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Comparison of pig production in China, Norway, and Ghana with special emphasis on breeds/breeding, feed and feed ingredients, management, health status, and economy

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Feed Manufacturing Technology

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Summary

This thesis give a comparison of pig production in China and Norway both temperate countries and Ghana (tropical country) with special emphasis on breed/breeding, feed and feed ingredients, health status, management and economy was undertaken. The objective of Comparing pig production in the three countries was to learn how production take place in each country, to reveal the strengths and weaknesses/barriers of each country and to suggest appropriate means of improving on production based on comprehensive study of the appropriate literature of the three countries.

The study showed that (i) The dominant local breeds are ADP in Ghana, TaiHu and Meishan in China and Norwegian Landrace in Norway. The exotic breeds are similar in the three countries (Large white, Landrace, Duroc, Hampshire and others). (ii) Breeding programmes in Norway are more advanced and purposeful, supportive and productive than in China and Ghana. (iii) Swine disease surveillance, veterinary services and biosecurity protocols are excellent in Norway, good in China and satisfactory in Ghana, leading to no swine diseases in Norway except A(H1N1)pdm09 but several swine diseases in China and Ghana including the deadly ASF which has claimed a lot of lives and caused massive culling of pigs. The result is that China with the largest population of pigs (700 million herds) and Ghana (759,000 herds) are net importers than exporters of pork and Norway regulates the production to cover national consumption (1700 herds). (iv) Commercial pig producers in the three countries used commercial prepared feed. Both Chinese and Ghanaian peasant farmers use locally available and cheap feed materials to feed pigs. Norway only use compound feed with fishmeal, imported soybean and rapeseed as protein sources and Norwegian produced grain. (v) China uses skyscraper to accommodate pigs because of the large number of pigs. Norway and China manipulate their sties to ensure the creation of thermoneutral zones for pigs because of extremes of temperature during winter and summer. Ghana uses Open yard sties with partial roofing and dwarf walls as well as Shades, sheds, yards and stalls.

Swine market in Norway is more stable than in Ghana and China because the production is regulated by involvement of Norwegian government. In Norway, the strengths of the production are effective control of diseases and pest except A(H1N1)pdm09, effective coordination and integration (networking) of all levels of production – commercial, medium scale and small scale, effective enforcement of laws in the sale of fresh pork at only designated points/places, high governmental involvement in the swine industry regarding production

volumes, pricing and the curtailment of the activities of middlemen and zero online sale of fresh pork. Weakness is high import of feed ingredients. The strengths of the production in Ghana is the effective use of ADP in breeding programmes, the use of baobab leafmeal to feed pigs, and cheaper buildings for production. Weakness is less effective production and partly regulated sales system. China have very effective production, effective breeding programmes, and use of skyscraper is a preserve and is the largest importer of pork even though she is the home to the largest population of pigs. Weakness is large concentration of pigs and high risk of disease.

Sammendrag

Denne masteroppgaven sammenligner svineproduksjon i Kina, Norge og Ghana. Produksjon og management, svineraser, fôring og fôrråvarer, helse og økonomi omsetning ble sammenlignet. Formål med studien var å sammenligne svineproduksjonen de tre landene for å vurdere styrker og svakheter som kunne brukes til å foreslå eventuelle endringer eller forbedringer. Studien viste at den dominerende lokale svinrasen er TaiHu og Meishan i Kina, Norsk Landsvin i Norge og Ashanti dverg svin (ADP) i Ghana. Utenlandske raser er like i de tre landene (Yorkshire, Landrace, Duroc, Hampshire og flere). Avlsprogram i Norge er mer avanserte og målrettede enn i Kina og Ghana. Overvåking av svinesykdommer, veterinærkontroll, og helseovervåking er svært godt i Norge, godt i Kina og tilfredsstillende i Ghana. I praksis er det derfor ingen alvorlige smittsomme virus-svinesykdommer i Norge bortsett fra A(H1N1)pdm09, mens det i Kina og Ghana finnes flere, inkludert Afrikansk svine feber (ASF) som har ført til høy dødelighet og sanering av mange besetninger. Resultatet av dette har vært at Kina (med høyest produksjon av svin, 700 million besetninger) og Ghana (759 000 besetninger) har så lave produksjon at begge land må importere svinekjøtt for å dekke etterspørselen.

Kommersielle produsenter i alle tre land bruker ferdige kraftfôrblandinger. Både kinesiske og ghanesiske småprodusenter bruker også lokale tilgjengelige, billige råvarer som fôr. I Norge brukes bare kommersielle kraftfôr basert på importert soyamel, rapsmel og fiskemel som proteinkilder, i tillegg til norsk korn som hovedråvare.

Kina bruker driftsbygninger med mange etasjer på grunn av det høye produksjonen. Både I Norge og Kina har termoregulerte bygninger som lager termonøyterale soner for dyrene bade sommer og vinter. I Ghana med mye varmere klima, brukes åpne skur med delvis takoverbygg for å skape skygge.

Produksjon og salg av svinekjøtt er markedsregulert for å dekke behovet i Norge. Produkjsonen er derfor mer stabil enn i Kina og Ghana hvor det ikke finnes markedsregulering.

Styrker med svineproduksjon i Norge er svært godt avlsarbeid, bruk av kryssinger, effektiv, liten produksjon og god helsekontroll. God integrering i alle ledd av produksjonen. Svakhet med den norske produksjonen er stor andel av importerte fôrråvarer.

Styrker med produksjonen i Ghana er fjerne ADP gjennom avlsprogram og bruk av lokale råvarer som baobab blader, og muligheter for å bruke billigere bygninger. Svakheter er lavere produksjonseffektivitet og bare et delvis regulert salgssystem.

Styrker med produksjon i Kina er at de har verdens største produksjon og har utviklet en effektiv produksjon og effektive driftsbygninger. Største svakhet er at de har svært store, konsentrerte populasjoner som er utsatt for smittsomme sykdommer.

Table of Contents

List of tables and figures

Tables

Figures

Acronyms

ASF – African swine fever

ADP – Ashanti dwarf pig

NOK – Norwegian krone

AI – Artificial insemination

DDGS – Dried distillers grains

ASFV – African swine fever virus

A(H1N1)pdm09 – Swine influenza disease

PRCV – Porcine respiratory coronavirus

AD – Aujeszky's disease

TGE – Transmissible gastroenteritis

PRRS – Porcine reproductive and respiratory syndrome

PED – Porcine epidemic diarrhoea

CSF – Classical swine fever

1. INTRODUCTION

1.1.General Overview

Pigs are prolific livestock farmed in many countries across the world. Pig keeping is one of the most profitable animal ventures in the world, and swine easily lend themselves to commercialisation (FAO, 2012). According to studies, a piglet grows twelve times as a calf and in terms of meat per tonne of live weight of breeding females per year, pigs produce in the region of six times that of cattle (Lander et al., 2020; Zhang et al., 1998). The provision of high-quality pork, bacon, and fat is the sole aim of keeping pigs. Swine domestication has played a pivotal role globally as means of survival for many livelihoods, and as a source of cash security for many poor and disadvantaged rural and peri-urban families (McBride and Key, 2003).

Swine production plays a crucial role in ensuring various cultural, religious, and social functions continue to exist in various communities across the world (Guo and Chen, 2009). Besides provision of proteins, pork is a reliable source of essential amino acids, vitamins and minerals needed for overall good health of man. Other parts such as the lard is an excellent source of cooking oil (Zhang et al., 2021; FAO, 2012; Gandini and Villa, 2003). Swine keeping is a potential source of bristles and manure, an avenue for employment opportunities to seasonally employed rural farmers, and supplementary income to improve their standard of living. Other potential valuable commodities or by products include suede for shoes and clothing, insulin for diabetes regulation, valves for human heart surgery, and gelatine for many food and non-food products (FAO, 2012; EPA, 2012).

Water filters, rubber, antifreeze, floor waxes, crayons, chalks, fertilizer, and adhesives are all products obtained from swine by-products (EPA, 2012). Distribution of pigs across the globe is mostly influenced by religious and cultural factors, leading to few pigs centred around Muslim or Islam dominated countries (Kurosaki, 1998). The ability of swine to survive under a wide range of environmental conditions make their rearing scattered all over the world (FAO, 2012). The worlds' leading production and consumption of pork are found in Asia, where a significant volumes of international and intercontinental trade occurs regarding both live and slaughtered pigs (FAO, 2020).

1.2. Chinese swine production

The Peoples Republic of China has been tagged as having the world's largest pig herd, with home to almost half of the global pig population (FAO, 2012). The last two decades have seen a sharp increase in demand for livestock in China due to rapid acceleration of economic development, rising living standards, and population growth (FAO, 2020). China's swine industry forms an integral part of the growth witnessed in the livestock sector as Chinese nationals consume almost 50% of the total pork produced in the world (Tan and Li, 2010). Though there has been an increase in demand for livestock over the last decades, Chinese swine industry has undergone massive structural changes leading to a reduction in the overall number of farms with an increase in large, and specialised farms (Lander et al., 2020). Despite the structural changes taken place in the Chinese livestock production over the past decades, pork production remains the backbone of China's livestock industry (Guo and Chen, 2009; Zhang et al., 2021).

