as sources of medicines (Farnsworth *et al*., 1986; van Seters, 1995). By 1996, the National Cancer Institute (NCI) collected more than 45,000 plant samples and extracted more than 40,000 to produce more than 87,000 organic solvents and aqueous extracts (Cragg *et al*., 1996).

More than 36,000 samples were tested in the anti-AIDS test and about 10% of some in vitro activity was shown (Cragg *et al*., 1996). Despite these developments, the rising cost of Western medicine means persons will depend on their traditional medicine in African countries. Eighty percent of individuals in developing nations continue to depend for primary health care on traditional healers (medicinal practitioners) and local medicinal plants (WHO, 1995). Some 35,000 to 70,000 plant species are estimated to be used in traditional medicine systems (Farnsworth *et al*., 1991). Natural products and plant-derived products, particularly those with traditional medicinal uses that have not yet been chemically analysed, stay excellent sources of new drug candidates. Rural communities harvest mostly for their own health care in wild medicinal plants, but this wild harvest was not detrimental to the survival of crops as the quantity collected tended to be small and most of the material collected came from the more common varieties. This is not true for companies on the pharmaceutical, phyto-pharmaceutical and local market that need an increasing amount of specific medicinal plants. It is essential to remember that approval of a clinical development agent may require 5 to 200 kg of dried plant material at the National Cancer Institute (NCI), preferably from the original collection site. NCI performs surveys to determine the abundance and distribution of the plant and the variation in drug content with harvest season to achieve such large collections (Cragg *et al*., 1996). For example, the NCI used no less than 3.25 tons of bark in taxol biological tests between 1977 and 1987 (Chevassus-au-Louis, 2000). This sort of inquiry may result in the danger of the wild gene pool being over-harvested and depleted. Knowing that many pharmaceutical companies around the globe have study programs that investigate plants for their biological activities in search of fresh drug entities (Phillipson, 1997), we should be aware of the impact of new drug research on forest ecosystems around the globe. Furthermore, there is huge demand for medicinal plants, domestic use and trade, leading to huge local, national and international trade (Hamilton, 1992; Lange 2006). It seems clear that increasing trade in natural products in medicinal plants is causing an increasing number of harvested crops primarily from the wild (Hamilton 1992; Kuipers, 1995; Lange, 2002). Given the growing pressure on the resources of medicinal plants, sustainable management of harvesting of medicinal plants is the key problem in avoiding over-exploitation leading to species extinction.

2.8.1 Ecological effect of medicinal plant harvesting.

Medicinal tree species harvesting has a variable effect depending on the parts harvested. For example, harvesting flowers, fruits and leaves has a significant impact on population regeneration and viability (Endress *et al*., 2004; Siebert, 2004; Gaoue and Ticktin, 2008). Tree survival, however, is more damaging to bark or roots cultivation (Davenport, 2002; Geldenhuys, 2004; Vermeulen, 2006; Geldenhuys, 2007;

Vermeulen, 2009). Moreover, most medicinal crops are gathered for more than one purpose (Shackleton *et al*., 2002). As suggested by Ticktin (2005), sustainable management of medicinal forests requires to understand how different species respond to different harvesting techniques. Sustainable management of species of medicinal tree is complex for two main purposes. First, the exploitation of these species has a variable effect on the plants themselves, depending on the parts harvested. Flowers and fruit harvesting, for instance, have a significant impact on species regeneration and on populations ' viability and survival (Endress *et al*., 2004; Gaoue and Ticktin, 2008). On the other hand, harvesting bark or root is more damaging in terms of tree survival (Davenport and Ndangalasi, 2002; Geldenhuys, 2004; Vermeulen, 2006). Second, most medicinal plants are multipurpose species: separate collector kinds are interested in the same species for different end uses (Shackleton *et al*., 2002). More usually, sustainability of perennial medicinal products requires knowledge of how individual trees belonging to different species can respond to different harvesting techniques (Geldenhuys, 2004). The same applies to Non-Timber Forest Product Trees (NTFPs) behavior during improved and continuous harvesting (Ticktin, 2005). In addition to being a source of medicinal properties, chemical substances such as medicinal plant trees may also have other uses, and the risk of over-harvesting may also be at least partly due to collection for purposes other than medicinal (Hamilton, 2004).

The need to identify suitable conservation strategies and to create and encourage sustainable harvesting of medicinal tree species through the use of improved harvesting techniques, but also through the domestication and cultivation of the best accessions and their incorporation into present livelihoods is constantly increasing.

2.8.2 African peach (Sarcocephalus latifolius)

Approximately 80% of the world's population relies as their main health care source on herbal preparations (Kusara, 2014). It is estimated that around the globe some 20,000 higher plant species will be used medicinally (Tagboto and Townson, 2001). Millions of Africans use these herbal preparations to base their main health care (McCaleb, 2000). Plants have given the foundation for traditional therapy of different kinds of diseases and are still providing an enormous potential source of fresh chemotherapy agents. Only after botanically recorded or scientifically proven biological activity (Elujoba, 1995) will a plant become a medicinal plant. Plants and their derivative products have also been a real source of food for humans and livestock from the beginning (Ogbonnia *et al*., 2011). *Sarcocephalus (Sm.) latifolius* is a hedge or tiny tree living in humid areas through Africa's tropical and southern regions (Arbonnier, 2009). The *Rubiaceae* are owned by *Sarcocephalus latifolius* (syn. *Nauclea latifolia* Sm.) or Afrikaan Negro peach. The plant's branches are flexible and drooping. The leaves (10–22 or 7–15 cm) are opposite to the touch, green, shiny and greasy. Many flowers make up its ball-like inflorescence. The fruit is red or maroon with a lot of alveoli, smelling like strawberries (Arbonnier, 2009). It is an irregularly balloony berry with a diameter of 3–8 cm and thousands of minutes of seeds in a purple flesh (Stangeland *et al*., 2007). This species has medicinal uses that in the traditional pharmacopoeia are much more known in sub-Saharan Africa (Badia-ga, 2011). Research has shown that *S. latifolius* has certain medicinal properties (Amos *et al*., 2005; Badiaga, 2011, Iwueke and Nwodo, 2008; Yesufu *et al*., 2010; Yinu-sa *et al*., 2012). Some studies also have documented its organs' phytochemical screening (Badiaga, 2011, Yinusa *et al*., 2012). It is used to treat certain significant illnesses like diabetes (Karou *et al.*, 2011), AIDS (Lam-orde *et al.*, 2010), and malaria (Benoit-Vical *et al*., 2011). In Burkina Faso's plant biodiversity, *S. latifolius* is one of the species most commonly known and used by local populations in some regions (Belem *et al.*, 2007). However, there has been no previous ethnobotanical study of this species among local traditional communities in the south-western region of Burkina Faso.

2.8.2.1 Origin and Distribution

Nauclea latifolia (*N. latifolia*) is originally from Africa and Asia (Gidado *et al.,* 2005). It is widely distributed throughout the woodlands and tropical forests of Benin, Burkina Faso, Cameroon, the Democratic Republic of Congo, Ghana and Nigeria (Lamidi *et al*., 1993)**.** *Nauclea latifolia* is prevalent in Tropical and Southern Africa including Senegal, Cameroon, Nigeria and Sudan, (Michel, 2004). It was discovered in Nigeria in regions such as Kontagora, Abuja, Shaki, Akwa Ibom, Cross River, Enugu, Abakaliki and other states.

Its generic name is derived in relation to the flowers from the Greek words "sarco" (fleshy) and "cephalus" (headed). The specific epithet is derived from "lati" (wide) and "folius" (leaved) in Latin (Arbonnier, 2000**).** There are three other species linked to *N. latifolia* (*N. Pobagini*, *N. diderichii*, and *N. vanderguchtii*) which are forest trees. *N. Diderichii* is planted in Nigeria's Omo Forest Reserve. In traditional medicine, *N. diderichii* and *N. orientalis* are used in the same manner as *N. latifolia*. In sub-Saharan traditional medicinal systems, *N. latifolia* is used to treat a number of illnesses which suggest that they may be a natural source of pharmacologically active drugs (Karou *et al*., 2011).

2.8.2.2 Botanical Description

From a botanical perspective, there are three subfamilies of the Rubiaceae family (Rydin *et al*., 2009), which include 220 species of 28 genera of Cinchonoideae. It includes 17 genera of the Naucleeae tribe (Löfstrand *et al*., 2014). The spherical inflorescences and epigenous floral nectarines profoundly integrated in the hypanthia can readily distinguish this group from those of other species (Verellen *et al*., 2007). It includes the genus Nauclea whose range is limited to tropical areas in Africa and Asia. These trees have flattened terminal buds and ovate to elliptic, evergreen or sub persistent stipulations have been pressed. They're lustrous, green and nervous, opposite to their leaves. Hypanthia and fruitlets can be free or connate in a syncarp. Flowers include corolla and imbricated lobes of fusiform stigma. In-florescence consists of 2-local ovaries with Y-shaped placentas (linked to the upper third septum) or discoidal ovaries (linked to the septum centre). Usually, ovules are pendulous or spreading in all directions. Seeds are pitted ovoid to ellipsoidal (Löfstrand *et al.*, 2014; Ridsdale, 1978). It has many branches that vary with an open canopy up to a height of 12 m. Flowers have spherical end heads like tiny whitish flowers cymes (Benoit-Vical *et al.*, 1998). The flowers, together with their calyces, are discovered. During July to September, the fruit is syncarp and ripens. The baboons, however, consume the fruits and scatter the seeds. Livestock are also recorded to consume shoots and leaves (Deeni and Hussain, 1991). In Africa, the genus Nauclea involves seven species that can be distinguished by a combination of criteria, such as their placentas, shape stipulations, and fruit type

(Ridsdale, 1975), shape of leaves, seed margin, length of petiole, pubescence of calyx and corolla, flower head diameter, pubescence of leaves (Ridsdale, 1978).

Nauclea latifolia Smith, *Nauclea pobeguinii* (Hua ex Pobég.) Merr. and *Nauclea diderrichii* (De Wild.) Merr. are seen as the most widely distributed in the areas extending from the centre to the west of tropical Africa whereas *Nauclea vanderguchtii* (De wild.) Petit. *Nauclea gilleti* (De Wild.) Merr. And *Nauclea xanthoxylon* (Chev.) Aubr. (Löfstrand *et al.*, 2014), appear to be far less common taxa. The exception is *N. nyasica* which occurs in Tanzania, Mozambique and Malawi

2.8.2.3 Importance of Sarcocephalus latifolius

Literature allusion has shown that *Sarcocephalus latifolius* can be found in most areas of the globe. *Sarcocephalus latifolius* develops luxuriously in the tropics throughout the seasons of the year. Nearly every portion of the *Sarcocephalus latifolius* plant is considered a helpful source of medicine or component of herbal medicine mixtures. In traditional healthcare delivery, there are many uses of the plant (Enemor *et al.*, 2013), including malaria, dysentery, fever, hypertension (Amos *et al.*, 2005; Abbah *et al.*, 2010; Ngo Bum *et al.*, 2009). *Sarcocephalus latifolius* leaves were associated with anti-diabetic impacts (Gidado *et al*., 2009); previous studies showed hypoglycaemic activity of *Sarcocephalus latifolius* **leaves** in diabetic rats caused by alloxane (Gidado *et al*., 2005). *Sarcocephalus latifolius* was also cited as helpful in the treatment of sleeping illness (Madubunyi, 1995) and hypertension (Akabue*et al.*, 1982**).** It is also used to treat rashes and filariasis (ASICUMPON, 2005). The plant may have been effectively implemented during pregnancy in Nigeria to regulate premature uterine contraction

(Duke, 2008). Another study reported a substantial reduction in uterus contraction in experimental animals caused by oxytocin and acetylcholine (Nworgu*et al*., 2010). Other medicinal properties of *Sarcocephalus latifolius* include its usefulness against stomach upset, measles, cough, cold, and overall body weakness (Gill, 1992). In circumstances like stacks, dysentery, colic, emetic and menstrual illnesses, the fruit is reported to be helpful. In Kano, Nigeria (Deeni and Hussain, 1991), the plant is used as a chewing stick and as a remedy for belly ache and tuberculosis. Parts of the plant are traditionally prescribed as a remedy for diabetes mellitus (Akabue and Mittal, 1982; Boye, 1990). For illness treatment, nearly every section of the plant is useful (Arbonnier, 2000), from the roots, followed by the stem, bark and leaves are the plant's most frequently used components.

2.8.2.4 Phytochemistry, Steroids and Saponins

Reference to the literature indicates that African Nauclea species' chemical composition has been discovered with the introduction of the β-sitosterol steroid and its palmitate ester as the first metabolites recognized from *N. diderrichii.* Several other triterpene derivatives have been discovered over the past few decades. A mixture of β-sitosterol fatty esters was reported in *N. diderrichii* (Adeoye *et al*., 1981) and β-sitosterol with two related glucosides were separated from the roots of *N. latifolia* (Abreu *et al*., 2001a; Ngnokam *et al*., 2003). However, quinovic acid derivatives are the most studied family of triterpene compounds in the genus. Quinovic acid itself was acquired from the Nauclea bark together with 11 glycosides (e.g. glucosyl, fucosyl, rhamnosyl and derivatives) and the 3-oxo analogue, were extracted from the bark of *N diderrichii*

(Lamidi *et al.*, 1997; Di Giorgio *et al.*, 2006). These saponins are not species-specific, they have also been described as assome compounds in *N. Zeches* (Mesia *et al*., 1985; 2010) and *N. Ngnokam* (Ata *et al*., 2003; 2009). Two additional triterpenes were recognized as rotundic acid and 3-acetoxy-11-oxo-urs-12-ene in the roots of *Nauclea* respectively as in *N latifolia* (Ngnokam *et al*., 2003) cum in the bark of *N. Pobeguinii* (Kuete *et al*., 2015). Nauclea latifolia also has the overall steroid precursor squalene, (Ngnokam *et al*., 2003).

2.8.2.5 Alkaloids

With the description of several nicotinate derivatives, terpenoids and β-carbolins in the N bark, the phytochemical studies of the genus Nauclea reached a turning point, (Mac Lean and Murray, 1970, 1972).

Interestingly, countless alkaloid derivatives were subsequently separated from these three classes of compounds as apparent biosynthetic adducts, particularly in N. Laphole, N. diderrichii and N. pobeguinii. Naucledine, desoxycordifolinic acid (MacLean and Murray, 1970; Murray et al., 1972; Adeoye and Waigh, 1983b), strictosidine, desoxycordifolin (N. pobeguinii; Xu et al.,2012) and 3α,5α-tetrahydrodesoxycordifolin (N. pobeguinii, N. latifolia and N. diderrichii;Lamidi et al., 1995c; Shigemori et al., 2003; Mesia et al., 2010) are five examples of β-carbolins modified by bio-synthetic seed. A number of reported indolo[2,3-a] quinolizidine compounds are the five-ring analogues of the β-carbo-lines mentioned above. Among them, there are about 14 different structures in a big sequence obtained from nauclefine. Apart from the naked nauclefine, the 20-vinyl analogue angustine were mined from the roots, stem bark, and N Latifolia leaves as well as the root bark of N. po-beguinii (Hotellier et al., 1975, 1979;

Zeches et al., 1985; Boumendjel et al., 2013). Several angustine derivatives were also discovered in Nauclea species: naucletine (*N. latifolia)*, angustoline (*N. latifolia* and N. po-beguinii); (Hotellier *et al*., 1975; Zeches *et al*., 1985; Abreu and Pereira, 1998b; Agomuoh *et al*., 2013), 19-O-methylangustoline (N. po-beguinii;Mesia *et al*., 2010), 19-O-ethylangustoline (*N. latifolia*;Abreu and Pereira, 1998b)

2.8.2.6 Phenolic Compounds

Six phenolic derivatives were isolated from the three main African species Nauclea: antiarol (*N. diderrichii*; MacLean and Murray, 1972b), kelampayoside A (*N. pobeguinii*; Xu *et al*., 2012), p-coumaric acid, resveratrol, resveratrol (*N. pobeguinii*; Kuete *et al*., 2015) and scopoletin (*N. latifolia*; Abreu and Pereira, 2001b).

2.8.3 Pseudocedrela kotschyi

2.8.3.1 Botanical Description

Harms belongs to the family Maliaceae and consists of one species (Ahua *et al.*, 2007; Oliver-Bever, 1986; Salvina, 1989). *P. kotschyi* has numerous uses in traditional medicine, particularly bark, roots and leaves, making it an important source of ingredient for local medicine (Kassim *et al*., 2009). The bark is bitter and a dark-colored gum emanates (Lemmens, 2008). *P. kotschyi's* roots are frequently used as chewing sticks in West Africa and its extract has been shown to inhibit the in-vitro growth and development of the schizontal stage of *Plasmodium falciparium*, so that the root can provide affordable treatment for malaria (Kassim *et al*., 2009). Natural products such as flavonoids, terpenoids and tree-derived steroids have received considerable attention in recent years due to their diverse pharmacological features including antioxidant and hepatoprotective activity (DeFeudis *et al*., 2003). The quantity and quality of phytochemicals based on plants may differ from part to part. In fact, there is a lack of information on the distribution of biological activity in distinct plant fields primarily related to the difference in the distribution of active compounds (or active values) that are more prevalent in some plant fields than in others (Solomon *et al*., 2013). Successful determination of biologically active compounds from plant material is primarily dependent on the type of solvent used in the extraction method (Solomon *et al*., 2013).

2.8.3.2 Ethno Pharmacological Studies of *Pseudocedrela kotschyi*

A number of medicinal properties have been found in the fruits, leaves, stem-bark and roots of this plant. Infusions, decoctions or concoctions of various components of it are used as an abortionist and also in the management of numerous infections and illnesses such as abdominal irritation, abscesses, anaemia, arthritis, delayed child development**,** chicken pox, conjunctivitis, constipation, cough, diabetes, diarrhoea, dysentery, fever, overall weakness, gonorrhoea, headache, hepatitis B, infant umbilical pain, and others**.** The branches and leaves are used in the treatment of malaria and stomach aches in Ghana (Asase *et al*., 2005). It has also been used as ulcer cleaning and decoction (Hutchison and Dalziel, 1958; Oliver-Bever, 1986). The roots and leaves are used to treat rheumatism and dysentery as well as an occasional ingredient for arrow poison in Nigeria, (Oliver-Bever, 1986). Kotschyi is widely used as chewing pads for dental cleaning (Okunade and Adejumobi, 2007; Kassim *et al*., 2009). In the northern areas of Cote d'Ivoire, it discovered significance in the therapy of toothache and inner injury.

The plant root was discovered to be a potential source of antibacterial agents (Koné *et al*., 2004), which is also used to treat intestinal helminthiasis. It is reported that the stem and root barks contain essential oils that have small antiradical and antioxidant impacts (Boyom *et al*., 2004). The new leaves ' ethanol extract was assessed in rats for its antipyretic impacts (Akuodor *et al.,* 2013). In addition, it has been shown that the n-butanol fraction from the leaves' ethanol extract exhibits anti-nociceptive and anti-inflammatory operations in mice and rats respectively (Musa *et al*., 2005). It is also demonstrated that the plant's aqueous leaf extract reduces the onset and length of pentobarbitone-induced sleeping moment in rats. Depression or sedation time followed by sleep was also shown in the same research (Anuka *et al.,* 2005). Some writers have also documented the antimicrobial activity of various organic and aqueous leaf extracts, stem bark and roots (Asase *et al.*, 2008; Ayo *et al.,* 2010; Adeniyi *et al.,* 2010). Extracts of the plant were explored for their molluscicidal activity against *Lymnaea natalensis* Krauss (Kela *et al*., 1989) in relation to other crops traditionally used in Nigeria.

2.8.3.3 Non-medicinal Uses of *Pseudocedrela kotschyi*

The plant is grown for its decorative advantages in the horticultural industry. The bark finds use among others in the manufacture of construction products, carpentry, and fishing. Reports of leaves being used as food for humans as well as leaves for livestock are available (Burkhill, 2004).

2.8.3.4 Bioactivity-isolated Chemical Constituents of *Pseudocedrela kotschyi*

A bitter non-nitrogenic compound, pseudocedrelin, was separated from the bark of *Pseudocedrela kotschyi* and was found to cause piscidal activity (Oliver-Bever, 1986). It is shown that the leaves contain 3-O-rhamnosides of myricetin and quercetin, and 3-O-glucosides of the same aglycones responsible for antimicrobial activity (Asase *et al*., 2008). The roots have also proven to be a helpful source of antiprotozoa against *Leishmania donovani*, *Trypanosoma brucei*, *Trypanosoma cruzi*, and *Plasmodium falciparum* (Hay *et al.*, 2007). Also separated from wood oil were the 7-deacetoxy-7-oxogedunin, limonoids and pseudrelones A, B and C (Taylor, 1979; Niven and Taylor, 1988). Research into essential oils from plant stem and root barks generated mostly sesquiterpenoids. Cadinene was discovered to be the most abundant (31.3%) in the stem bark, while the root bark oil contained the majority of oxygenated sesquiterpenoids with cubebols, almost one-third of the product. It has been shown that these compounds play a part in the extracts ' antiradical and antioxidant impacts (Boyom *et al*., 2004).

2.8.3.5 Ecology of *Pseudocedrela kotschyi*

Pseudocedrela kotschyi derives well on heavy and poorly drained soils. It is mostly found in savanna woodland and woody vegetation up to 1200 m of altitude. The tree is very resistant to bushfires and survive over 50 years of annual fire, as shown in a long-term experiment in central Côte d'Ivoire. It has been noted in Uganda that in the rainy season there is often profuse regeneration, and it has been suggested that dry season fires enhance seed germination. On the other side, it has also been noted that the seed is destroyed by fire and that regeneration is restricted to root suckers in locations that are subject to frequent fire, Lemmens *et al*. (2008)

2.8.3.6 Propagation and Planting of *Pseudocedrela kotschyi*

According to Lemmens *et al*. (2008), the weight of 1000 seeds is around 230g, the viability of the plants is quickly reduced and should be seeded shortly after collection. The germination outcomes are improved by immersion in warm water and soaking for one night. The seeds can be stored in sealed containers in a cool place for up to 2 months. They are readily attacked by insects and when they are stored it is suggested that ash be added. Wind scatters the seeds (Lemmens *et al*., 2008). Seedlings have a lengthy taproot, which makes it hard to transplant. The plant grows root suckers, which allows it to spread relatively well, leading in trees clumps.

2.9 Microorganism History

Microorganisms are described as living things that are so tiny that they must be seen with a microscope. Microorganisms have existed over 3.8 billion years on earth and display the biggest genetic and metabolic diversity (Aerestrup *et al*., 2001). They are a key element of the biosphere and play a significant part in the ecosystem's maintenance and sustainability. They are thought to make up about 50% of living biomass (Hadault *et al*., 2001). It is also possible to group microorganisms, including bacteria, according to their oxygen requirements. Some develop only in the presence of oxygen (aerobes), while others develop only in the absence of oxygen (anaerobes). Some may develop with or without oxygen (facultative anaerobes). Antibiotics were found in the mid-19th century, causing infectious diseases created by microorganisms ravaged by humans and animals (Hadault *et al*., 2001). However, microorganism resistance to antibiotics began to occur shortly after the first antibiotic (Byarugaba *et al.,* 2005**).** Recent studies have shown that microorganisms can transmit resistance genes using a technique known as conjugation. Bacterial cells transmit genetic information through direct cell contact through hollow pipes called pili (Brunsima *et al.*, 2003; Depardieu *et al*., 2007) in conjugation.

2.9.1 Fastidious and Non-Fastidious Microorganisms

Fastidious microorganisms are microorganisms with a complex requirement for nutrition. That is, when specific nutrients are included in a diet that fastidious organisms will grow. On agar plates, they show a slow growth. It also takes more time for them to multiply. Examples of fastidious microorganisms are *Neisseria gonorrhoea*, Campylobacter species, Lactobacillus species, Helicobacter, and haemolytic Streptococci (Wikipedia, 2018; Todar, 2009).

Non-fastidious microorganisms are microorganisms which grow rapidly without unique nutritional supplements or circumstances in agar plates. They can quickly develop and reproduce. In reality, unlike fastidious microorganisms, they can synthesize all the organic molecules necessary for their development. Under normal atmospheric conditions, they can also grow. The non-fastidious microorganisms are staphylococcus and streptococcus (Wikipedia, 2018; Todar, 2009).

Antimicrobial agents have been widely used in livestock and poultry production as early as the 1950s. Since that time, food animal production has increasingly included larger farms and greater animal densities, requiring a greater need for disease management. Health management improvement in contemporary livestock production has been partly ascribed to the introduction of anti-microbial agents (Mathew *et al*., 2007).

Antibiotics are used in livestock production for purposes such as therapeutic use, for the treatment of sick animals; metaphylaxis or short-term medication, for the treatment of diseased animals and the prevention of infection in other animals; prophylaxis, for the prevention of infections in times of risk such as transportation or sewage; and growth to improve the use and production of feed (Viola and DeVincent, 2006; McEwen and Fedorka-Cray, 2002; Mathew *et al*., 2001).

Antibiotics based on feed continuously benefit production, enhance farmers' capacity to retain profitable margins, reduce the impacts of animal waste on the environment and reduce carriage of pathogens (Mathew *et al*., 2001). Disease causing organisms and diagnosis of infection are very important health constraints, especially the fastidious organisms which are very difficult to culture in the laboratory (Ahmed *et al.*, 2019). Studies have demonstrated a link between antibiotic use in swine and increase incidence of resistant bacteria (Mathew *et al.*, 2001; Mathew *et al*., 2005). While such studies have shown significant increases of resistance in the gut flora following use of antibiotics, it has also been shown that rapid reversion to susceptibility in commensal microflora following drug withdrawal may also occur, depending upon drug type, (Mathew *et al*., 2005).

Studies with the aminoglycoside drug apramycin have shown that the general population of faecal *E. coli* demonstrate an increase in apramycin resistance soon after initiating use of that antibiotic; however, this increase is followed by a return to more normal susceptibility when the drug is withdrawn (Mathew *et al*., 2002; Mathew *et al*., 2005).

According to Burch (2005), there is high level of resistance of fastidious organism's especially *E. coli* which is resistant to tetracycline and trimethoprim/sulphonamide combinations. Of great important of fastidious organisms is the *E. coli* which usually affect young suckling pigs especially (neonatal scours) and in particular the weaned pigs at about 28 days of age. *E. coli* affect adult pigs especially sows at the time of farrowing causing Mastitis-metritis-agalactia (MMA) syndrome and may also be associated with vulva discharge and infertility.

Burch (2005) reported that, pig herds impacted by multi-systemic waste syndrome (PMWS) post-weaning had an increase in diarrhoea and respiratory disease due to mixed infections and systemic infections caused by *Streptococcus suis* and *Haemophilus parasuits.*

Studies have shown that the use of antibiotics in livestock production improves the incidence of resistant bacteria (Mathew *et al*., 1999; Mathew *et al.*, 2001), but few surveys have, in the lack of antibiotic use, described the prevalence of resistant organisms on farm.