With an increased urbanisation, continued income growth and rising meat demands, more input will be required from the swine industry to be able to meet the needs of the substantial market potential (Woolsey and Zhang, 2009). In mainland China, a greater percentage of individual families with small number of animals predominates the Chinese pig population (McOrist and Walters, 2009). Despite being home to half of the worlds pig population, China is considered a net importer of pigs with its import drive expanding exponentially during the economic development era (Woolsey and Zhang, 2009). Total swine inventory in 2020, exceeded over 700 million herds surpassing that of 654 million herds in the preceding year (Lander et al., 2020). Although China leads in terms of the highest number of pig herds than any other country, the European Union holds the title in terms of pork exports followed by the United States (Zhang et al., 2021).

Pork exports exceeding 3 million metric tons were exported by the EU in 2018 alone, followed by the United States with about 2.7 million metric tons (Lander et al., 2020). China's high demand for pork in homeland cannot be met by domestic production alone and as a result, led to the importation of over 1.62 million metric tons of pork in the year 2017 (Zhang et al., 2021). System of production ranges from huge capital-intensive production units to small labour-intensive systems, where scavenging for food is done by the pigs (Tan and Li, 2010). Other production systems includes small numbers being kept inside a shed in owner's residence in a

village or town and fed with waste or leftover food as a supplement aside scavenging (Huang et al., 2009).

1.3. Norwegian swine production

Norwegian pig production has witnessed massive structural transformation than any other livestock production in the country (Borgen et al., 2005). Holding-sow piglet population have seen a half reduction in terms of numbers in the last decades, as well as number of piglet producers (Borgen et al., 2004). Meanwhile, size of the average herd has seen a double growth over the same period (Fredriksen, 2005). Annually, Norway produces approximately 1.4 million fattening pigs or 108 thousand metric tons of pork (Elvbakken, 1997). A total of NOK 2.20 billion is realised from the production and sales of pork annually and the number of herds is 1700 (Kyrre et al., 2004).

Norwegian pig producers can be classified as either fattening or piglet/combined producers. Combined producers involves fattening of their own piglets till they reach slaughter weight. Meanwhile, fattening producers secure piglets from piglet producers at around 25 kg weight and fatten them up to slaughter weight at 75-90 kg (Fredriksen, 2005). Other category of swine production in Norway is known as Sow pool. Under this system of production, a hub of sow owners and several satellite of piglet producers lease out highly pregnant sows from the hub to potential seekers (Jacobsen, 2003). The sows are later transported back to the hub after farrowing and weaning of the piglets are done.

The pyramid in figure 2 describes the structural organisation or setup of the Norwegian pig production. The structure begins with the nucleus herds whose primary duty is to ensure the supply of a specific pathogen free stock to help improve pig production, followed by the multiplier herds which also ensures the multiplication of the nucleus herd through the use of technological advancement such as genomic selection. These are followed by the conventional sow herds, fattening herds and sow pool, respectively.

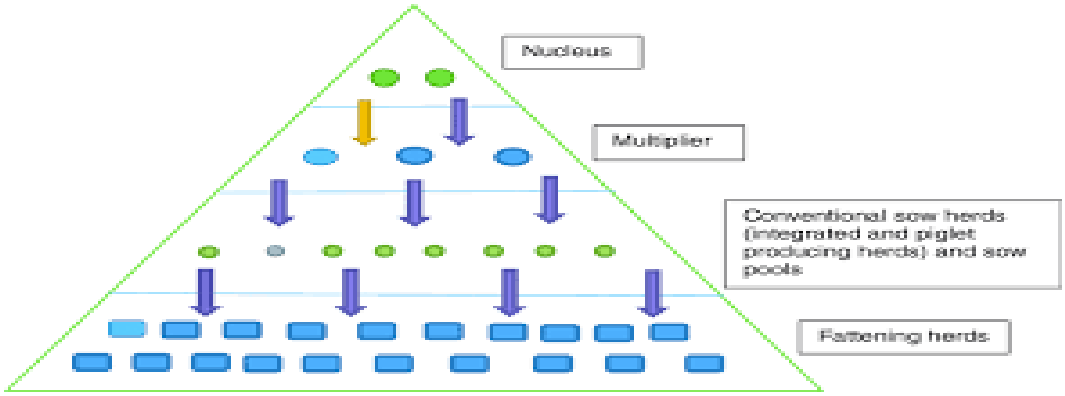

Figure 1. Pyramid structure of Norway's pig production. (image courtesy: researchgate.net)

Considering the lowering number of pig producers in the last decade irrespective of the fact of doubled herd size averagely, Norwegian pig production is globally recognised according to international standards as relatively small production. Most of the pigs produced in Norway emanates from certain geographical locations. Three areas namely, Nord-Trøndelag, Rogaland and parts of Austlandet represents the most dominant producing regions considering the volumes (tons of pork) produced (Borgen et al., 2005; Kjærnes et al., 2003). These locations are characterised by rich farmlands with grain production, found in the south and middle parts of Norway and possess mild climate in addition (Fredriksen, 2005). The hierarchy among commercial pig units are arranged as individual family farms with special focus on piglets production, grower-finisher production, or combined production (Kjærnes et al., 2003).

1.4. Ghanaian swine production

Swine production has an immense growth potential in the tropics. It is a source of livelihood to many families especially in the rural areas in sub-Sahara Africa (Gandini and Villa, 2003). Pig production is spread all over the continent including Ghana due to high prolificacy rate of the species, ease of management, and versatility and adaptability to wide range of environmental conditions (Akwetey and Yamoah, 2013). Swine keeping serves as a source of protein and income for many poor and rural dwellers in Ghana (FAO, 2012). In Ghana, many people venture into this lucrative business due to the following high potentials i.e. fast growth rate, high feed conversion efficiency, high dressing percentage, short gestation length, large litter sizes compared to other livestock and shorter generational interval (APD, 2003).

Swine production by the local or small-scale farmers in Ghana is characterised by lack of or need for more information on production practices needed to cause appropriate changes for

increased productivity (Akwetey and Yamoah, 2013). Different systems or methods are used in raising swine in Ghana. These ranges from a pasture facility where little or no shelter is provided over the animals, and where they can move about freely to one where proper shelter is provided to ensure proper growth and productivity of the herds (FAOSTATS, 2004). According to FAO (2021), Ghana's pig population stood at 759,211 thousand herds in 2020, showing a downwards turn from 768,000 herds the preceding year.

As the economy of the study regions/countries begin to expand exponentially, livestock production experiences an accompanying structural changes. In order to assess the magnitude of economic impact associated with swine keeping at the sector level (both on farm and in value chain), on livelihoods and the broader national economy pertaining to the study regions, a comprehensive study involving breeds/breeding, feed and feed ingredients, health status, management, and economy will be delved into to ascertain their real impact on the economy and the swine enterprise as a whole. The magnitude to which each sector is transformed bear a direct relationship or correlates with the government, policy makers, practitioners, and other actors to determine their effectiveness to the growth of the swine industry.

Thus, it is worth comparing production of pigs in the three countries so as to be able to learn how production goes on in each of the countries pertaining to breeds/breeding, feed and feed ingredients, management, health status, and economy. The study also sought to learn the strengths and weaknesses/barriers of each country in the production and based on these, suggest appropriate means of improving on the production of pigs in the three countries and beyond.

2. BREEDS/BREEDING OF PIGS

Domestic pig breeds are mostly classified as either native or exotic. The type of breed predominant in a locality is mostly determined by the ability to survive under wide range of prevailing environmental conditions. Through breeding, healthy and disease resistant herds, high litter producing animals, lean-meat herds, good mothering ability sows, and harsh environmental resistant pig breeds have evolved over the past decades.

2.1.Native breeds of China

China is the place not only referred to as home to half of the worlds' pig population, but also a country where majority of unknown pigs originate from with different characteristic and features (Zhang et al., 2019). In China, swine domestication occurred in few separate provinces around 7,000 - 9,000 years ago (Fabuel et al., 2004). The native Chinese breeds at the time were bred over desirable traits such as outdoor hardiness, fatty carcass with lard deposition and good foraging appetite (Ramljak et al., 2018). China can boost of approximately 108 local pig breeds and strains designated into separate groups (Ramljak et al., 2018; CAG, 2001).

The TaiHu pigs, one of the most popular native breeds have performed extremely superior over many western breeds due to their high fertility, excellent mothering ability, placid make up and possession of extra teats (Zhang et al., 2019; Ma et al., 2013). Striking external features of the TaiHu pigs includes a big head, and a wide forehead with thick and wrinkled skin (Duchet-Suchaux et al., 1991; Li et al., 2013). They also have big droopy ears and mouth flaps, and eight or nine pair of teats (Li et al., 2013). Other characterisations include slow-growing reaching an average body weight of 48 kg at six months of age (Ma et al., 2013).

It can produce average litter sizes of 12, 14, and 16 at the first, second and third farrowing respectively (Li et al., 2013). Other local breeds such as Bihu pigs, Lanxi Hua pigs, and Shengxian pigs are known to be highly adaptable and resistant to rough feeding (Zhang et al., 2019). There is existence of larger native breeder establishments besides the backyard farms, where breeding of some of the most popular native breeds are carried out (Ma et al., 2013; Fabuel et al., 2004). A typical of such establishments can be found in several Zhejiang breeding centres having over four hundred sows each. The Suzhou city centre offers both meat breed

sows like SuTai and mothering TaiHu sow breeds such as the Meishan and Fengjing (Duchet-Suchaux et al., 1991).