2.9.2 Antibiotics

The term antibiotic comes from the Greek words anti (against) and bios (life) and basically means a substance which kills any living creature (Russell, 2004). According to Gracey *et al.* (1999), antibiotics are chemical compounds that are synthesized in whole or in part by particular microorganism types, generally a fungus or bacterium; capable of inhibiting the development or murder of another microorganism. Penicillin was the first antibiotic to be discovered in September 1928 by an English bacteriologist, late Sir Alexander Fleming, who accidentally obtained the antibiotic from a soil inhabiting the *Penicillium notatum* fungus, but was first discovered in 1929 (Aminov, 2010) and first clinical trials in 1940 (Russell, 2004; Schlegel, 2003). Antibiotic use began soon after it was used to treat bacterial diseases in humans in the veterinary field. Treatment, avoidance and control of illnesses such as respiratory disorders, mastitis, gastrointestinal infections, tuberculosis and other invasive bacterial diseases were the primary use of antibiotics in livestock production (Draisci *et al.*, 2001). It can be categorized either as bactericidal (meaning they function by killing bacteria) or as bacteriostatic (meaning they function by preventing bacteria from multiplying) or as narrow spectrum (either Gram-positive or Gram-negative organisms) or wide spectrum (goal both) depending on the scope of effectiveness (Aminov, 2010).

There are many distinct types of antibiotics. The classification of antibiotics is focused on their chemical composition, mechanism or activity range (Calderon and Sabundayo, 2007). The primary types of bacteria are:

- Aminoglycosides
- Cephalosporin

- Fluoroquinolones
- Macrolides
- Penicillin
- Tetracyclines
- Quinolones

2.9.2.1 Aminoglycosides

First isolated in 1943, Streptomycin, was the first drug to be found among participants of this category of antibiotics (Mahajan and Balachandran, 2012). However, its efficacy against a broad range of diseases has been discovered to be extremely toxic, leading to the finding of others like gentamicin, neomycin, tobramycin and amikacin (Gilbert, 2000). These antibiotics are produced of different streptomycin species. They are used to cure gram-negative bacteria diseases. Aminoglycosides work by obstructing the bacteria protein synthesis that is vital to the bacteria's development. Their intervention centres are the digestive tract and are therefore efficient in the fight against enteric diseases. Examples of aminoglycosides include spectinomycin, streptomycin, gentamicin, kanamycin and neomycin (Calderon and Sabundayo, 2007; Jacob, 2015).

2.9.2.2 Cephalosporin

Cephalosporin is a category of antimicrobials used in gram-negative and gram-positive bacteria to manage insect diseases (Pegler and Healy, 2007). Members of this antibiotic community are comparable in composition and method of operation to penicillin. In accordance with their destination organism and antimicrobial characteristics, they are split into decades (1st-5th) with each batch getting a wider spectrum of operation than before (Talaro and Chess, 2008). First launched in 1945 as natural product derivatives, the first batch was launched to interrupt the cell wall by stopping peptidoglycan synthesis, triggering bacterial lysis (Butler and Buss, 2006). One of the most commonly used subclasses of medicines is cefotaxime, ceftazidime, and ceftriaxone. This category of antibiotics is given specifically to handle hospital-acquired infections to eradicate Enterobacteria-caused diseases, for example. *Escherichia coli* and *K. pneumoniae*. Cephalosporin interferes with bacteria's cell walls by disrupting the peptidoglycan layer structure of the bacterial cell wall. Examples include cefazolin (the first generation), cefoxitin (the second generation), ceftriaxone (the third generation), cefepime (the fourth generation) and ceftarolin (the fifth generation) (Calderon and Sabundayo, 2007; Anonymous, 2012a; Jacob, 2015).

2.9.2.3 Fluoroquinolones

These are antibiotics of synthesis and have a wide bactericidal impact on the spectrum. Furthermore, fluoroquinolones are split into first, second, third and fourth centuries with each generation getting a wider spectrum of operation than before (Anonymous, 2012a) and fifth generation growth is progressive (Guan *et al.*, 2013). By preventing them from creating DNA by inhibiting DNA gyrase, they stop bacteria from multiplying (Jacob, 2015). Examples are nalidixic acid, ciprofloxacin and gatifloxacin (first generation), and moxifloxacin (fourth generation). Fluoroquinolones have an effect on salmonellosis, colibacillosis and fowl cholera (Calderon and Sabundayo, 2007).

2.9.2.4 Macrolides

They can be produced from the organisms of Streptomyces. Streptomycin species source macrolides are bacteriostatic and work by interacting with 50S attachment of bacteria protein. Macrolides are efficient through reversible rhinotracheale against mycoplasma, pneumonia, *Haemophilus influenza*, and Orhnithobacterium and can be used to cure necrotic enteritis. Azithromycin, clarithromycin and erythromycin are examples (Calderon and Sabundayo, 2007; Jacob, 2015).

2.9.2.5 Penicillin

The first antibiotic, penicillin, first discovered and reported in 1929 by Alexander Fleming, was later found to be one of several other antibiotic compounds called penicillin (McGeer *et al*., 2001). Penicillin is the earliest antibiotics accessible; its bacterial action is linked to cell wall receptor suppression. Penicillin destroys bacteria by inhibiting bacterial cell membrane development prompting the collapse of the ceiling to discharge cell nutrients. Penicillin in poultry is efficient in treating sinusitis and chronic respiratory disease. Penicillin group members includes penicillin G, penicillin V, oxacillin (dicloxacillin), methicillin, nafcillin, ampicillin, amoxicillin, carbenicillin, piperacillin, mezlocillin, and ticarcillin.

2.9.2.6 Tetracyclines

Tetracycline was found by Benjamin Duggar from a Streptomyces species soil bacterium in 1945 (Sanchez *et al*., 2004). Antibiotics assigned to this category have been the envy of countless clinicians in the past because of their broad antimicrobial spectrum, but this is no longer the case because many bacteria are now able to resist them (Chopra, 2001). Most are obtained from species of Streptomyces and have wide bacteriostatic impacts on the spectrum. They stop multiplication of bacteria by preventing tRNA, while the immune system of the host animal functions with the initial infection. Tetracyclines work against mycoplasma, clostridium and certain protozoa (Calderon and Sabundayo, 2007; Anonymous, 2012a; Jacob, 2015).

2.9.2.7 Quinolones

The researchers engaged in the quest for antibacterial drugs first found this category of antibiotics as nalidixic acid (Andersson and MacGowan, 2003). During quinine growth in the mid-sixties, nalidixic acid was found as an impurity. They can disrupt with bacteria's replication of DNA and transcription.Two important classes of compounds were developed from the basic molecule, including cinoxacin, norfloxacin, ofloxacin, ciproxacin, temafloxacin, sparfloxacin, nalidixic acid, enoxacin and others (Domagala, 1994). It is known that changes in the basic structure of quinolones have increased their bioavailability and increased their operating spectrum and potency; enhanced their efficiency in treating multiple types of diseases such as urinary, pulmonary and pulmonary system diseases. However, there are still safety issues with certain representatives of this category of antibiotics that have resulted to the removal from the industry of grepafloxacin, sparfloxacin, temafloxacin, trovafloxacin and others, all of which belong to the category of quinolones (Domagala, 1994).

2.9.3 Antibiotics Mechanism

Bactericidal drugs cause cell death while bacteriostatic drugs behave as regulators of plant development (Kohanski *et al*., 2010). However, the antibiotic action system involves;

- tissue wall formation inhibition
- tissue membrane formation or tissue breakdown
- nucleic acid composition and cap inhibition
- Protein pathway inhibition
- Key cellular processes blockage

(Talaro and Chess, 2008; Madigan and Martinko, 2006).

2.9.4 Development of Microorganism Antibiotic Resistance

Microbes have known how to create antibiotic resistance in existence over a million year's earlier (Coates *et al*., 2002). Antibiotic inappropriate use may further boost the danger of antibiotic and prescription fragile microorganisms and the accessibility of over - the-counter antibiotics without prescription (Van der Meer and Gyssens, 2001). While there are growing worries about antibiotic resistance, there is proof that antibiotics are being recommended in circumstances where there is little proof of advantage to physicians and sometimes opposite to domestic guidelines (Smith *et al.*, 2004). Microorganisms may develop resistance to it if the same antibiotic is given over a long period of time. Human activities such as huge manufacturing and consumption of antibiotics in both medication, livestock husbandry and forestry are regarded as selective pressure on environmental genes for antibiotic opposition (Baquero *et al*., 2008; Allen *et al*., 2010).

Resistance emerges from the phrases "re" (against) and "sibling" (to resist) in Latin (Blomberg, 2007). The development of drug-resistant bacteria is a particular issue in the therapy of infectious diseases. Antibiotic resistance is a characteristic of microorganisms that were once susceptible to antibiotic contact (Ventola, 2015). It was anticipated that antimicrobial resistance would increase after the first use of vaccines (Silbergeld, 2008). Antibiotics are produced by agricultural bacteria and there was opposition to antibiotics shortly before the first antimicrobial substances were used by humans to heal infectious diseases. During this "pre-antibiotic era," antibiotic-producing and antibiotic-resistant bacteria coexisted in their ordinary habitats without allowing the technique of choice of deadly-resistant living pathogens to remain susceptible to most common drugs (Sengupta *et al*., 2013). Antibiotics are highly essential in medicine, but sadly, when microorganisms are subjected to the same antibiotics over and over, they can develop opposition to them. Microorganisms can change and the drug will not affect them anymore. Over moment, antibiotic-resistant species led to growing relative strain to invasive illness with related financial and safety cost increase and categorized strength in two types: strength intrinsic and strength acquired (Fluit *et al*. 2001).

Bacteria's natural capacity to withstand the intervention of a specific antibiotic drug through its intrinsic composition or functional features is intrinsic (Hooper, 2008). This type of opposition or features of specific bacterial species acts as the basis for antibiotic production (Russell and Chopra, 1990). According to Russell and Chopra (1990), this form of resistance, mainly due to certain microorganism characteristics, cannot be transferred from one microorganism to another, but only from microorganism to descendants.

This type of opposition happens when a microorganism that is vulnerable to a specific antibiotic agent develops the capacity to withstand that antibiotic attack (Hooper, 2008). Resistance is developed by mutating current DNA or acquiring fresh DNA through horizontal transfer of genes (Thomas and Nielsen, 2005). The more severe issue is acquired opposition because it can also be the source of several uncontrollable illnesses and epidemics. Bacteria obtain opposition through two processes. They are;

- Chromosome mutation (Birošovă, 2005) and
- Transfer of parallel or lateral genes (Bawah, 2014).

Mechanisms for antibiotic resistance in bacteria can be split into three wide classifications:

1) Enzymatic inactivation of the antimicrobial agent,
2) Replacement, amplification or alteration of the target of the drug to reduce the attraction of the drug to the target, or
3) Decreased entry to the goal by antimicrobial agents through permeability obstacles or efflux pump (Sundsfjord *et al*., 2004; Fluit *et al*., 2001).

2.10 Biosecurity of African Swine Fever

African Swine Fever Virus (ASFV) is not transferred over lengthy distances without human help, it can be avoided by rigorous biosecurity. This means applying laws not only to prevent ASF, but also other undesirable illnesses. These regulations include limiting access for individuals and cars to the region where the pigs are held, ensuring that employees and other vital visitors such as veterinarians are disinfected before entering the premises, preferably by offering them with protective clothing that does not leave the premises with them, and not feeding swill that may contain pork. Inadvertently, the last involves leftover feeding, so no human food should be permitted into the pig plant. In general, disinfectant foot baths are not extremely efficient in the destruction of the virus and should therefore not be used as the only precautionary measure, but should definitely be included in the farm's biosecurity plan (Penrith *et al*., 2009).

In village settings where pigs can roam freely, there are additional biosecurity challenges, although the same principle of biosecurity is presented. Equipment and premises should be cleaned and disinfected from time to time. Discourage the sharing of equipment between farms/villages, unless proper cleaning and disinfection is carried out. Pig owners/workers should avoid contacting other pig populations and strictly encouraging the use of dedicated working clothing and foot gear. Breeding stock replacement should come from trusted sources dealing with healthy animal trade. Casual visitors to the swine holding should not be allowed, especially those who have contact with pigs. Also recommended is a sign at the entrance of the farm / village advising visitors not to come close to pigs. Entrails and other parts discarded from slaughtered pigs should be disposed of appropriately, such as composting, burial, rendering or burning (EMPRES, 2008).

CHAPTER THREE

METHODOLOGY

3.1 Research Design

Descriptive research design, field and laboratory work was used in the study. The design is suitable as the research tries to determine and validate herbal medicine required in the study region to prevent ASF. In order to validate its efficacy, it will require collecting information from pig farmers and administering the herb (Luwine solution) to pigs.

3.2 Study Area

The Upper East region is situated in Ghana's north-eastern corner, exactly in the Dagbon Kingdom and lies between longitude 0 ° and 1 ° West and latitudes 10 ° 30 North and 11 ° North, Wikipedia (2019). The region shares boundaries with Burkina Faso northward, Togo eastward, the Upper West region westward, and the Northern Region southward. The Upper East region is divided into 15 districts, each headed by the district's head. The demographic centre of the Upper East Region is located in its capital of Bolgatanga. The population is predominantly rural (79%) and distributed through scattered villages. The rural population was 87.1% in 1984 and 84.3% in 2000. Thus, the rural population share reduced by 2.8%between 1984 and 2000 and by 5.3% between 2000 and 2010, Wikipedia (2019). The region is the least urbanized in Ghana, with only 21% of the population residing in metropolitan areas. In reality, together with Upper West, they are the two areas with less than 20% metropolitan inhabitants. Figure 1 shows the map of the Upper East Region of Ghana.