In many of these establishments, cross breeding involving local breeds are performed to form new lines. The current expansion or consolidation of the pig farm sector in China does not include the native pig breeds (Zhang et al., 2019). The non-involvement of the local breed in the expansion drive is mostly related to lower market prices and slow growth rate. The improved western breeds when compared to the native or local ones, provide greater turnover with their faster growth rate and high-priced breeds (Ma et al., 2013). This development has led to a reduction in herd size of some of the more ambiguous Chinese native breeds.

Figure below showing a typical TaiHu pig with exceptional phenotypic features such as big head, a wide forehead with thick and wrinkled skin and droopy ears and mouth flaps.

Figure 2. The Meishan Chinese pig breed (image courtesy: pinterest.com)

2.2. Native breeds of Norway

Relative to the local domestic pig breed in Norway, the Norwegian Landrace is the leader or dominant breed recognised. Norway cannot boost of having numerous registered strains of swine, as number of the registered strains are limited (Hansson, 2008). Norwegian landrace together with other pig breeds are mostly farmed in the southern part the country (Ollivier,

2009). Many of the landrace species are concentrated in the Hamar regions, with a whitish coat colour and possesses a droopy ear. Aside these two features, other striking features of the Norwegian Landrace includes a small head, narrow shoulder, hooked and elongated back, and a plumb ham (Hansson, 2008).

The Norwegian Landrace breed originated from the importation of landraces from neighbouring and other European countries having the landrace traits or genes of interest (Laval et al., 2000). Their importation was followed by a special selection to offer the mixing of introduced strains a unique settlement to the environment of concern (southern Norway). Due to special qualities or features possessed by this breed, it has become a high demanding commodity resulting from its breeding stock spread across the entire European circles, and beyond (Chevalet et al., 2006). The spread of the breed across borders is due to the high feed conversion efficiency and potential high growth rate.

Countries such as England, Ireland, France, Denmark, Poland, Canada, and the Czech Republic are all net importers of Norwegian Landrace (Hansson, 2008). Most of these importing countries have a strain or breed of landraces of their own, yet still they import Norwegian Landrace to show the level of significance in stocking up their swine genetic pool or base (Chevalet et al., 2006; Ollivier, 2009). One important characteristic of Norwegian Landrace is the ability to produce 8 to 9 litter of mean weaned piglets twice or trice per annum (Ollivier, 2009). Another important characteristic is the ability to attain a 100 kg weight within 142 days after farrowing and omnivorous in nature (Laval et al., 2000; Hansson, 2008). A full-grown Norwegian Landrace sow breed has an average mature weight of 204 to 272 kg, with a 226-318 kg as an average boar weight at maturity (Ollivier, 2009).

Figure below depicting a Norwegian Landrace with white skin coat, small head, narrow shoulder, hooked and elongated back and plumb ham as physical characteristics.

Figure 3. Norwegian Landrace pig breed (image courtesy: bib.ge)

2.3. Native breeds of Ghana

The Ashanti dwarf pig is the main and dominant local pig breed in Ghana and has demonstrated to possess both European and Asian traits (Amponsah et al., 2017). It can withstand harsh environmental conditions, less susceptible to many local diseases and parasites, hardy, more resistant to heat strokes, able to survive under poor supervision and management, mostly scavengers and able to digest high fibre contents, low demand for feed, and possess good mothering ability (Ramirez et al., 2012).

The latter quality is particularly important especially in free ranging system where piglets are needed to be protected from predators. The meat of Ashanti dwarf pig is also considered superior to exotic pigs (Madzimure, 2011). Ashanti dwarf pigs are smaller in size than most imported commercial breeds, has lower growth rates, and reproductively poor performers. The average number of young ones produced per Ashanti Black pig is 5-7 piglets with a 22.3% pre weaning mortality rate and average mature body weight of 60 kg (APD, 2003).

Figure 5 showing a typical local pig breed of Ghana called the Ashanti dwarf pig, a popular and most revered native breed with Black skin coat, concave head, erect ears with backwards projection and a short cylindrical snout.

Figure 4. Ashanti black dwarf pig breed (image courtesy: ug.edu.gh)

Table 1 below showing differences and similarities among the native or local breeds in the study countries.

Native or local pig breed		
China	**Norway**	**Ghana**
TaiHu Good foraging appetite. Good outdoor hardiness. Highly fertile. Excellent mothering ability with extra teat. Slow growing with average body weight of 48kg in six months. Litter size of 12, 14 and 16 at first, second and third farrowing respectively.	**Norwegian Landrace** High feed convertor. High growth rate. Farrows 8 to 9 litters of mean weaned piglets two times or three times yearly. Body weight of 100kg within 142 days after farrowing. Matures sow weighs 204 to 272kg and mature boar weighs 228 to 300kg.	**ADP** Thrive in harsh environmental conditions. Less susceptible to local diseases and pest. Hardy and resistant to heat stroke. scavengers Digest high fibre content. low demand for feed. Good mothering ability.

High adaptable and resistant to rough feeding. Other local breeds are Bihu pigs, Lanxi Hua pigs and Shengxian pigs with similar characteristics.		High survival rate under poor supervision and management. Poor reproductive performance. Small in size. Slow growth. Superior meat taste. Lower piglet production (5-7 piglets). Average mature body weight of 60kg.

2.4. Chinese and Norwegian exotic breeds

The early modern Europeans discovered the superiority of Chinese pigs regarding certain traits to their own and bred the two to produce a progeny, now being used across the world in industrial pork production, including China (Zhang et al., 2015). The exotic pig breeds found in most Chinese and Norwegian pig farms are similar or same and they include the Landraces, Large whites, Hampshire, Tibetan, Tamworth, and Duroc breeds (Zhang et al., 2019). Significant improvements in connectivity to breeding have been witnessed in Norwegian pig production following an introduction of these breeds, and also the use of genomic selection in pig breeding programme since 2014 (Nordbø et al., 2014).

The massive growth seen over the last decades in the Chinese swine industry with an extension of making it a world leader in terms of production, can be attributed to the introduction of these high-performance breeds (Zhang et al., 2019). The maturing age of the sows occurs early, larger litter size producer (up to fifteen piglets), usually a fair mothering ability, and high feed convertor (Ramirez et al., 2012; Zhang et al., 2015). Duroc is best known as an excellent weight gainer with body weight reaching 400 kg and 350 kg for mature boar and sows, respectively.

2.5. Ghanaian exotic breeds

The Large white and Landrace are the two most successful and dominant exotic pig breeds in Ghana (Amponsah et al., 2017). Their introduction to the Ghanaian pig keeping has shown a tremendous level of success with over 95% succession rate (FAO, 2012). Other physical characteristics includes a long neck, slightly dished face, a broad snout, fine and long neck, and evenly full to shoulders with deep and wide chest (Ramirez et al., 2009). Large white is an efficient user of feed, highly prolific, very docile, has excellent mothering ability, boars attain a mature body weight between 300 kg to 450 kg, and mature sows weigh between 250 kg to 350 kg (FAO, 2012; Zhang et al., 2015).

The Landrace breed is highly prolific, efficient feed utilizer, has leaner carcass than meat, and a less back fat and lard (Ramirez et al., 2013; Madzimure, 2011). Mature boars usually weigh around 380 kg and mature sows attaining 320 kg in weight. A crossbred obtained from crossing Large white or Landrace and Ashanti black pigs possesses qualities of both breeds, highly efficient and productive as well (Amponsah et al., 2017).

Table 2 describing the differences and similarities among the exotic breeds in the three study countries.

Exotic/foreign breeds		
China	**Norway**	**Ghana**
The exotic breeds (Large white, Landrace, Hampshire, and Tamworth) of the three countries are similar. Sow is early maturing. Larger litter size (15 piglets). High feed convertor. Fair mothering ability. Highly fertile. The Duroc being an excellent weight gainer (400kg per six months for boar and 350kg per six months for sow) in terms of body weight is exclusive to China and Norway.	The sows mature faster. Produces large number of piglets (up to 15 piglets per farrowing). Sows have fair mothering ability. Highly conceivable.	**Landrace** Highly prolific. Mature boar is 380kg and mature sow is 320kg. High feed convertor. Learner carcass than meat and less back fat. Docile. **Large white** Excellent mothering ability. Very prolific and docile. Boar is 300 to 450kg at maturity and sow is 250 to 350 at maturity.

2.6. Pure breeding

Pure breeding in swine production involves the mating of purebred individuals of the same breed leading to the progeny having the same genetic makeup (Hope, 2008). Pure breeding helps in the identification and propagation of superior genes vital and crucial for commercial

production specifically in crossbreeding programmes (Solberg et al., 2008). Superior females which helps in maintaining valuable genetic materials are identified through pure breeding technique (Van Overwalle, 2009). Crossbreeding becomes worthless without the usage of pure-bred individuals.

Artificial Insemination (AI) is the technique usually employed by purebred producers to capture the best heritable traits available (Norsvin, 2010). On merit, semen from purebred boars can be purchased for usage from many commercial boar outlets scattered all over the world (Ramstad and Stokstad, 2005). Some key parameters are critically considered by purebred producers before selecting a breeding stock. Structural correctness, performance data, muscling and leanness are some of the main factors considered in purebred stock selection (Zhang et al., 2015; Norsvin, 2010).

2.6.1. Chinese Pure breeding practices

Chinese pig industry witnessed a tremendous herd growth with approximately 406.5 million pigs bred in 2020 alone (Lander et al., 2020). This growth is recognised as huge and massive success by the pig livestock fraternity following from 2019 when the pig industry was struck by the African swine fever (FAO, 2020). The preceding year saw a total number of breeding pigs hovering around 310.41 million (Lander et al., 2020). The use of right breeding techniques and methods such as pure breeding, accounted for the significant growth in pig numbers post African swine fever in China. Purebred individuals with high performance standings were used for multiplying the herds with the aid of artificial insemination procedures to bridge the gap in pig numbers post swine fever (Tan and Li, 2010).

2.6.2. Norwegian Pure breeding practices

In Norway, there exist approximately forty closed herds that produce thoroughbred animals of the breeds Norwegian Landrace, Duroc and Hampshire (Grindflek, 2012). These breeds have exhibited good health profile and possesses the best semen from the breeding elite Norsvin (Jensen, 2008). Through pure breeding, most herds are able to supply high performance boars to the testing station and semen collection centres (Norsvin, 2010). Distribution of purebred Norwegian Landrace sows designated for multiplying the breeding herds also emanates from this practice.

During the process of herd multiplication, Landrace sows are inseminated with Yorkshire semen, and the hybrid sows produced are sold to the breeding herds (Bogers, 2012). Norsvin, a Norwegian speciality in genetics and breeding have developed programmes for pure breeding, crossbreeding and artificial insemination in swine production (Bogers and West, 2012). Their developments has led to the production of effective, healthy, and robust pigs that perform well under different contingencies and production environments (Grindflek, 2012).

2.6.3. Ghanaian Pure breeding practices

Many of the pig breeding improvement programmes in Ghana often comes through the importation of improved sires to upgrade the local breeds (BSR, 2014). Most breeding programmes including pure breeding has not been successful to a larger extent in Ghana based on the following reasons. The researcher-initiated, researcher-planned, and researcher-executed scale of most of these programmes with truly little involvement of the intended beneficiaries (farmers) accounts for the failure (Fleischer et al., 1995).

Another cause for the failure can be attributed to lack of proper record keeping among most Ghanaian pig keepers which is vital in breeding programmes. Most pig farmers also perceive some of these breeding programmes as cost-effective pertaining to associated technologies involved (Fleischer et al., 1995). These combining factors accounts for the low purebred pigs compared to other breeding practices in the livestock hierarchy in Ghana. Majority of the breeding programmes that produce purebred pigs are mostly carried out at animal research station, demonstration farms, university farms, and the large commercial pig units (Amponsah et al., 2017). Smallholder or backyard producers who produces substantial population of pigs are mostly left out of such an important initiative for obvious reasons (MOFA, 2013).

Shown in the figure below involves a crossing between an American Landrace boar and a British Landrace sow which resulted in the production of a purebred Landrace progeny. The purebred progeny is expected to possess both the superior traits inherited from the involved parents and performs better than either of the parents.

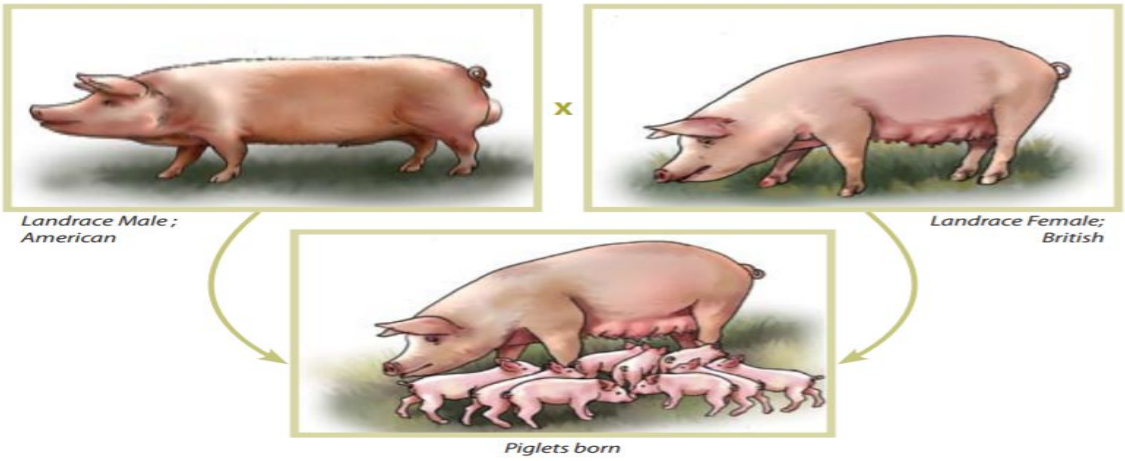

Figure 5. Purebred Landrace pigs and their progenies (image courtesy: pigsite.com)

2.7. Crossbreeding

This system of breeding involves the mating of two individuals from different breeds with the aim of inculcating into the progeny a gene combination usually different from that already existing in either of the participating parents. Mostly, this practice involves the use of two or more breeds, depending on the expected results or outcome from the breeder. Crossbreeding is performed to witness an improvement in the performance of the progeny above that of either parents. Courtesy crossbreeding, local or indigenous sow can be taken to exotic boar for crossing to produce a hybrid. Crossbreeding gives room for another exotic male or female which is not part of the herd to be introduced. Crossbreds usually possessed healthy and bigger body size, strong, active, and piglets dubbed as fast growers.

2.7.1. Chinese Cross breeding practices

There exist many outlined crossbreeding systems regarding swine production that producers commonly prefer in China. The use of crossbreeding programmes involving some indigenous Chinese breeds like the Meishan, and other western breeds have spearheaded the fast growth witnessed in the swine industry over the last decades (Guo and Chen, 2009). A significant improvement in sow productivity has been realised through maximization of maternal heterosis during crossbreeding (Tan and Li, 2010). Crossing between a highly prolific Chinese breed

like the Meishan and other western breeds turns to produce a higher level of heterosis than it is found in crosses between western breeds (Zhang et al., 1998).

Many crossbred Meishan females have proven to be superior in the area of reproductive and litter productivity traits compared to purebred and F1 crosses of western breeds (Guo and Chen, 2009). An example of the crosses between the Meishan, and other western breeds includes (Meishan x Yorkshire) x Landrace and Duroc x (Meishan x Yorkshire). Purebreds involved in crossbreeding programme are selected on merit of their ability to add certain new traits to the final crossbred pig (Woolsay and Zhang, 2009; Tan and Li, 2010).

In China, pig breeders usually include western breeds such as Landrace or Yorkshire in their crossbreeding practices based on their superior maternal traits including number born alive and/or milking ability (Lander et al., 2020; Chen et al., 2001). The involvement of Duroc or Hampshire breed by Chinese producers or breeders in their crossbreeding system is due to their high growth rate, feed efficiency and carcass traits (FAO, 2012).

2.7.2. Norwegian Cross breeding practices

The introduction of selective breeding in Norwegian swine production has helped place a high pressure on increasing the litter size, in order to maximise profit (Norsvin, 2010). One key technique used in achieving a large litter size in the swine industry is the use of crossbreeding programme, which is of no difference than what is practiced in China. The use of crossbreeding by Norwegian pig breeders has led to the production of more healthy, prolific, tolerant, faster growth, and genetically diversified and improved pig breeds (Grindflek, 2012). Most crossbred pigs in Norway comes from a Landrace and Duroc cross with the progeny becoming the terminal sire at the end (Fredriksen, 2005).

The use of crossbreeding strategies by Norwegian pig breeders has promoted the exploitation of genetic and reproductive technology to meet the needs of the next generation of production animals (Norsvin, 2010; Kyrre et al., 2004). Crossbreeding strategies employed has helped create a pool of animal species with many changes genetically, for sustainable development of the Norwegian livestock industry (Elvbakken, 1997). Development of Norwegian crossbred pigs through its breeding strategies has increase the ability to better match up the next generation of production as means of enhanced sustainability (Borgen et al., 2005). Others such as exploiting the complementarity of breed lines and achieving characteristics that would have

become impossible to be improved upon in a single breed, becomes realisable through crossbreeding by pig producers in Norway (Jacobsen, 2003).

2.7.3. Ghanaian Cross breeding practices

Crossbreeding is a customary practice among Ghanaian pig farmers both at the smallholder and the large-scale commercial farms. Most of the crossbred pigs produced in Ghana are usually from a crossing involving either of the two most dominant exotic breeds, Landrace or Large white and Ashanti Black pig (Amponsah et al., 2015). The resulting progeny exhibits greater embryonic survival, greater vigour at birth, and lowered death rates after farrowing. They also shows a faster growth leading to reaching marketing age earlier (Ayizanga et al., 2018). Crossbred sows turn to have high conception rate, larger litter size at birth, improved milking ability, as well as displays good mothering ability (Ayizanga et al., 2018).

Though crossbred pigs have proven superior to local or native pigs, however, indiscriminate crossbreeding still remains a potential threat. Through indiscriminate crossbreeding, hundreds of domestic pig breeds worldwide stands in danger of going extinction, and the few remaining ones being threatened by inefficient use or loss due to this practice (Nidup and Moran, 2011). Most swine producers or breeders in Ghana normally focused on peculiar performance characteristics regarding their breeding stock before selection for crossbreeding to complement one another in terms of desired traits (MOFA, 2013). Boars for crossbreeding are mostly selected based on superiority regarding economically viable traits (Akwetey and Yamoah, 2013).