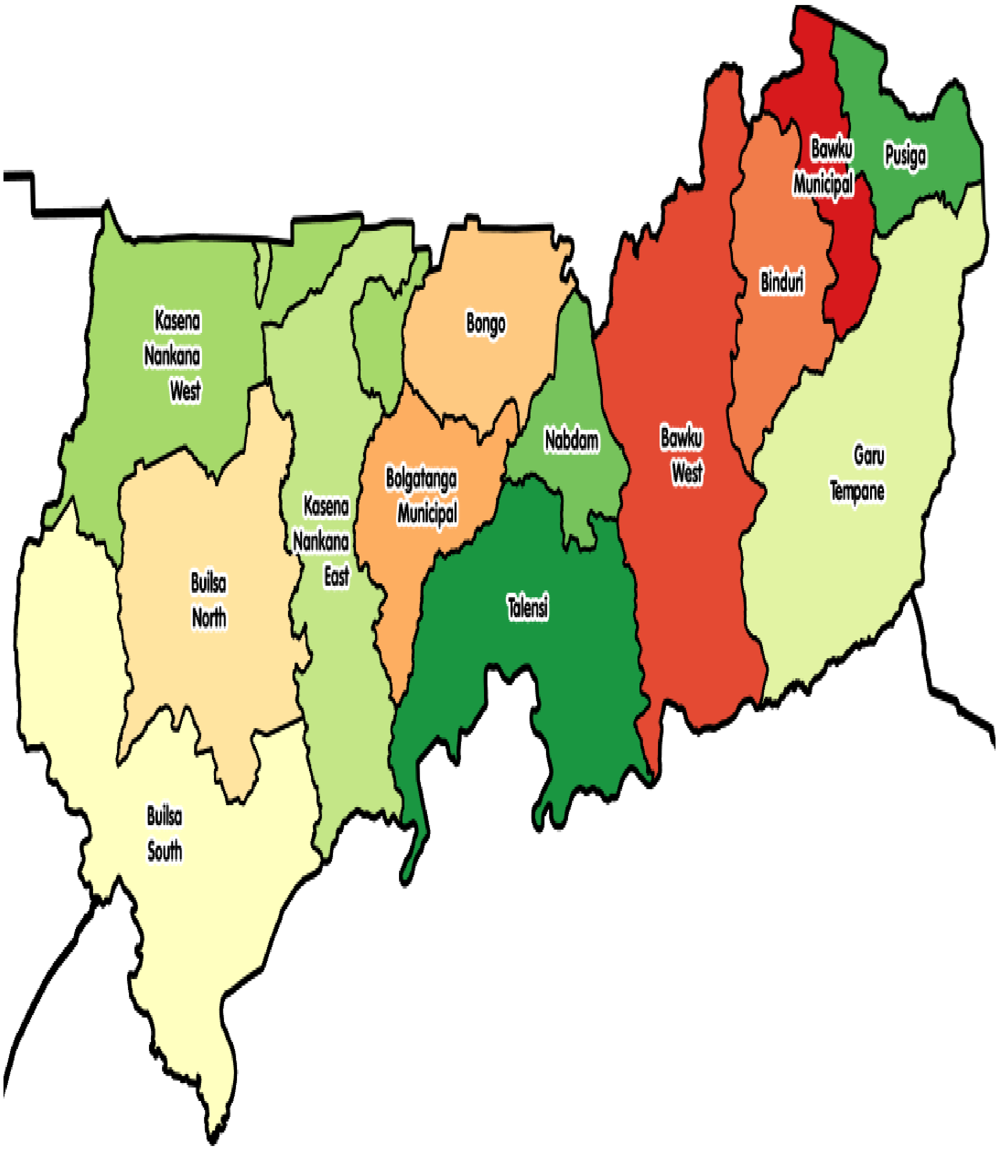

Figure 3.1: Map of Upper East Region

Source: Wikipedia (2019)

The Kassena Nankana East now upgraded to Kassena-Nankana Municipal (KNM) is one of the fifteen (15) districts and municipalities in Ghana's Upper East region. The political and administrative capital of the municipality is Navrongo. Its geographical coordinates are latitude 11° 10' and 10 ° 3' North and longitude 10 ° 1' West. The municipality is bordered by Kansena-Nankana West and Burkina Faso to the north, the

Kassena-Nankana West district and the Bolgatanga municipality to the east, the Builsa district to the west and the West Mamprusi district to the south. According to the 2010 population census, the population was 109,944 with 51.2% (56,268) women and 48.8% males (53,676) women (GSS, 2014).

Kassena Nankana Municipality's climatic circumstances are described by dry and humid seasons. In the municipality there are two primary kinds of soil, namely the Savannah ochrosols and laterite groundwater. The municipality falls within the forests of Guinea Savannah, distinguished primarily by vegetation kinds of the Sahel and Sudan-Savannah, consisting mainly of savannah with short trees and thumps. Typically, the municipality is agricultural with agriculture employing 66.7% of the total active population and the remaining 33.3% found in the services and commerce sector (GSS, 2014). Major crops include millet, sorghum, rice, groundnuts, cowpea, beans from bambara, okro, cotton, tomatoes, and onions. In the municipality there are cattle, sheep, goat, pigs, guinea fowls, fowls and other domestic animals like donkeys. Farm sizes are quite small, due in part to bad soil and unreliable precipitation, with very low returns compared to other areas of the nation.

The Kassena -Nankana West District Assembly (KNWDA) was created from the Kassena- Nankana East District Assembly in 2008. The KNWDA is situated in Upper East region and has its capital in Paga. The district is located between 10' 97''North latitude and 01' 10'' West longitude, (GSS, 2014). The district consists of 134 communities and has 1,004km^2 of total land area, (GSS, 2014). This suggests that the district is big and rural in nature and will require a lot of socio-economic infrastructure in terms of the district's geographic spread and newness.

The District is underlain mainly by Birrimian and Granitic rock formation. The relief of the District is generally low lying and undulating with isolated hills rising up to 300 meters in the Western. Notable among these hills are Fie, (9280 metres), Busono (350metres), and Zambao (360metres) and Atamolga. The district is mainly drained by the Sissili River and its tributaries. There are however some few dug-outs and dams which are used for livestock rearing, vegetable production and for domestic purposes.

Kassena-Nankana West District is part of the continental interior climate zone of the country defined by two seasons- dry and wet seasons. The two seasons are influenced by two oscillating air masses. First, the warm, dusty and dry harmattan air mass blowing across the entire district from the Sahara Desert in the north-eastern direction.

The rainfall is completely absent during its period of influence (late November–early March), the vapour pressure is very low (less than 10 mb) and the relative humidity rarely exceeds 20% during the day, but may increase to 60% at night and early morning, (GSS, 2014)

At this time of year, temperatures are generally modest, falling within tropical standards (26 ° C –28 ° C). The wet season takes place between May and October. During this era, a profound tropical sea air mass influences the entire Western African sub-region, including the Kassena-Nankana West District. Together with increasing standard currents, this air mass offers the neighbourhood with rain. The average total annual rainfall is 950 mm, GSS (2014). The above phenomenon adversely affects the water table, decreasing underground water that adversely affects boreholes drilling in the district. Water harvesting is proving to be a viable option.

The population of Bongo District is 84,545, representing 8.1% of the region's total inhabitants, with 52.4% females and 47.6%males, (GSS, 2014). Ninety-four percent of the inhabitants are in rural areas, (GSS, 2014). The neighbourhood population is young (42.7%), representing a broad base population structure that tapers with a comparatively small number of elderly individuals (9.7%) aged 60 and older and that of the District's complete age dependence ratio is 99.2, male age dependence ratio is greater (113.6) than female age dependence ratio (87.7), GSS (2014).

It was established in 1988 with Bongo as its capital by Legislative Instrument 1446 (LI 1446). The district ranges from lengths 0.45^o W to latitude 10.50^o N to 11.09 and has a complete land area of 459.5 km^2, GSS (2014). The Bongo District shares northward limits with Burkina Faso, westward Kassena-Nankana, south-westward Bolgatanga Municipal, and southeast Nabdam District. The district lies within the area freed from onchocerciasis.

The district's climate is comparable to that encountered elsewhere in the Upper East region. The average monthly temperature is about 21^oC (Ghana Statistical Service, 2014). Very high temperatures of up to 40^oC occur just before the start of the single rainy season in June and low temperatures of around 12^oC can be experienced when dehydrated Sahara winds dry up the vegetation in December, GSS (2014). During the dry season, ideal circumstances for bush fires develop, which has become an annual event in the region. The district has an average of about 70 days of rain in a year ranging from 600 mm to 1400 mm, GSS (2014). Within a short time, the rains drop strongly, flooding the fields and eroding soils into waterways. After the rainy season, however, the fields dry up (Ghana Statistical Service, 2014).

3.3 Population of the Research

The target population for the study included all household heads of pig farmers and pig farmers in the Kassena-Nankana municipality, Kassena-West and Bongo districts. For the list of pig farmers in each district, MOFA offices in the study fields provided data.

3.4 Sample Size and Sampling Techniques

For the research, a multi-stage (three-stage) sampling method was used. First, Kassena-Nankana Municipality, Kassena-Nankana West and Bongo Districts were deliberately chosen owing to the high rate of pig production in the districts. A random selection of large pig communities in the districts followed this. The pig farms were selected randomly from the communities for a fair representation of the entire district. A total of two hundred and seventy-three (273) pig farmers were selected for the study, comprising two hundred and twenty-eight males and forty-five females (Table 3.1).

Table 3.1: Sample size

REGION	DISTRICT	MALE	FEMALE	TOTAL
UPPER EAST	Kassena- Nankana municipal	64	19	83
	Bongo	35	11	46
	Kassena-Nankana West	129	15	144
TOTAL		228	45	**273**

3.5. Data Collection Methods and Tools

The primary data collected from the targeted respondents were data for the study. The study data was collected from the primary source through semi-structured questionnaire. The questionnaires covered a wide range of topics including demographic features, pig type reared, management practices, ASF and other strategies for disease management and extension services. Detailed information on contracting and managing ASF was also collected through personal interviews with farmers, guided by the study's goals.

3.5.1 Data Analysis

3.5.2 Probit Model

The research used the probit to evaluate factors affecting the contraction of ASF. According to Asante *et al*. (2011), the probit model has the capacity to limit the dependent variable (whether a farm agreement ASF or not) to be within 0 and 1, and its capacity to correct the heteroscedasticity issue. In estimating marginal impacts that determine the likelihood of a farm contracting ASF, the probit model was also chosen for its appropriateness. The dependent variable (Y) assumes two values: 1 if ASF is a farm agreement, 0 if not.

$$Y = 1 \; if \; a \; farm \; iexperienced \; ASF$$

$$Y = 0 \; if \; otherwise$$

The standard probit model is specified as;

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \varepsilon$$

Where;

Y = ASF contraction,

X_1= age,

X_2= educational level,

X_3= Number of years in pig farming,

X_4= type of pig farm,

X_5=income,

X_6= training on pig farming education level,

X_7=housing for pigs,

X_8=fore knowledge on ASF,

β_0= constant,

ε =error, and

β_1, β_2, β_3, β_4, β_5, β_6, β_7, β_8, are regression coefficients to be estimated.

Table 3.2: Measurement of Variables

	Variable	Description
1	ASF contraction	Whether a farm contracted ASF or not. This was coded 1 if a pig farm contracted ASF and 0 if a farm did not contract ASF prior to the study
2	Age	Age of pig farmers is measured in years and is expected to have a negative ASF contraction. Farmers tend to be less energetic and are less likely to put in measures to prevent the ASF attack on their farms. Age of farmers was categorized as 1 = 30 – 45, 2 = 46 – 60, 3 = 61 – 75, and 4 = 75 and above
3	Educational level	A pig farmer's highest level of education. Formal education offers helpful and systematic understanding necessary to manage pigs for disease prevention. This was coded using: 0= no formal education, 1= primary, 2= junior high, 3 = SHS and 4 = tertiary education
4	Experience	Number of years in pig farming or experience is expected to negatively influence ASF contraction. The experienced farmers are more informed about pig management and tend to put in measures that will prevent the contraction of ASF.
5	Type of pig farm	1 = Commercial and 2 = Subsistent
	Income	Income of pig farmers measured in Ghana cedis is also expected to have a negative relationship with ASF contraction. Farmers with

		higher income are able to adopt expensive strategies that curb the occurrence of ASF.
	Training on pig farming	Training received on pig farming was also coded 1 = Yes and 0 = No. Extension agents provide farmers with information on technologies and educate them on farm and disease management including ASF. It is expected that training received by pig farmers will enlighten them to take proper care of their farms to improve the welfare of farm animals.
	Housing for pigs	Housing for pigs keep them warm during cold weather and also prevent pigs from excessive heat. Again, housing protect pigs from infected animals and other intruders that may affect the animals. Housing for pigs was dummied, thus 1 = Yes and 0 = No
	Fore knowledge on ASF	Farmers with knowledge or farmers who have heard about the ASF and its consequences would put in measures to prevent its infection. Fore knowledge on ASF was also dummied, thus 1 = Yes and 0 = No

3.6 Experimental Sites

The plants (African peach, *Sarcocephalus latifolius* and African dry zone ceder, *Pseudocedrela kotschyi*) used for 'Luwine' preparation were obtained from Bongo Soe, Upper East Region, Ghana. 'Luwine' preparation was also done in Bongo Soe by a pig farmer. Antibiotic sensitivity testing was performed at the University for Development Studies' Spanish Laboratory, Nyankpala Campus, Ghana.