Some of the boar traits considered for selection includes growth rate, feed efficiency, desirable body conformation, and carcass quality (Kamuah et al., 2018). The crossbreds obtained from Landrace or Large white and Ashanti Black pig are usually rugged and less susceptible to diseases and pest in the prevailing environment (Ayizanga et al., 2018). They performs better under less favourable management and housing conditions.

The image in the figure below shows a crossbred piglets with high superior genetic features obtained from a crossing between a Hampshire sow and Duroc boar. The progeny or hybrid which is the end product is expected to exhibit the distinct features of each parent involved in the crossbreeding exercise.

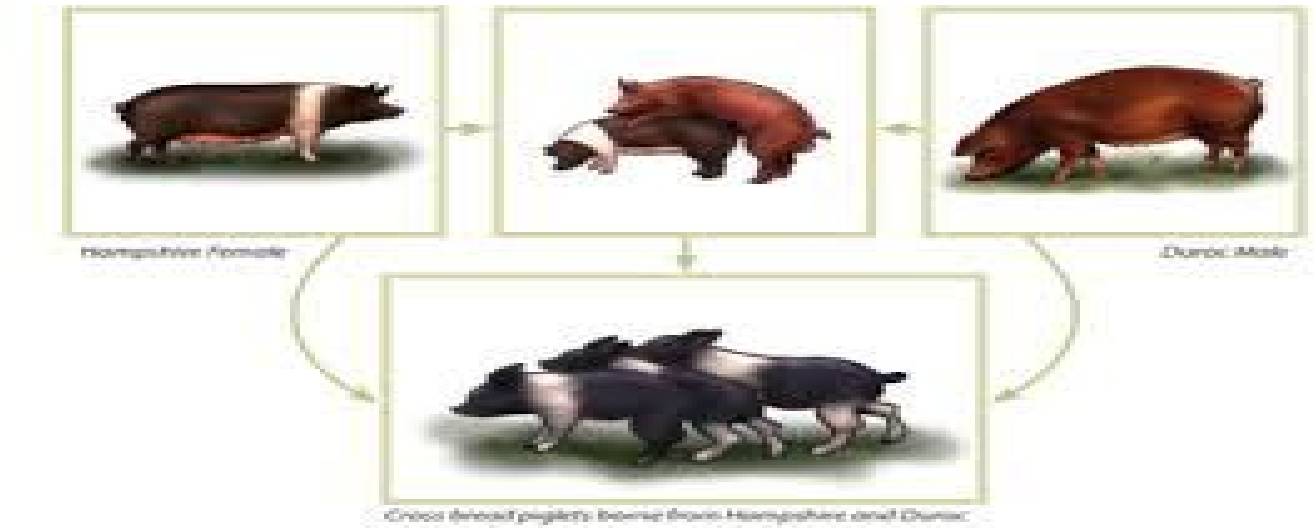

Figure 6. A crossbred between Hampshire and Duroc (image courtesy: pigsite.com)

2.8. Inbreeding

This breeding method is considered the most common, involving crossing individuals belonging to same breed but most often closely related than the average of the breed. Despite this practice being a global problem, it is found in abundance in many parts of Africa and the Asia-pacific regions, than any other regions globally (FAO, 2004). Resulting from this practice is the concentration of common genes in the progeny (Chen et al., 2001). The involvement of homozygous gene pair and their high frequency often leads to the creation of both desirable and undesirable traits (Borgen et al., 2005; Tan and Li, 2010).

Decreased litter size and increased mortality are some of the realising consequences which emanates from this practice (Zhang et al., 1998). Inbred sows are poor in milking and possesses bad mothering ability. Sexual maturity in gilts and boars are delayed as a result of this practice and inbred boars have less sexual libido (FAO, 2004). Gilts that are products of inbreeding produces fewer egg during oestrus and farrow small litters compared to crossbred ones (Grindflek, 2012).

2.8.1. Chinese and Norwegian Inbreeding practices

The closeness of the elite herds working together in pig breeding programmes, makes inbreeding a critical issue compared to other species. Geneticists in both China and Norway are aware of the devastating consequences of inbreeding and tries as much as possible to do away with their herds (Woolliams et al., 2015). Procedures such as selection based on genetic evaluation using animal models, whose accuracy is increased via parental additional information, aids in increasing probability of co-selection of relatives (Falconer and Mackay, 1996). This scenario promotes inbreeding and causes a reduction of genetic variation which could in effect negatively affect breeding programmes by way of inbreeding depression (FAO, 2000).

Some of the ways employed by both Chinese and Norwegian pig breeders in curbing high levels of inbreeding among their herds includes critically examining relatedness allowed in mating, selection within the families, and the number of progeny per male and female to be selected (Alvseike et al., 2016). Inbreeding practice is under serious elimination drive in both Norwegian and Chinese swine farms as the practice is known to have detrimental effects on the herds. Most of the breeds used in their breeding programmes have a pedigree information and moreover, pedigree information has existentially been used in monitoring and evaluating genetic diversity of part taking breeds (Melka and Schenkel, 2010).

2.8.2. Ghanaian Inbreeding practices

Mating of individual pigs closely related is a common phenomenon found in Ghana. Adoption of this breeding technique by most Ghanaian pig producers or breeders has led to a reduction in performance with variations among traits of the end products (progenies) (Nidup and Moran, 2011). Numerous factors ranging from lack of or improper records keeping, to the viewing of other breeding systems as expensive by most pig producers, accounts for high number of inbred pigs found in Ghana (Ayizanga et al., 2018). Most inbred pigs produced falls under smallholder farmer system, mostly with lack of estimated breeding values due to improper records keeping on the herds to be selected for breeding programmes (Kamuah et al., 2018). This scenario does not promote identifying animals that are closely related which share more genes associated with superior genetic status for use.

In order to avoid closely related boars and sows from mating, proper examination of pedigrees must be performed before mating commences (Nidup and Moran, 2011). Occurrence of inbreeding amongst Ghanaian pig farms has led to a decreased genetic variation (FAO, 2012). Boars emanating from high inbred lineage achieved puberty lately and usually has less or lack libido (Amponsah et al., 2015). Inbred pigs has poorer reproductive efficiency, higher frequency of hereditary abnormalities, lower growth rates, mostly poor performers and do not looks attractive in the eyes of customers interested in performance (Ayizanga et al., 2018). Most pigs in Ghana are kept in small, closed population leading to a surge in inbreeding and causes loss of alleles, which does not become possible to counterbalance without migration (Madzimure, 2011).

Table 3 comparing different breeding practices/programme among the study countries

Breeding practices/programmes		
China	**Norway**	**Ghana**
Effective usage of purebred lines enabled China to record significant growth in pig numbers post ASF. Purebred individuals with high performance standings were selected and used for herd multiplication through artificial insemination. Crossbreeding has helped to improve sow productivity through maximisation of maternal heterosis. Crossbreeding between highly prolific Chinese breed and other western breeds produces progeny	Norway can boost of approximately 40 closed herds that are used to produce purebred animals. High performance boars at testing stations and semen collection centres were raised through pure breeding. Crossbred produced in Norway are more healthy, prolific, tolerant, grows faster and genetically diversified breeds. Terminal sires are produced through crossbreeding.	Pure breeding has not been very successful based on the fact that most of the practice are researcher-initiated, researcher-planned and researcher executed. Low or little involvement of the intended beneficiaries (farmers) in pure breeding programmes. Most pig producers especially peasant/backyard producers view pure breeding as costly due to the associated technology involved. Pure breeding practices are mostly restricted or practiced

with higher level of heterosis than found in crosses between western breeds. Crossbred females like Meishan have proven to be superior in the area of reproductive and litter productivity traits compared to purebred and F1 crosses of western breeds. Selection within the families and number of progeny per male and female to be selected is critically examined to prevent inbreeding. Proper record keeping has been prioritised as means of stopping inbreeding. Likewise in Norway, Chinese geneticists and pig breeders are fighting meticulously to end or reduce inbreeding to the barest minimum.	Crossbreeding is used to improve upon a single breed that would have become impossible. Geneticists and pig breeders are fighting tirelessly to end the inbreeding menace because of its devastating effects. Critical examination of relatedness allowed in mating to avoid inbreeding. Use of pedigree records during selection of animals to prevent inbreeding.	by animal research stations, university farms and large commercial pig farms. Improper record keeping found in most farms limits the practice of pure breeding. Crossbred pigs are usually from crossing involving Landrace or Large white and ADP with progeny exhibiting greater embryonic survival, greater vigour at birth and reduced death rate at birth. Crossbred sow shows high conception rate, larger litter size at birth, improved milking and good mothering ability. Inbreeding has led to a reduction in performance with variations among traits of the end product. Improper record keeping on animals accounts for the high inbreeding numbers. Decreased or reduced genetic variation due to inbreeding.

2.9. Summary of breeds/breeding

In comparison of the native breeds found in the study regions, local Ashanti dwarf pig is hardier in terms of resistance to many local diseases and pest, more resistant to heat strokes, able to survive under poor supervision and management, and able to digest high fibre content. It also has low demand for food and its meat is considered most superior to that of the exotic breeds if prepared hygienically. The ADP is the most dominant local breed in Ghana and apart from the outscoring characteristics listed above, its excellent mothering ability led to the high survival rate of its piglets in a free range, hence, its dominance in Ghana. However, the Ashanti dwarf is a poor and low producer of about 5-7 piglets per farrowing.