3.7 Preparation of 'Luwine'

The root of African peach (*Sarcocephalus latifolius*) weighing 0.38kg and dry bark peels of African dry zone ceder (*Pseudocedrela kotschyi*) weighing 2.32kg were boiled in 12 liters of water for 1 hr. After which, 0.17kg of salt was added and boiled for further 30 min. It was then allowed to cool and decanted into sterilized bottles for used. About 6.5 liters of 'Luwine' was obtained from the 12 liters of water after boiling, cooling and decanting. It was then stored in a refrigerator at 4^{o}C for further used.

3.8 Collection of Swab Samples

Sterilized swabs were used to swab the anus (n=3), mouth (n=3) and nose (n=4) of pigs infected with African swine fever. The swabs were transferred to the laboratory in an ice chest containing an ice block and analyzed immediately upon arrival at the Spanish Laboratory.

3.9 Antibiotic Discs and Impregnation of Blank Disc with 'Luwine'

The standard antibiotic discs used were amoxycillin/clavulanic acid 30µg (AMC), azithromycin 15µg (AZM), ceftriaxone 30ug (CRO), chloramphenicol 30ug (C), gentamicin10ug (CN), teicoplanin 30µg (TEC), tetracycline 30ug TE and suphamethoxazole/trimethoprim (SXT). Blank antibiotic discs were soaked in 'Luwine' for 5 min to allow impregnation of same with the herbal medicine.

3.10 Antibiotic Susceptibility Test for Fastidious and Non-Fastidious Bacteria

The antibiotic susceptibility test was done using a slightly modified method of Kirby-Bauer (1966). For the antibiotic susceptibility test for fastidious bacteria, the swabs were dipped in 10ml sterilized Trypticase Soy Broth (TSB) and spread plated on Müller Hinton Agar (MHA). Four antibiotic discs and a blank disc impregnated with 'Luwine' were placed on the MHA at a distance to stop inhibition areas from overlapping. The MHA sheets were incubated for 24 hours at 37^{o}C. With regards to antibiotic susceptibility test for fastidious bacteria, the swabs were dipped in sterile 10ml TSB and incubated at 37^{o}C for 18h. After incubation, it was adjusted to 0.5 McFarland turbidity using sterile TSB and spread plated on MHA. The MHA plates were also incubated at 37^{o}C for 24h.

After incubation of the MHA plates (for both fastidious and non-fastidious bacteria), the inhibition areas were evaluated and the outcomes interpreted by the Clinical Laboratory Standard Institute (2008) as susceptible, intermediate or resistant. The multiple antibiotic resistance (MAR) index was calculated and interpreted according to Krumperman (1983) using the formula: a/b, where 'a' is the amount of antibiotics resistant to a specific plant and 'b' the total number of antibiotics tested. All media and antibiotic discs used were procured from Oxoid Limited, Basingstoke, UK.

CHAPTER FOUR

PRESENTATION OF RESULTS

This section presents the outcomes of the field's information gathered. It detailed the demographic characteristics of respondents, breeds of pigs reared and information about pig rearing in the study areas.

4.1 Demographics Characteristics

4.1.1 Sex Distribution of Respondents

The analysis from (Table 4.1) revealed that female participation in pig rearing is less compared to their male counterparts in the study area. It was found out that pig rearing in the study area is dominated by males constituting 83.52% of the population whereas females constituted 16.48% of the population.

Table 4.1: Sex Distribution of Respondents

Sex	Frequency	Percentage
Male	228	83.52
Female	45	16.48
Total	273	100

4.1.2 The Respondents' Age

The age distribution of farmers in the study area is presented in figure 4.1 below. The result indicated that larger proportion of the respondents in the study area fall within the age group of 31 to 45 years constituting 63.0% of the total respondents sampled. Again, farmers within the age group of 46 to 60 years and 61 to 75 years constitute 31.14% and

5.13% respectively while those with age above 61 years formed the lowest percentage (Fig 4.1).

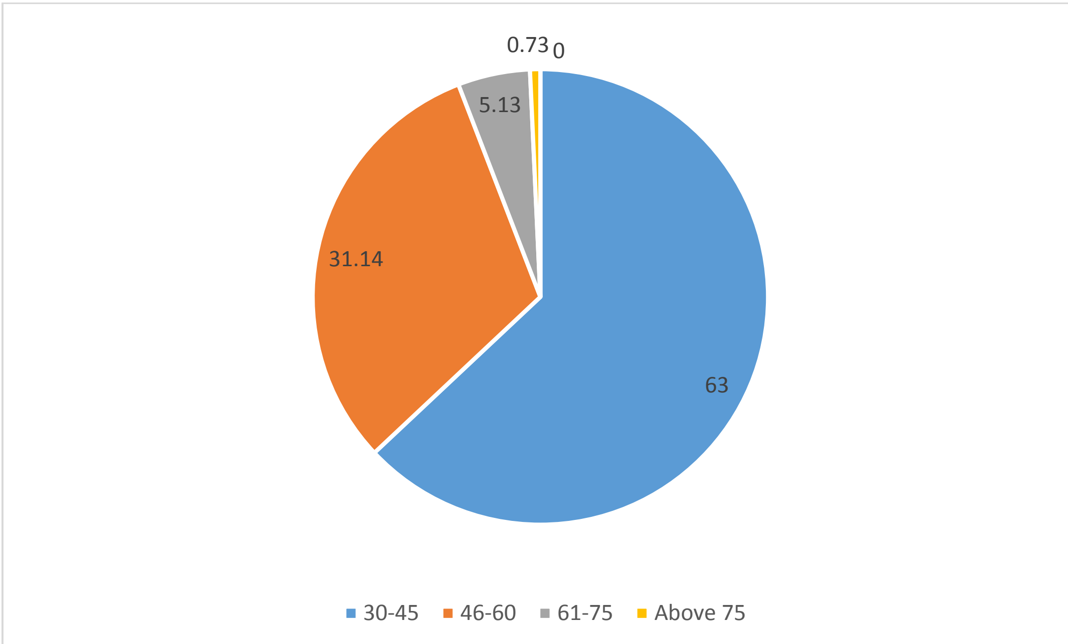

Figure 4.1: Age distribution of Pig farmers

4.1.3 Educational Level of Respondents and Knowledge in Pig Production

According to the result, farmers with no formal education constitute 30% of farmers in the study area. However, more than half (70%) of the respondents obtained some form of formal education. It was found out that 23.7% and 21.85% had attained primary and Junior High school qualification. About one out of ten famers (10.74%) hard tertiary education.

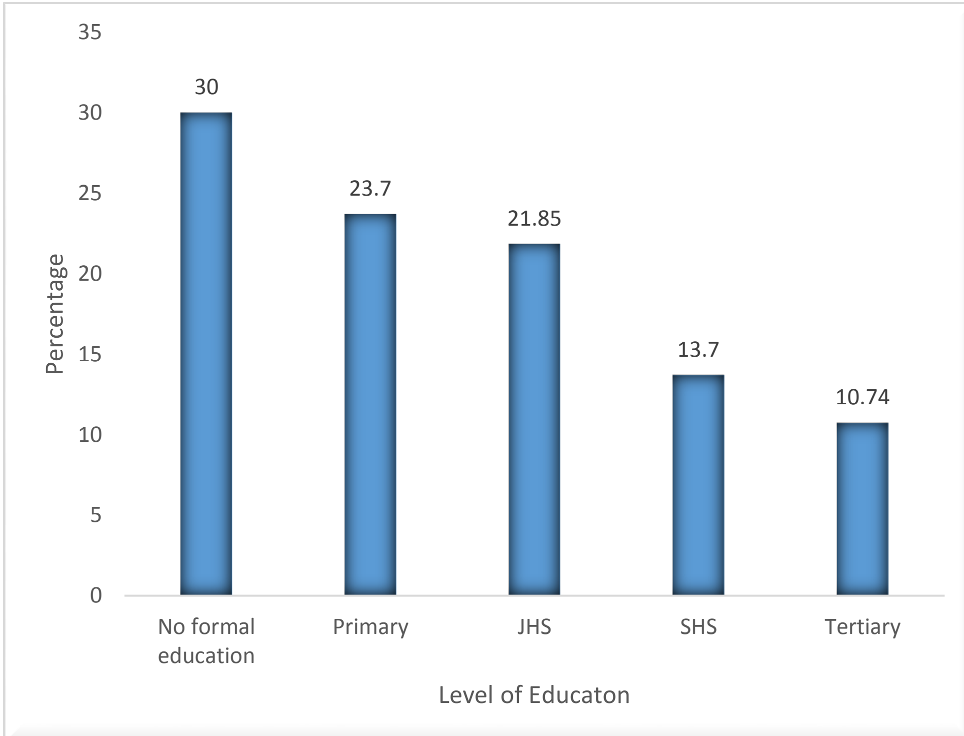

Figure 4.2: Educational level of Pig famers

4.1.4 Years in Pig Production

The study as shown in (Table 4.2) indicates that most (45.05%) of the farmers are relatively new in pig farming with at least less than five years of experience in pig farming. Farmers with 5 to 10 years of farming experience further constituted 28% of the sample size. This was followed by the farmers with 10 to 15 years of farming experience whereas 13.55% of the farmers had at least 16 years of experience in pig farming.

Table 4.2. Experience in pig farming

Group	Frequency	Percentage
<5	123	45.05
5-10	78	28.57
11-15	35	12.82
16-20	19	6.96
21-25	15	5.49
>25	3	1.10

4.2 Effect of ASF on the Income of Pig Producers

The study found a significant difference between the mean income of farms infected with ASF and farms that have not been infected with ASF. At 1% level of significance, the mean income of GhC 1091.723 for non-ASF farms is significantly different from the mean income of ASF farms which recorded an average income of GhC 568.7071.

Table 4.3: T-test of mean income of ASF farmers and non-ASF farmers

Group	Mean	SD	t-statistics	P value
ASF	568.7071	898.9123	3.9356	0.000
No ASF	1091.723	1018.386		

4.3 Sources of Feed for Pigs

Sources of feed for pigs in the study area is presented in (figure 4.3) below. Major source of feed identified for pigs among the farmers was local market. As high as 94.14% of farmers in the study area obtained their pig feed from markets in their localities. However, 3.5% of the farmers obtained their feed designated shops whiles 5.13% of the farmers prepare their own pig feed.

Figure 2.3: Sources of Feed for Pigs

4.4 Sources of Water for Pigs

The presentation of result further shows that pipe water formed the major source of water for most farmers in the study area. About 93% of the famers rely on pipe born water for their pig management (figure 4.4). Few farmers also rely on dam and other sources.

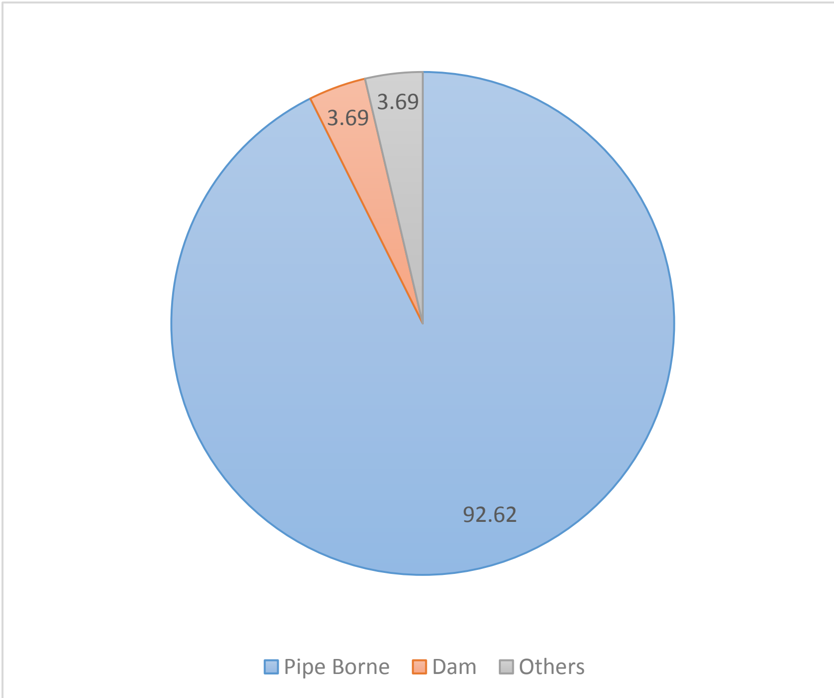

Figure 4.4: Sources of water for pigs

Table 4.4: Number of pigs that suffered from African swine fever

No. of Observation	Mean	Standard Deviation	Minimum	Maximum
212	20.099	17.324	0	115

The study found out that an average of 20 pigs suffered and died from ASF outbreak in the study area (Table 4.4). Mortality was found to be very high (45.12%) among old pigs in the study area (Figure 4.5). Again, mortality among other age groups were 36.28% for piglets, 12.56% for matured pigs and 27.44% (Figure 4.5) among any of all these age groups. Most farmers (67.14%) reported that they report and seek veterinary advice during ASF attack on their farms. In (Figure 4.5), mortality exists in all age groups of pigs. This agrees with Sánchez-Vizcaíno *et al*., (2012) who reported that ASF is one of the most complicated and economically destructive viral diseases in swine herds, with a significant socio-economic effect in the nations affected since mortalities occurs in all races and ages.