Norwegian Landrace being the most popular local breed is able to produce 8-9 litters of mean weaned piglets twice or trice per year as a result of its good mothering ability. The Norwegian landrace is most accepted by a lot of countries such as England, Denmark, Ireland, France, Poland and Canada than the TaiHu in China and ADP of Ghana. In China, TaiHu pig is the most popular and its performance is most superior to many of the western breeds. It is of high fertility, excellent mothering ability, possessed extra teats (about 8-9 pairs of teat), produces large litter size of 12, 14 and 16 at first, second and third farrowing, respectively. However, the TaiHu pig is a slow grower reaching an average body weight of 48kg at 6 months. Other locals in China such as the Bihu, Lanxi Hua and Shengxian pigs are highly adaptable and resistant to rough feeding. China has more local strains of pig followed by Norway and the least is Ghana.

In terms of foreign or exotic breeds, the Landraces, Large whites, Tamworth, Hampshire and Duroc in China and Norway are same and similar, but the Duroc matures faster, produces large litter size (about 15 piglets), have fair mothering ability, and high feed conversion efficiency. The Duroc is the best weight gainer (about 450kg and 350kg for mature boar and sow respectively). However, the Ghana Landrace is highly prolific, has leaner carcass than meat, and less back fat and lard. The mature boar usually weigh around 380kg and sow about 320kg. The Ghana Landrace is also an efficient feed user. The Ghana Large white has excellent mothering ability, very prolific and docile. The boars attain in-body weight of about 300kg and 450kg and sow between 250kg and 350kg on maturity.

The success of pure breeding hinges on the production of proven purebred progenies (males and females). Comparison wise, Norway has about forty closed herds used to produce thorough bred Landraces, Duroc and Hampshire individuals. The high-performance boars of these breeds are used to supply semen to the collection centres (for Artificial Insemination). Also purebred

Landrace sows are produced for multiplying herds by inseminating them with semen from the Yorkshire breed. The hybrid sows from this insemination are sold to the breeding herds. Unlike Norway where structures and programmes for breeding are well developed, little or none exists in Ghana where many breeding improvements are achieved through the importation of proven/improved sires which are used to upgrade the local breed.

In China, the use of pure breeding accounted for the appreciable growth in the population of pig in the post African swine fever menace where these purebred individuals were used through or in artificial insemination. Pure breeding programmes have not been successful in Ghana due to a number of factors including improper records keeping, sidestepping of smallholder/peasant/backyard producers of the animals, most pig producers considers the improvement programmes as costly and technically cumbersome, and restriction of the improvement programme to research station/farms/demonstration and university farms and large commercial farms. In China, purebred individuals are used to multiply herds through Artificial Insemination. Although the right breeding techniques and methods were used, the extent of the programmes does not measure up to that adopted/used in Norway.

Not much difference exist in Norwegian and Chinese crossbreeding. Norwegian crossbreeding practices have led to the creation of a pool of swine species that are superior genetically for the sustenance and development of the Norwegian livestock industry. Also terminal sires are able to be produced through this improvement programme by crossing Norwegian Landraces and Duroc and the progeny used for such purpose. In China, a significant improvement in sow productivity has been realised through the maximization of maternal heterosis during crossbreeding. Likewise in Norway, highly genetically improved and superior pig breeds have been raised in China resulting from this practice. In each country, the dominant indigenous breeds are crossed with the proven exotic breeds. The only slight difference which goes against Ghana in particular is that indiscriminate crossbreeding causes a lot of domestic pig breeds to suffer from underuse and extinction.

With regards to inbreeding, is a common phenomenon in all the three countries. Norway and China have geneticists fighting the practice aggressively by avoiding the selection of animals based on genetic evaluation using animal models whose accuracy is increased via parental additional information, which helps in promoting co-selection of relatives. These countries keep proper pedigree records of the animals at all levels of production which is crucial to the fight against the menace. In Ghana, improper pedigree records kept on the animals is promoting

the practice. Also, most pig producers consider other breeding systems (pure breeding, crossbreeding and artificial insemination) as expensive. Moreover, most pigs are kept in small, closed populations which is an added advantage for inbreeding. Additionally, the shelfing of crossbreeding outcomes of research stations/universities to the disadvantage of small-scale or peasant producers who forms the majority has added another dimension to the practice in Ghana.

3. FEED AND FEED INGREDIENTS

To ensure proper growth and productivity, pigs diet must be able to supply adequate amount of all the vital nutrients required in their right quantities and quality, as well as being fully utilised in the most efficient way (FAO, 2004). Good feed is responsible for growth, body maintenance and production of meat and milk. Some of the ingredients often used in preparing swine diets includes soybeans, maize, rice bran, broken rice, vegetables, and distillers' residue. For the realisation of proper growth and productivity from pig feeding, feeding must follow suite starting with creep feeding for piglets, followed by weaner/grower feeding, and finisher feeding (Close and Cole, 2000).

3.1. Chinese pig feed and feed ingredients

China's utilisation of excellent quality feed enabled it to produce 50 million metric tons of pork from a 660 million swineherd in 2010 (NBSC, 2020). The above figures doubles as the quantity produced in all 27 EU countries combined, and five times the quantity produced in the United States when compared. Achievement of such an amazing feat became possible through provision and proper utilisation of balanced and nutritious swine feed, which promotes proper growth and reproduction. Since most pigs in China are raised in confined/concentrated areas, sources of feed and its quality has been given a topmost priority by both state and private industry players to ensure smooth running and growth of the livestock sector (Guo and Chen, 2009).

In China, most of the pigs are fed commercially prepared swine diets produced out of grains, fruits, and vegetables from markets (Shuang et al., 2009). These feeds usually comes in bags or sacks with labels depicting available ingredients, nutrients, and the amounts contained. Others also comes with the stage and/or category of animals which it can be provided with to ensure its right demands are met (Zhang et al., 2015). Also, Chinese swine producers or farmers feed other forms of feed usually considered cheap, obtained locally, and can be nutritionally balanced when properly treated (Pomar et al., 2016). These kind of feeds are mostly utilised by the backyard or smallholder pig farmers in mainland China.

Kitchen waste from a family's household, restaurants leftovers, and scraps from fruits and vegetables, cooked or treated are also provided as a useful source of swine feed (FAO, 2012). Commercial feed producers in China ensure that sows diet are fortified with dense nutrient

composition based on her growth pattern, body composition, and feed intake (Black, 2009). Chinese feed formulators also ensure that diets meant for breeding gilts or sows contain ingredients capable of providing enough fat reserve that will be of crucial need during rigorous processes such as lactation and strong bones formation (Cameron and Curran, 1994). Chinese boar diets are enriched with enough vitamins and minerals good for boosting boar semen quality.

Commercial swine diets meant for fattening in this region are fortified with low fibre, thus pigs save most of the energy that would have been wasted on the digestion of fibre and transform them into fat. Protein and fat supplements are made use of by fattening producers in China with little or no use of soy hulls, wheat midds, and distillers dried grains with solubles (DDGS) in fattening diets. Most Chinese swine producers ensure there is a considerable amount of saturated fat (with concentration not exceeding 10% of the total energy) in the diet to help promote lean meat production. Also, there is a less use of dairy products or is virtually absent in Chinese swine diet meant for lean meat production.

3.2. Norwegian pig feed and feed ingredients

Norway imports a lot of legumes and seeds, such as soybean meal and rapeseed meal due to their high participatory levels in the feeding of its livestock population, of which pigs are no exception (Alvseike et al., 2016). Currently, most of the common proteins used in producing swine feeds in Norway are being sourced from grasses and grains. Norwegian swine feed producers or formulators are gradually drifting away from the use of fish meal, a particularly good protein source, and instead, substituting with soybean meal. This is due to a restriction of its levels in diets as a result of the taste and smell which becomes transferable to meat products, as well as soaring prices (Glende, 2014).

Other ingredients such as barley, corn, and wheat are used in formulating healthy and nutritious pig diets to promote good growth. The use of other raw materials or ingredients such as rapeseed meal and yeast is becoming prominent and promising, as well as on the increase in the formulation of swine diets in Norway (Øverland and Skrede, 2016). Studies by Foods of Norway reveals that a rapeseed-based diet caused positive changes in the intestinal flora profile of piglets, thus increasing their survival rate post weaning (Alvseike et al., 2016; Kuhad et al., 1997). Breeding diets are enriched with excessive amounts of lysine to promote lean growth and helps in the development of the reproductive system. Norwegian breeders also enrich their

diets with vitamins and minerals, aiding in the formation of stronger bones to survive the rigours of long breeding life (Eissen et al., 2003).

Mature boar diets are fortified with enough grain-soybean meal to meet its nutritional needs. Also, enough vitamins and minerals are included in boar diets to promote quality semen production. Most of the pig producers who can afford skimmed milk, yogurt, and dairy-like products include them in their fattening diets (Alvseike et al., 2016). Other fattening producers also include protein and fat supplements to topple their complete commercial pig feed to ensure pigs put on the needed body mass. In the quest for producing lean meat, most swine producers in Norway include more grains such as corn, wheat, barley, protein supplements, and mineral mixture during formulation (Glende, 2014). Others also achieve this same purpose by feeding herds with diets low in fat and sugars.

3.3. Ghanaian pig feed and feed ingredients

Rice bran is an ingredient obtained from various rice mill centres in Ghana, with excellent quality protein profile at 11% and can be used as a primary ingredient in swine feed formulation (Ganaba et al., 2011). One feature which makes rice bran a preferred feed stuff in formulating pig diets is its high percentage mixing rate with other ingredients during compounding (Komatsi and Kitanishi, 2015). In Ghana, ingredients such as maize, broken rice, cassava and yam peels, industrial by-products e.g., distillers waste and other ingredients are used in formulating pig feed. Distillery or brewers waste plays a key role in traditional pig nutrition in Ghana and mostly found in over 80% of all swine diets (Okai et al., 2000).

One most popular distillery residue used in formulating Ghanaian pig diets is “pito mash” obtained from brewing millet. Majority of swine producers in Ghana are of the peasant or backyard background and cannot afford to feed a complete commercial pig feed/fattening diet. They resort to the use of distillers’ residue in fattening the herds. This high valued ingredient is mostly absent in pregnant/lactating sow, and piglets/weaner diets due to the high content of alcohol in the waste which could have a detrimental health effects (FAO, 2012). Damaged fruits from harvesting, poor handling, and storage are provided as supplemental feeds to the pigs (Okai et al., 2003).

Most pig producers or farmers feed as part of supplemental feeding, household or kitchen leftovers deemed nutritionally fit to their animals especially those under peasant or smallholder

systems. In Ghana, bins/bowls are made available to food joints, restaurants, and neighbouring households for leftover collection, later treated and used as supplemental feed in feeding the stock/herd (Ganaba et al., 2013). Other sources considered cheap, locally obtained and highly nutritious such as leafmeals of baobab, alfalfa, and clover are provided as pig feed. These materials are high in crude protein, crude fibre, vitamins and important minerals capable of promoting swine growth and productivity (Komatsi and Kitanishi, 2015). Dried yam peels which promotes reserved fat build-up are included in the diet of breeding gilts or sows to provide the needed energy required for undergoing rigorous processes such as lactation (Okai et al., 2003).

Table 4 showing the comparison of various feed and feed materials used in feeding pigs in the study regions.

Feed and feed ingredients		
China	**Norway**	**Ghana**
Use of expensive complete commercial feed stored in bags with indications of available nutrients and quantities in commercial farms. Use of local and cheap sources of materials such as kitchen waste, restaurant/food joint leftovers properly cooked or treated. Maize/corn, rice bran, wheat bran, soybean meal and distillers spent grains are used to formulate local swine feed.	Use of expensive complete commercial feed stored in bags with indications of available nutrients and quantities in commercial farms. Use of barley, corn and wheat to prepare swine diet. Use of yeast as substitute for expensive fishmeal. Use of legume/soybean and seeds/rapeseed as protein sources to reduce cost of feed.	Use of expensive complete commercial feed stored in bags with indications of available nutrients and quantities in commercial farms. Universities, research stations and demonstration farms also use complete commercial feeds. Locally available materials such as vegetables, kitchen waste, restaurant and food joint leftovers properly treated are used just as in China. Use of broken rice, rice bran, leafmeal of baobab as source of protein and mineral, as well

Use of DDGS in feeding pig which help reduce feed cost significantly is exclusive to China and Norway.		as leaves of alfalfa and clover. Other materials used are pito mash.

3.4. Summary of feed and feed ingredients

Relating to similarities and differences in terms of feeding, the quality of pig feed should be of paramount relevance to the country, producer and farmers because the quality of feeds reflects positively in the quality of animals produced as well as their numbers. For commercially prepared feeds, no significant difference exist among manufacturers in the three countries. The feeds come in bags or sacks with labels indicating availability of nutrients and their quantities. Some differences exist in locally prepared feeds for small-scale/backyard productions.

Norway relies on the imports of legumes/soybeans for soybean meal and seed/rapeseed for rapeseed meal. Currently, a high proportion of proteins for feeding pigs are obtained from grasses (yeast) and grains (soyabean/rapeseed meal) leading to a move away from the use of expensive fishmeal. Apart from the above in Norway, Norway also use ingredients such as barley, corn and wheat in preparing pig feed. Both Ghana and China make use of cheap and locally available materials such as household/kitchen/restaurant/food joint waste and scraps from fruits and vegetables properly treated or cooked in feeding the herds.

In Ghana, apart from the use of cheap and locally available materials, use is also made of pito mash and baobab leafmeal in feeding pigs. The peels of yam and cassava are dried and mashed for feeding the pigs. Also, a special mixture of corn/millet/rice/sorghum/soyabean and dried cassava obtained from corn mills is also available for feeding pigs mostly in rural settings. In Northern part of Ghana, baobab leafmeal is mixed thoroughly with the mixture and fed to the animals. The inclusion of baobab leafmeal is crucial/vital as it contains high dietary fibre, crude proteins, vitamins and important minerals needed for proper growth and functionality of the animal.

In Ghana, small-scale pig producers are on the majority side, and these do not have enough capital or money to depend on commercially formulated feed and therefore depend very much on feed obtained from local sources or materials. In Norway, yeast has been tested to substitute for fishmeal (about 40% of proteins from fishmeal and soybean meal is provided by yeast). Norway imports a lot of legumes/soybean and seeds such as rape seed for protein and is therefore doing research to increase the utilisation of alternative protein ingredients to be less dependent on import. Where good and cheap sources of local materials are available, it is best to use such materials to beat down the cost of feed without compromising on quality.

Among Ghanaian and Chinese peasant farmers, cheap sources of local materials such as kitchen leftovers, scraps from restaurants and food joints as well as broken ingredients from harvesting, transportation, processing and hulling of grains and vegetables, when well treated, can serve this purpose. In some Norwegian and Chinese commercial farms, the use of DDGS over the past two decades has helped to appreciably reduce the cost of feed. DDGS supply an appreciable amount of lipids in feed making the use of additional lipid unnecessary. In Norway, the use of yeast has also gone a long way to achieve this purpose and also the use of soybean products which are least protein source has reduced cost of feeds.

In all the three countries, commercial feed formulators include certain ingredients or additives for marketing purposes especially when they are cheap. The removal of such ingredients/additives, without affecting the quality of the feed is also a means of reducing the cost of feed. In Ghana, some peasant farmers mash the pod of used groundnut which is an exceptionally reliable source of protein and can be cheaply obtained especially in the Northern sector of the country and add to the diet of pigs. Also, the use of baobab leafmeal which is very abundant in Ghana is also a means of cost reduction without affecting quality. In the three countries, some ingredients can be substituted, to cheapen feed comparatively. Typical example is the use of molasses, dextrose and sucrose in place of lactose for piglets which requires about 20% lactose for proper functioning.

Feed formulators in the three countries prepare feed for the production of lean meat pork in the same manner in that feeds are rich in protein or protein supplements, minerals/mineral mixture, vitamins and cheap but quality/essential nutrients. There is a reduction in the inclusion of fat/fat supplements, sugars and dairy products. Sometimes dairy products are excluded totally from the feed. In China, however, there is the inclusion of substantial proportion of lysine in the first phase of feeding the animal, but this is reduced in the latter phase. In Norway, pigs are fed with

more grains such as wheat, barley and corn to achieve leanness. In Ghana, there is limited amount or total absence of distillers waste in the feed. Also, feeding the pigs with mash of dried cassava peels properly prepared can also lead to leanness. Some Ghanaian pig farmers also prepare cooked meal of sweet potato to feed the animals for leanness, but the problem in the use of this material is its excessive cost and unavailability most of the time.

Regarding feed for fattening, commercial swine farmers in Norway, China and Ghana, depend on commercial feed fortified with high fat, high protein and sugars but low in fibre. Those who can afford add skimmed milk, yoghurt and dairy-like products. Backyard producers in Ghana and China use pito mash mixed with fruits, vegetables waste and household leftovers to prepare pig feed for fattening. In Ghana, peasant farmers mix the pito mash with rice bran, fresh cassava peels, fresh yam peels, broken rice or maize and soybean meal/copra cake/fishmeal. In China, there is non-use of soyhulls, wheat midds and dried distillers grains with solubles (DDGS) in the diet of a fattening pig.

Regarding feed for proper growth, China's ability to provide excellent quality feed responsible for proper growth enables it to produce double the size of pork that the entire 27 EU countries produced in 2010 and five folds that produced in the United States. Again, both Chinese state and private co-operations keep exerting a lot of effort regarding sources of feed and quality by making them their topmost priority which all accounts for the growth witnessed. Unlike China and Norway, supervision/monitoring of the sources and quality of feed materials used to prepare feed especially at the peasant level is below expectation in Ghana, hence, swine producers tend to prepare pig feeds from any raw materials or ingredients locally obtained without verifying the nutritional status. These could have a negative effect on proper growth of the herds as many of ingredients used might not be fit for the purpose.

For breeding purposes, the feed prepared by commercial feed formulators are similar in the three countries. Boar diets should contain enough vitamin E, trace minerals like selenium and grain like soybean meal for quality semen production. The diet should also be rich in calcium and phosphorus for maximum bone mineralisation for longer breeding life. To prevent the occurrence of delayed puberty, the feed is enriched with proteins and amino acids. The sows/gilts are given dietary fat at the latter stages of gestation so as to increase the survival rate of litters. Diets of gilts/sows should be able to provide reserved fat for processes such as lactation and strong bone formation to prevent lameness. Gilts/sows feed are enriched with lysine to promote the development of the reproductive system. In Ghana, dried yam and

cassava peels are used to provide the reserved fat in breeding sows/gilts. However, distillers residue is not used to feed breeding gilts/boars.