The high mortalities experienced could be linked with direct infections from neighbour farms as reported by researchers Costard *et al*., (2013) and Sargsyan1 *et al*., (2018), who indicated that ASF can be transferred between household by direct contact with infectious excretions and secretions.

4.5 Age Group of pigs that suffered from African swine fever

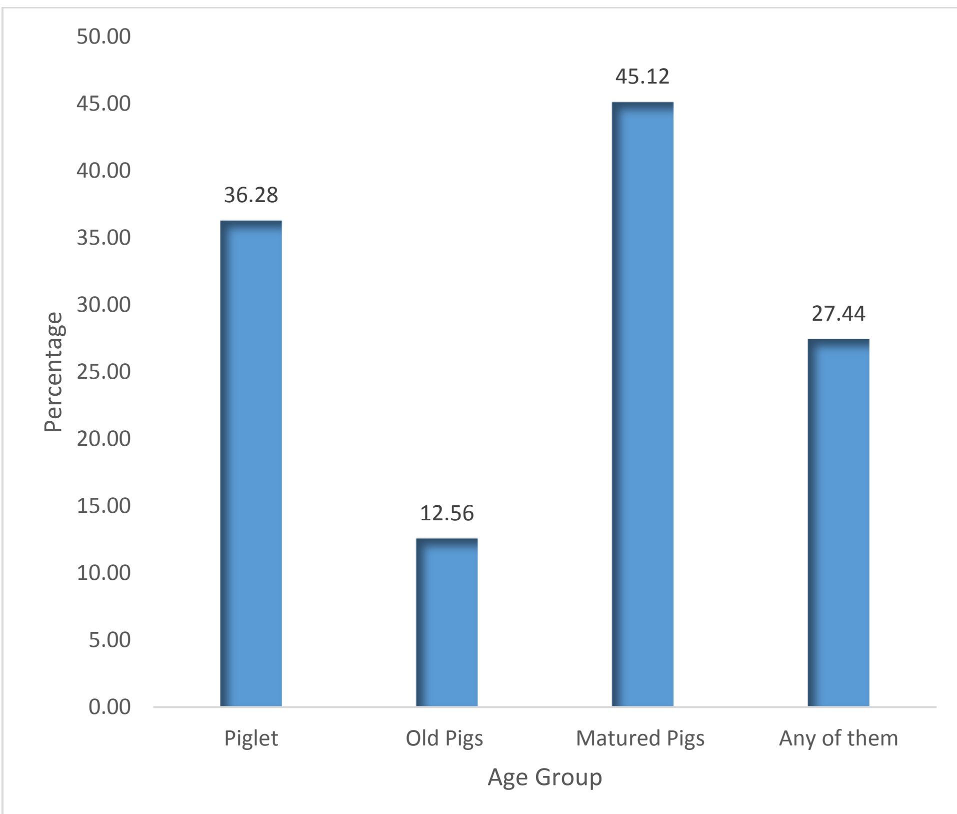

Figure 4.5: Age Group of pigs that suffered from African swine fever

Table 4.5: Sample t-test of treated versus control

Sample	**Size**	**Mean**	**Variance**	**Standard deviation**	**Standard error of mean**
Treated	10	0.508	0.079	0.2818	0.0891
Control	10	2.575	2.153	1.4675	0.4641

Many farmers resort to veterinary officers for the management of ASF on their farms as in (Figure 4.6)

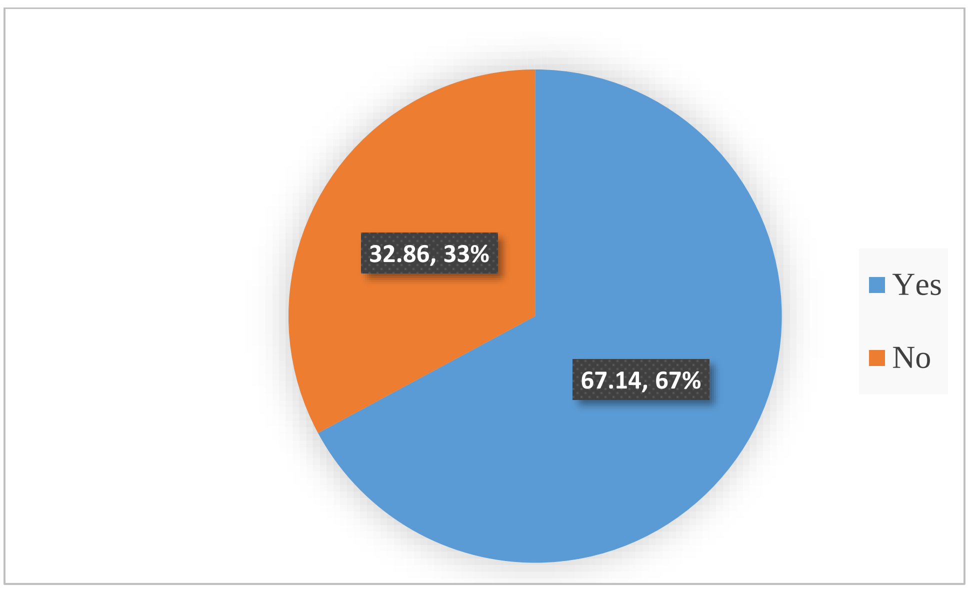

Figure 4.6: Seek veterinary attention anytime there is African swine fever outbreak

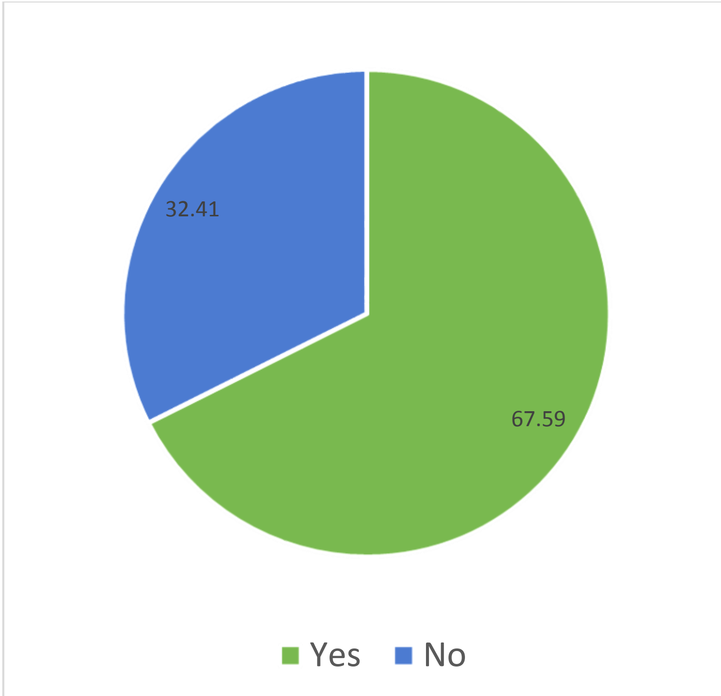

Figure 4.7: Veterinary officers confined diseased pigs

The available effective and safe method of controlling the spread of ASF after it has affected a farm would be isolating infected animals to reduce the spread of the disease to healthy animals and reducing economic losses in the affected farms. According to the result of the study as in (figure 4.7), most farmers (67.59%) who contacted veterinarians explained that these veterinarians isolate the affected animals as a preventive measure against the spread of the disease. This will also enable the veterinarians to give maximum attention and care to the diseased animals.

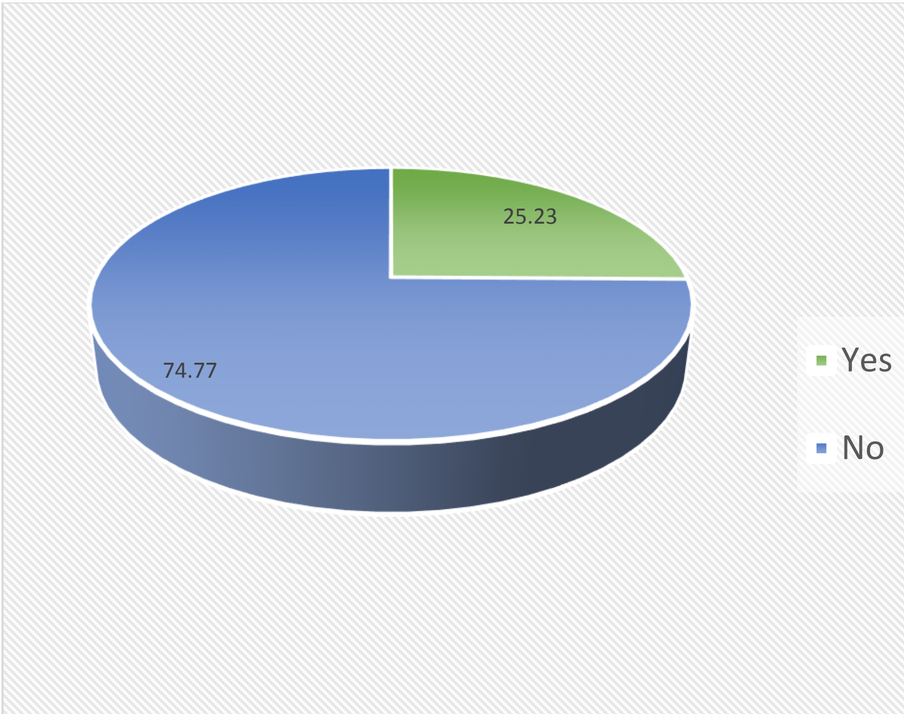

Figure 4.8: Heard of compensation

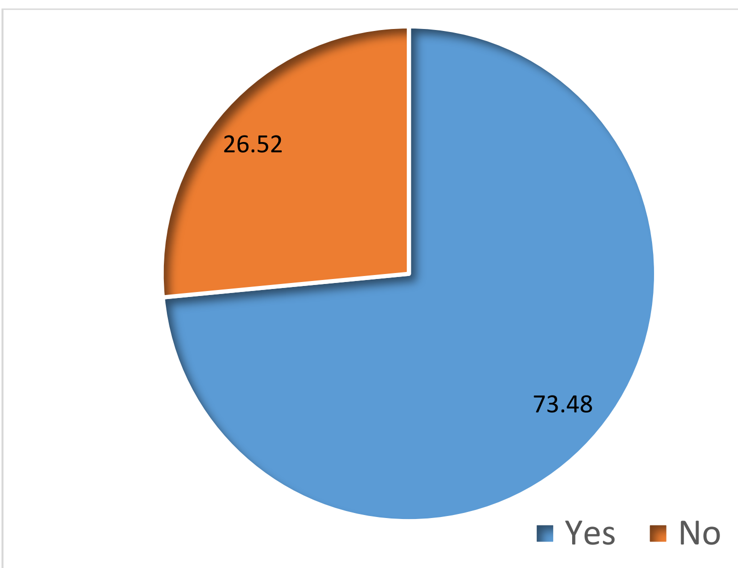

Figure 4.9: Seek veterinary at all times

4.6 Association between ASF and Demographic Characteristics

Table 4.6: Chi Square Tabulation

		Experience ASF					
		No		Yes			
		Frequency	Percentage	Frequency	Percentage	Pearson chi2(1)	P value
Heard of ASF	No	17	6.27	17	6.27	11.8546	0.001
	Yes	53	19.56	184	67.90		
Age	30-45	35	12.82	137	50.18	11.7150	0.008
	46-60	33	12.09	52	19.05		
	61-75	2	0.73	12	4.40		
	Above 75	1	0.37	1	0.37		
Educational Level	Primary	8	2.96	56	20.74	10.7928	0.029
	JHS	16	5.93	43	15.93		
	SHS	15	5.56	22	8.15		
	Tertiary	7	2.59	22	8.15		
	No formal Education	24	8.89	57	21.11		
Other work	No	21	7.72	29	10.66	8.0261	0.005
	Yes	50	18.38	172	63.24		
Farm Type	Subsistence	14	5.15	68	25	4.6086	0.032
	Commercial	56	20.59	134	49.26		

The study found out that there is a significant (χ^2 = 11.8546, p = 0.001) association between

ASF disease infection and age of pig farmers. This suggests that age is one key driver of pig rearing across the regions of study. On contrast**,** there are relatively many young farmers in the study region who are deemed active and curious to learn new ways of doing things including disease control techniques. Again, there was a significant association between ASF attack and educational level (χ^2 = 10.7928, p = 0.029). The study further found a significant association between ASF contraction and other economic activities engaged in by pig farmers (χ2 = 8.0261, p = 0.005). The farming type practiced by farmers was also found to be significantly associated with ASF contraction (χ^2 = 4.6086, p = 0.032).

4.7 Determinants of African Swine Fever Contraction

The study further sought to find out socioeconomic factors of pig farmers that expose pig farms to ASF contraction. The probit analysis was conducted to determine factors that influence or expose farmers to ASF in the study areas as in (Table 4.7). ASF contraction (whether a farmer has experienced ASF or not) was regressed on age, educational level, experience, farm type, income, training, housing, and fore knowledge on ASF.

Table 4.7: Determinants of African swine fever contraction using Probit regression

Variable	Coefficients	Standard Error	Marginal Effects	Standard Error
Age				
46-60	-0.937875**	0.3833885	-0.1285182**	0.0542923
61-75	-0.7711192	0.9325241	-0.1025923	0.1384826
Sex	0.7691396	0.4844805	0.0983525	0.0608723
Level of education				
Junior High School	-1.941071**	0.8672617	-0.168657***	0.0641703
Senior High School	-2.817155***	0.9041536	-0.305216***	0.0834518
Tertiary	-2.049895**	0.946205	-0.183622**	0.0880064
No formal Education	-2.206203***	0.8420004	-0.206186***	0.0596805
Experience	.0557636*	0.033487	0.0071307*	0.0042038
Other work	.8294931	0.4320676	0.1060701**	0.0536478
Farm Type	1.761201**	0.8707252	0.2252107	0.1094138
Income	-0.0004237*	0.0002338	-0.000054*	0.0000291
Training	.1519655	0.42371	0.0194323	0.0541162
Housing	-.129889	1.203917	-.0166093	.1539207
Heard of ASF	3.376714***	.8863501	.4317919	.1046612

*, ** and *** denote significance at 10%, 5% and 1% respectively

The pseudo R2 explains proportion of variation in the ASF contraction that is explained by the explanatory variables. According to the result (Table 4.7), it was found out that the pseudo R2 was 0.2400. This means that about 24% of variation in ASF contraction has been explained by age, gender, educational level, experience, farm type, income, training, housing, and fore knowledge on ASF. This indicates a moderate goodness of fit model. The probability ratio Chi-squared test shows that ASF contraction was explained collectively and substantially by the chosen factors. As expected, most of the expected signs of the explanatory variables were not met, with the exception of income and education.

4.8 Effect of Herbal Treatment in Controlling ASF

The results showed some effect of 'Luwine' on mortality rate of pigs during ASF outbreak. It could be seen from Table 4.4 that, the group treated recorded less mortality than the control group. The difference of means in terms of mortality was up to 5 pigs. However, the administration of the 'Luwine' could not treat ASF since mortality was increasing with days

Table 4.8: Sample t-test of treated versus control

Group	Sample Size	Sample Mean	Sample Variance	Standard deviation	Standard error of mean
Control	10	13.5	28.28	5.318	1.682
Treated	10	8	6.22	2.494	0.789
Difference of means		**5.5**			
Standard error of difference		**1.857**			
Test statistic (t)		**2.96**			
P-value		**0.011**			

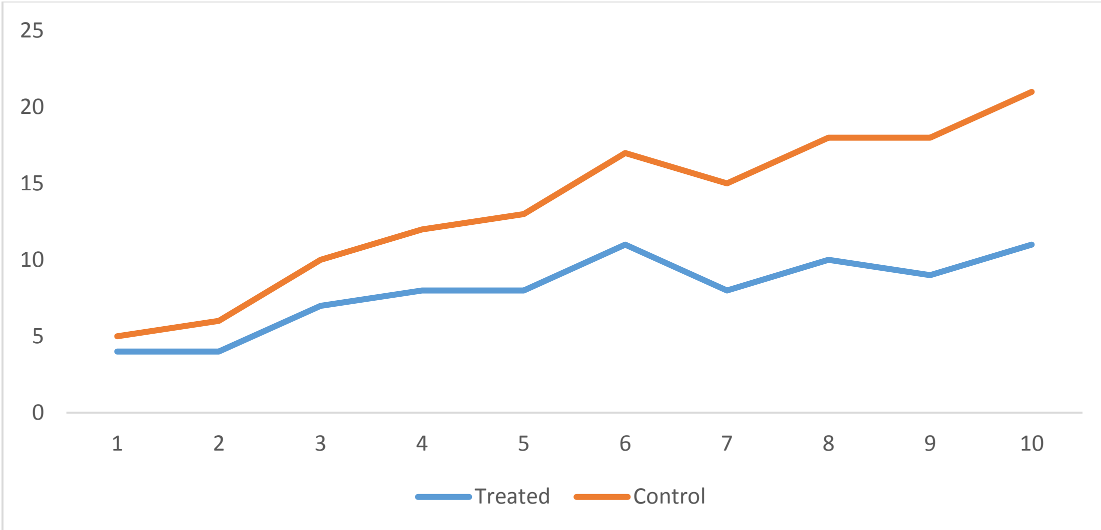

Figure30: Mortality of pigs observed over a period of 10 days.

The graph (Figure 4.10) indicated that whereas there was a mortality observed for both the control and the treated group, the administration of the 'Luwine' solution brought about relative reduction in pig mortality. From the graph, there was a relatively sharp increase in the mortality of control pigs from day 1 to day 6. This was followed by a drop in mortality on day 7 and a relative rise up to day 10. On the other side, the treated group showed a gentle rise in pig mortality across the days' period.

Table 4.9: Percentage antibiotic resistance of non-fastidious bacteria isolated from pigs affected with African swine fever

Antimicrobial	R (%)	I (%)	S (%)
Amoxycillin/clavulanic acid 30µg (AMC)	0.00	20.00	80.00
Azithromycin 15µg (AZM)	0.00	0.00	100.00
Ceftriaxone 30ug (CRO)	40.00	30.00	30.00
Chloramphenicol 30ug (C)	40.00	10.00	50.00
Gentamicin10ug (CN)	0.00	0.00	100.00
Teicoplanin 30 µg (TEC)	70.00	10.00	20.00
Tetracycline 30ug TE	20.00	30.00	50.00
Suphamethoxazole/trimethoprim (SXT)	40.00	10.00	50.00
'Luwine'	100.00	0.00	0.00

S, susceptible; I, Intermediate; R, resistant; Luwine, herbal medicine made from the root of *Sarcocephalus latifolius* and dry bark peels of *Pseudocedrela kotschyi*.

Table 4.10: Percentage antibiotic resistance of fastidious bacteria isolated from pigs affected with African swine fever

Antimicrobial	R (%)	I (%)	S (%)
Amoxycillin/clavulanic acid 30µg (AMC)	30	40	30
Azithromycin 15µg (AZM)	30	20	50
Ceftriaxone 30ug (CRO)	100	0	0
Chloramphenicol 30ug (C)	80	20	0
Gentamicin10ug (CN)	20	10	70
Teicoplanin 30 µg (TEC)	100	0	0
Tetracycline 30ug TE	50	10	40
Suphamethoxazole/trimethoprim (SXT)	20	10	70
'Luwine'	100	0	0

S, susceptible; I, Intermediate; R, resistant; Luwine, herbal medicine made from the root of *Sarcocephalus latifolius*dry bark peels of *Pseudocedrela kotschyi.*

The antibiotic resistant profile of the non-fastidious bacteria can be found in Table 4.9. The non-fastidious bacteria exhibited 6 different profiles, which is TecTeCroSxt, TecCCroSxt, TecCCro, TecCSxt, TecTeC, TecSxt, Tec and Cro with a multiple antibiotic index ranging from 0.13 to 0.50. Two non-fastidious bacteria from mouth sources were susceptible to all the antibiotics. Five groups of non-fastidious bacteria displayed multidrug resistant (resistant to 3 or more distinct classes of antibiotics).

Table 4.11: Profile of antibiotic resistance and multiple antibiotic resistance index (MAR index) of non-fastidious bacteria isolated from pigs affected with African swine fever

Code	Source	No. of Antibiotics	Antibiotic resistant profile	MAR Index
A1	Anus	4	TecTeCroSxt	0.50
4A	Anus	4	TecCCroSxt	0.50
5N	Nose	3	TecCCro	0.38
4N	Nose	3	TecCSxt	0.38
2N	Nose	3	TecTeC	0.38
3N	Nose	2	TecSxt	0.25
3A	Anus	1	Tec	0.13
1M	Mouth	1	Cro	0.13
5M	Mouth	0	-	0
2M	Mouth	0	-	0

The antibiotic resistant profile of the fastidious bacteria is shown in Table 4.10. The fastidious bacteria exhibited 10 different profiles, which is AmcAzmTecTeCroSxt, AzmTecCnTeCCro, AmcTecTeCCro, TecTeCCroSxt, AmcTecCCro, AzmTecCCro, TecTeCCro, TecCnCCro, TecCCro and TecCro with a multiple index of antibiotics between 0.25 and 0.75. Nine groups of fastidious bacteria also displayed multidrug resistant.

Table 4.12: Profile of antibiotic resistance and multiple antibiotic resistance index (MAR index) of fastidious bacteria isolated from pigs affected with African swine fever

Code	Source	No. of Antibiotics	Antibiotic profile	MAR index
A1	Anus	4	TecTeCCro	0.50
3A1	Anus	4	AmcTecCCro	0.50
4A1	Anus	5	TecTeCCroSxt	0.63
3N1	Nose	6	AzmTecCnTeCCro	0.75
2N1	Nose	3	TecCCro	0.38
4N1	Nose	2	TecCro	0.25
5N1	Nose	4	AzmTecCCro	0.50
2M1	Mouth	4	TecCnCCro	0.50
1M1	Mouth	5	AmcTecTeCCro	0.63
5M1	Mouth	6	AmcAzmTecTeCroSxt	0.75

CHAPTER FIVE

DISCUSSIONS

5.1 Demographic Characteristics of Livestock Farmers

5.1.1 Gender of Farmers

Previous African swine fever disease incidence studies had comparable results. Saka *et al.* (2010) researched the incidence of African swine fever disease and its related effects on pig production and recorded a large prevalence among pig farmers in Nigeria. The high level of drudgery involved in pig farming has made the enterprise a male dominated enterprise (Table 4.1).

5.1.2 Age of Farmers

Age of farmers forms an important demographic characteristic that influence the managerial capabilities and physical strength needed for pig management. The research (Figure 4.1) discovered a high rate of young farmers involved in pig farming in the study region. Most participants were between 31 and 45 years of age, suggesting large active farmers that possess the needed strength for high energy demanding management practices. The age distribution further showed that 31.14% and 5.13% of the farmers were within the age range of 46 to 60 and 61 to 75, respectively (Figure 4.1).

5.1.3 Educational Level of Livestock Farmers

The result of the study further indicated that pig farmers with formal education dominate the respondents. Pig farmers with formal education was found to constitute 70% of the population whereas farmers with no formal education forms 30% of the population (Figure 4.2). The highest level of formal education attained by most (23.7%) of the farmers is primary education. The high level of farmers with formal education reflects innovativeness and technical skills available needed not only to increase pig production but also take preventive measure to avoid African Swine Disease. Saka *et al*. (2010) also indicated that literacy level among pig farmers enhances their managerial capabilities that is emanated from education and innovativeness among smallholder farmers.

5.1.4 Experience of Farmers

The numbers of years in pig farming (Table 4.2) indicates that most of the farmers are relatively new in pig rearing and are more likely to be susceptible to ASF. This outcome is comparable to that of Saga *et al.* (2010) who reported that most pig farmers had less than five years in pig industry and relatively new in pig farming as well as livestock farming.

5.2 Effect of ASF on Farmers' Income

The results further indicated in (Table 4.3) shows that more than 8 out of 10 (81.62%) farmers in the study area engaged in other forms of economic activities but kept pigs as an additional source of income. This suggests possible means of coping with risk particularly African swine fever associated with pig rearing. The analysis further revealed that these farmers could make up to Gh₵ 1,000.00 as an additional income in the absence of ASF. However, the t-test (Table 4.3) indicated that, ASF could reduce up to half of this additional income. Similar findings also indicated that thirteen million, nine hundred and thirty-nine thousand naira (N13, 939,000.00), at the 2001 market price was reportedly lost due to ASF outbreak in Nigeria (Babalobi *et al*., 2001).

5.3 Type of Feed

There was no organized feed formulated to feed pigs in the study area (Figure 4.3). Most (94.14%) farmers obtain pito mash, corn flour, soya-beans, rice chaff, rice brand, cassava flour and concentrate from their local markets. These feeds are mixed in different quantities for their ration formulation. Previous research also found that staple pig feeds on most farms were cereal products that were difficult to acquire on an ongoing basis due to competition from other livestock farmers and humans (Osei Sekyere and Adu, 2015). In addition, 5.13% prepare supplementary feed on their own farms to feed their pigs (Figure 4.3). Other feeds such as grasses, household leftovers, cassava and yam peels served as a feed for pigs mostly under the extensive and semi extensive system.

5.4 Source of Water for Pigs

Continuous and regular supply of water for pigs ensures hygiene and well-being of the pigs. Main source of water for many pig farmers was pipe borne water. Most (92.62%) farmers in the study area rely largely on pipe borne water for exclusive usage (Figure 4.4). Few farmers also used dams and other sources such as well and streams. However, this is opposite to the scenario in the Ashanti region where well water and boreholes were the most common sources of water for pig farmers (76.5%) (Osei Sekyere and Adu, 2015).

5.5 Contact with Veterinary Officers

Even though there are limited veterinary officers operating in many districts in Ghana, the result indicated that (Figure 4.6) many pig farmers (67.14%) obtained information about veterinary services in the study area (figure 4.6) on management and handling of pigs in the advent of ASF outbreak. In addition, some NGOs complement the work of these veterinary officers in the provision of free services in the study area. Previous study indicated that pig rearing is poorly characterized by lack of information about veterinary services or intentional refusal to seek veterinary assistance by farmers in South Africa (Munzhelele *et al*., 2016).

5.6 Determinants of ASF Contraction

The variable income in probit regression was statistically important ($P<0.1$) and was negatively associated with ASF contraction. This means that farmers with higher income were less likely to contract or experience ASF disease on their farms. The marginal effect showed that an increase in the income of a pig farmer by one Ghana cedis will decrease the chances of a farmer experiencing ASF on his or her farm by 0.0000542, holding other factors constant. This result buttress the fact that higher income farmers plough back their profits and also invest more in the welfare of their animals. They provide more medication, housing against harsh environmental condition and other intruders that have the potentials of infecting their animals. This is consistent with the earlier findings that indicated that poorest pig keepers and smallholders, are the ones that suffer most from ASF outbreaks (Chenais *et al*., 2017). Similarly, Wagstaff (2006) stressed that poor people are more vulnerable to shocks such as animal diseases. Osei Sekyere and Adu (2015) also indicated that wealthier farmers with high income adopts improved and modern infrastructure that provided better security from harsher environmental conditions and thieves. Most tangible effect of animal disease particularly ASF are reduction in income, loss of herd and increase in pork and pork product deficit.

Respondents selected for the study were asked to recall if they had a fore knowledge or have heard of ASF prior to the study. The primary interest of the study was to find out if farmers who has heard of the disease were proactive and had put in measures to prevent its infection. More interesting and contrast to the expectation of the researcher, the variable whether pig farmers have heard of ASF or not was significant and positively related to the risk of ASF contraction. This implies that farmers who have fore knowledge on ASF were more likely to contract ASF. From the result, the marginal effect means that farmers who have heard of ASF prior to the survey are 0.432 times more likely to contract ASF on their pig farms, controlling for other factors. This suggests that most farmers who have heard of the disease may have heard it for the first time and as such may be unfamiliar with the disease and its virulence effect.

The model estimate for the impact of agricultural experience on ASF contraction was also discovered to be positive and statistically important at a significant point of 10%. This means that pig farmers who spent more years in pig farming are more likely to contract ASF on their farms. The result indicated that an additional increase in the number of years spent in pig farming will increase the probability of a farmer contracting ASF by 0.007 holding other factors constant. Over the years, experienced farmers have gathered more knowledge on pig management. Most of these experienced farmers find it difficult to unlearn this knowledge for other innovations hence tend to be reluctant in adoption of innovations, consequently they become more prone to risk including ASF contraction. Previous studies have also shown that farmers who learned from experience and from friends were comparatively less educated in pig science, although they were very skilled (Osei Sekyere and Adu, 2015).

According to the result, relative to farmers within the age range 30 to 45, farmers between the ages of 46 and 60 have less chance and are less prone to ASF. The result indicated that, the marginal effect of farmers within the age range of 46 to 60 is negative relationship with ASF contraction and statistically significant. This means that relative to the 30 to 45 years' age group, farmers within the age group of 46 to 60 years are 0.129 times less likely to contract ASF.

The study further explored the relationship between educational level and ASF contraction among farmers. Primary education was set as the base education. According to the result, relative to primary education, all forms of formal education and no formal education was found to have a negative and significant relationship with ASF contraction. The result indicated that, relative to primary education, farmers who had no formal education are 0.206 times less likely to contract ASF, holding other factors constant. Similarly, relative to primary education, respondents with junior high education are 0.169 times less likely to contract ASF disease. Relative to primary education, pig farmers with tertiary and senior high education are 0.305 and 0.184 times less likely to contact ASF, respectively. This result is highly expected as formal education especially high education provides respondents systematic knowledge on pig management especially ASF preventive measures. Osei Sekyere and Adu, (2015) also explained that highly educated farmers are more informed about pig business.

5.7 Effect of Herbal Treatment in Controlling ASF

In (Figure 4.10), the treated group experienced low mortality compared with the controlled group. This could be due to the fact that (Luwine) is able to treat some of the secondary infections associated with ASF. This is consistent with Koné *et al*., (2004); Asase*et al*., (2008); Ayo *et al*., (2010) who documented that *Pseudocedrela kotschyi* has a potential source of antibacterial agents and antimicrobial activity of various organic and aqueous leaf extracts, stem bark and roots that help in the treatment of illnesses such as abdominal irritation, abscesses, anaemia, arthritis, conjunctivitis, constipation, cough, diarrhoea, dysentery, fever, overall weakness and others**.** Another study reported a substantial reduction in uterus contraction in experimental animals caused by oxytocin and acetylcholine (Nworgu*et al*., 2010). *Sarcocephalus latifolius* on the hand, has medicinal properties used in the management of numerous infections and illnesses usefulness against stomach upset, cough, cold, and overall body weakness (Gill, 1992).

The percentage antibiotic resistant of non-fastidious bacteria is presented in Table 4.9. From Table 4.10, the fastidious bacteria were resistant to ‘Luwine’ (100%), teicoplanin (70%), ceftriaxone (40%), chloramphenicol (40%), and suphamethoxazole/

trimethoprim (40%). They were however, highly susceptible to azithromycin (100%), gentamicin (100%) and amoxycillin/clavulanic (80%). Moderate intermediate resistant occurred for ceftriaxone (30%), tetracycline (30%) and amoxycillin/clavulanic acid (20%). The antibiotic susceptibility of the fastidious bacteria to the antibiotics examined is shown in Table 4.11. All the fastidious bacteria were resistant to 'Luwine' (100%), ceftriaxone (100%), and teicoplanin (100%). Nonetheless, they were highly susceptible to gentamicin (70%) and suphamethoxazole/trimethoprim (70%). Moderate intermediate resistant also occurred for amoxycillin/clavulanic acid (40%), azithromycin (20%) and chloramphenicol (20%).

Non-fastidious bacteria are those bacteria that are able to grow and replicate without special nutrient supplements, and includes *Escherichia coli*, *Listeria species*, *Pseudomonas species* and *Staphylococcus species* (Rishmawi *et al.*, 2007). In contrast, fastidious bacteria are those that require special nutrient requirements, and sometimes atmospheric environment to grow and replicate (Doern, 2000; King, 2001). They include *Brucella species*, *Campylobacter species*, *Helicobacter species* and *Legionella species*. These groups of bacteria are involved in causing illnesses, food spoilage, food poisoning and secondary infections in animals and/or humans. African swine fever is an extremely contagious viral hemorrhagic infection of pigs with the following symptoms high fever (41-42°C), rapid breathing, flushing skin and thick whitish discharges from the nose and eyes (World Organization for Animal Health, 2018). The disease is highly fatal (almost 100% mortality) and results in significant losses to the pig and meat industry (FAO, 2000; World Organization for Animal Health 2018; FAO, 2019).

Pig farmers in Navrongo, Ghana and its environs use 'Luwine' to control African swine fever. They believed that the 'Luwine' was effective in controlling African swine fever due to their experience with the treatment of African swine fever pigs with 'Luwine'. According to the farmers, they observed that African swine fever pigs treated with 'Luwine' survived better than non-treated pigs. Scientifically, the cure for the virus responsible for African swine fever is yet to be discovered. The prevention and management of the diseases rely on vaccination, the immune system of pigs and the use of antibiotics to control secondary infections. The rational of this work was to determine the antibiotic(s) that could help control secondary infections in pigs affected with African swine fever. It also sought to determine whether 'Luwine' played a role in reducing secondary infections associated with African swine fever. From the results, the non-fastidious bacteria were highly susceptible to azithromycin, gentamicin and amoxycillin/clavulanic acid whist the fastidious bacteria were susceptible to gentamicin and suphamethoxazole/trimethoprim. Thus the afore-mentioned antibiotics are recommended for the management of secondary infections associated with African swine fever. When an antibiotic is required, gentamicin will be a better option sine a high proportion of both fastidious and non-fastidious organisms were susceptible to this antibiotic.

However, the fastidious bacteria were highly resistant to 'Luwine' and teicoplanin; while it was 'Luwine', ceftriaxone, chloramphenicol and teicoplanin for non-fastidious bacteria. These antibiotics are therefore, not recommended for the treatment of secondary infections associated with African swine pigs. Intermediate resistant and multidrug resistant were also exhibited by the non-fastidious and fastidious bacteria.

Intermediate resistant easily becomes resistant to antibiotics (Adzitey *et al*., 2016; Adzitey *et al*., 2019) and multidrug resistant are those resistant to three or more classes of antibiotics. Fifty percent (50%) of the non-fastidious bacteria exhibited multidrug resistant. As high as 90% of the fastidious bacteria exhibited multidrug resistant. Both intermediate and multidrug resistant bacteria are difficult to treat when they are involved in an infection and a significant threat to infectious disease therapy worldwide (McEwen *et al*. 2002, Adzitey *et al*., 2019).

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Pig farming in the study area is a promising one since majority of pig farmers are the youth ranging from age 31 to 45 as well as having formal education. Again, most of them do other jobs like crops farming, livestock keeping and petty trading and do plough back some of their income from those sources into the pig production especially when ASF infest their farms with high mortality cases. Farmers in the study area are aware of the devastating effects of ASF. 'Luwine' was able to reduce mortality in ASF pigs.

Antibiotics such as azithromycin, gentamicin, suphamethoxazole/trimethoprim and amoxycillin/clavulanic could be used in the management of secondary infections in African swine fever pigs. When only one antibiotic is required, gentamicin will be the best choice.

The use of herbal concoction ('Luwine') shown effectiveness in the reduction of the mortality among pigs infected with ASF. Pig production serve as major livelihood for most dwellers in the study area. Substantial among of pig farmers are males. The breeds of pigs reared in the study comprises mainly local breed (Ashanti black) whereas few farmers keep exotic and cross breeds. Pig production was found to be highly profitable but the advent of ASF can reduce farmers profit to about half. The study has also empirically established socio-economic characteristics such as age, educational level, experience, income, and fore knowledge on ASF have significant effect on the contraction of ASF.

6.2 Recommendations

Based on the results, the study recommends that:

Strict biosecurity measures should be observed among farmers.

Farmers should form cooperative groups so as to be strong to insure their farms against disease (ASF) outbreaks to enable them get compensation.

In addition, farmers should be encouraged to confine their pigs and purchase breeding stock from well accredited sources

Intentions to control ASF could include the use of 'Luwine' as it was found to reduce mortality among ASF pigs as compared to the control.

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APPENDIX

ASSESSMENT OF PIG LOSES AT FARM LEVEL DUE TO INCIDENCE OF AFRICAN SWINE FEVER IN UPPER EAST REGION

1. Name of the farmer …………………………………………………………………….
2. Age of farmer (a) 30-45 (b) 45-60 c) 60-75d>75
3. Sex……(a)male (b) female
4. Marital status a) married (b) single c) dependent d) divorced
5. Educational level a) primary b) JHS/Middle school c) SHS d) tertiary
6. What is the category of the farm family? A) extended family (b) nuclear family
7. How many years of experience have you had in pig farming?...............................
8. Do you have another work/ job besides pig farming? …………………………….
9. Do you rear for commercial or subsistence? (a) commercial benefit (b) subsistence purposes
10. Is pig farming profitable to you? (a)yes (b) no
11. How much income do you gain from selling the pigs?..
12. Which types of pig breed do you rear?...
13. Who takes care of the piggery? A) hired labour b) family labour c) owner labour
14. Do you have any formal training in pig farming? A) yes b) no
15. Who gave the training? A) NGOs b) veterinary/government c) neighbour
16. What was the training about?...
17. How many pigs did you start with?...
18. Has your pig population increased or decreased or stayed the same for the past years? Explain why? ………………………………………………………………………...
19. which group of pigs are allowed to go out a) piglet b) sows c) boar d) all of them e) none of them
20. List the feed ingredients used in feeding your pigs? ………………………………………………………………………………………………

21. Source of feed a) local market b) designated feed shops market c) owners farm
22. Sources of water. (pipe borne, well, river, stream, dam, and rain water.)
23. Do you feed the pigs on the same types of feed always? If yes why

    …………………………………………………………………………………………………
24. Have you heard of African Swine Fever a) yes b) no
25. If yes, when?

    …………………………………………………………………………………………………
26. Have you experienced African Swine Fever on your farm? A) yes b) no if yes explain how it was

    …………………………………………………………………………………………………
27. How many times have you experienced the disease? ………………………………………..
28. Which period of the year does the disease occur? A) rainy season b) dry season
29. What did you do when the disease strikes your farm?

    ………………………………………………………………………………………
30. Which sex suffered most? A) male b) female c) both
31. Which age group are usually affected? A) piglet b) old pigs c) matured pigs d) any of them
32. How many died during the outbreak of the disease? ………………………….
33. Did you seek for veterinary attention? A) yes b) no
34. How did the farmer recognize that the disease was African Swine Fever?

    …………………………………………………………………………………………………
35. Did the veterinarian confine the pigs when he/she saw it?

    …………………………………………………………………………………………………
36. Has the farmer heard of compensation given to farmers whose animals are condemned due African Swine Fever?..
37. If yes which region or district? ……………………………………………………………………

38. What are the bio-security measures that you adopt to stop African Swine Fever from entering to your farm?

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

39. Can you mention other diseases affecting your farm beside African Swine Fever?
40. Among the disease mentioned which one affected production most on the farm?

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

41. What measures do you put in place when there is a disease outbreak in your farm?

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

42. Do you seek for veterinary attention on your farm whether or not there is a disease outbreak on your farm? ……………………………………………………………….
43. What are the health problems of mature pigs?

…………………………………………………………..

44. What are health problems of the piglet?

………………………………………………………….

45. Do you have a housing unit for your pigs? …………………………………………………..
46. How do your pigs get infected with African Swine Fever?

…………………………………………….

47. Are humans susceptible to the disease? If yes, is it through infected pigs or can human transfer the disease to pigs.………………………………………….

48. Will you continue the pigs rearing after an outbreak of African Swine Fever? if yes why and if no why?

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

49. Do the sources of feed have influence on pigs acquiring African Swine Fever?

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

50. What is your advice for MoFA or veterinary to improve upon the health of pigs in general?

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

51. Do you have any comment on African Swine Fever?

…………………………………………………