4. HEALTH STATUS

Pig production plays an integral role in global food security, agricultural economies, and both local and international trade. Infectious diseases impact negatively on pig health, and the stability and productivity of the swine industry worldwide. Sudden notification of dullness, laboured or rapid breathing, loss of appetite, loss of weight, sudden death, and low weight gain in a pig herd should clearly indicate the presence or existence of a disease. Other signs are reddening of the skin or skin discolouration, loss of hair, hardening of some parts of the skin, lameness, cough, abnormal nasal discharges, and diarrhoea.

4.1. Diseases and pest affecting pigs in the study regions

The discussion on the most feared diseases in the pig industry recently cannot be complete without the mentioning of the African swine fever (ASF) disease. ASF is a fatal and highly haemorrhagic disease known to be devastating and transboundary, caused by the African swine fever virus (ASFV) and mostly susceptible to pig species in animal population (Quembo et al., 2018). Based on the p72 genotypic classification, twenty-four genotypes of the said disease have been recorded worldwide to date (Hutchings et al., 2003). Out of these numerous viruses, the genotype II viruses is currently dominant within European and Asian circles and regarded as highly virulent (Beer et al., 2020).

The image below is showing the regional or global distribution of African swine fever, with the deep blue areas showing the presence or availability of the disease whiles the pale-yellow areas signifies no ASF occurrence. There is no available information indicating the presence or absence of the disease in the white painted regions.

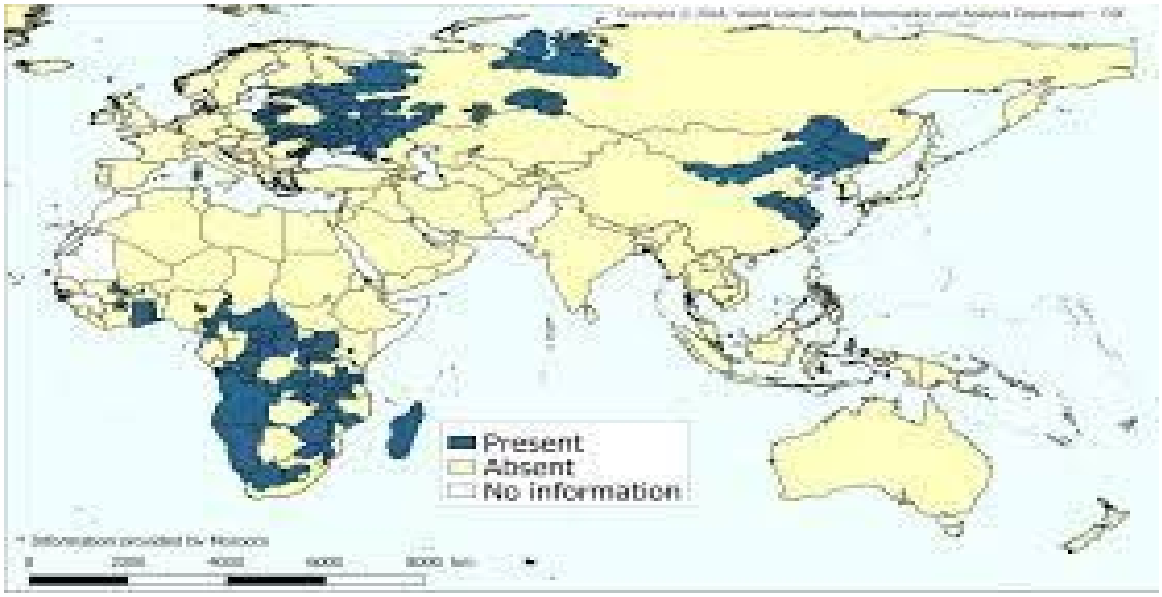

Figure 7. Global distribution of African swine fever disease (image courtesy: Oie.int)

The clinical signs usually exhibited by infected animals can be classified into four stages based on clinical presentations and pathological lesions. The Peracute, Acute, Subacute, and Chronic stages can be mentioned talking about the categorisation of this deadly disease in terms of the virulence and clinical signs (Sanchez et al., 2015). Lower mortality rate of ASF among infected animals have been exhibited at both the Chronic and Subacute stages with no clear clinical symptoms, permitting individual carriers to spread the virus for a long time (FAO, 2017). African swine fever (ASF) can be contagious with individual pigs coming into contact with the virus via direct or indirect contact with infected animals or contaminated substances (Sanchez et al., 2015).

The ASFV is highly resistant in its combating against the environment. Studies have shown the virus surviving for 15 weeks at room temperature, months at 4°C, and indefinitely when frozen (Fapa, 2019). The ASFV can survive for over 3 months in meat and offal under the raw form (Fapa, 2019; FAO, 2017). Another potential source of contracting ASF is via urine and faeces, with the virus showing virulence level of up to 15 days in urine depending on the prevailing environmental conditions (Carvalho et al., 2014). The half-life of the virus in the faeces is reported to be 5-8 days, whiles viral DNA presence from two up to four years can be detected in the faeces of affected animal (Carvalho et al., 2014).

These circumstances pose a considerable risk in terms of the environmental contamination for further outbreak in areas or countries which has already been infected. Such conditions open room for contaminated materials or infected meat products to be abandoned, which could in

turn promote the spread of ASF to areas or countries free of ASF disease (WAHIS, 2021). The ASFV does not affect humans, but the worst virulent strains have proven to be fatal for pigs worldwide. The inexistence of vaccine or no cure for ASF has led to the destruction of all affected animals and products, as a measure of controlling the spread of the disease (FAO, 2019).

Aside ASF disease, other diseases such as Classical Swine Fever (hog cholera), Swine Dysentery, Swine flu, Pneumonia-disease complex, and Roundworm infection have all been long standing diseases associated with swine production over the past years. With the exception of Norway which is on the brink of eradicating diseases from its swine population, most of the afore mentioned diseases still persist in many Ghanaian and Chinese pig farms especially at the peasant level.

4.1.1. Swine diseases in China

Many swine diseases existed in China before the insurgence of African swine fever but in terms of the most deadly and devastating, ASF occupies the summit. China is the first Asian country where ASF outbreak was reported in Shenyang, northeastern China, in August 2018 (FAO, 2021). A rapid spread of ASF across mainland China was due to multiple outbreaks in several provinces leading to the culling of over one million pigs as an attempt to curb this deadly viral disease among the worlds' largest pig herd (FAO, 2019). China was most hit by ASF than any other country due to being home to about half of the worlds' pig population and also, about 40% of pigs are raised in peasant farms with weak biosecurity/hygiene measures or standards (Quembo et al., 2018).

A type II genotype lower virulent ASF virus and emergence of genotype I ASF virus have been reported in China in 2021 (FAO, 2021). The ASF epidemic spelled a considerable economic losses to the Chinese economy especially the animal husbandry division and led to a sharp break in the livestock and meat distribution chain (Zhang et al., 2019). As part of the ripple effects suffered, China's GDP got shrunk by almost 1% in 2019 as a result of the culling of infected pigs due to ASF outbreak (FAO, 2021). The total economic losses incurred due to ASF outbreak from producers standpoint in all sectors of Chinese economy was estimated to be around $111.2 billion in 2019 (FAO, 2021). Another negative impact of ASF on Chinese economy was an increase in imports of pork and products which eventually sends meat cost soaring.

African swine fever outbreak reported in China has been attributed to have occurred mostly in domestic pigs, though some outbreak elsewhere were believed to have migrated from wild boars (FAO, 2021). The higher occurrence of ASF among domestic pigs is due to the dominance of smallholder or backyard farms and the non-transparent distribution network of livestock and their products (Sirisereewan et al., 2020). Other diseases such as Swine flu (swine influenza), classical swine fever (hog cholera), Pseudorabies and others affect swine in China with devastating losses.

4.1.2. Swine diseases in Norway

In terms of animal health profile, Norwegian pigs are considered extremely good as they do not exhibit many of the diseases found elsewhere. Swine keeping in Norway is gradually becoming devoid of the use of antimicrobial drugs and nearing a point of eradicating diseases from its animal population (Ritzmann et al., 2008). Viral swine diseases such as Aujeszky's disease (AD), transmissible gastroenteritis (TGE), porcine respiratory coronavirus (PRCV), porcine reproductive and respiratory syndrome (PRRS), porcine epidemic diarrhoea (PED), and swine influenza viruses apart from A(H1N1)pdm09, have never been detected and recorded in Norwegian swine health books (Jørgensen et al., 2019).

Norway is the only European country designated with the award of freedom from other Influenza A viruses, other than the A(H1N1)pdm09 (Ritzmann et al., 2008). Norwegian pig production continues to show traces of influenza A(H1N1)pdm09 virus since its first occurrence in 2009 (Animalia, 2017; Jørgensen et al., 2019). It has been labelled as endemic since then, and seen a decline in seroprevalence, with close to 25% of herds testing positive in the last three years (Hauge et al., 2014). Norway recorded its first case of PCRV in 2018, and the seroprevalence in the southwestern part of the country is on the increase and spreading at an alarming rate to other parts of the country (Grøntvedt et al., 2013).

4.1.3. Swine diseases in Ghana

Before the declaration of African swine fever in Ghana in October 1999, Ghana had managed to stay out of the disease despite a successive infection occurring in two of its close neighbours Cote d'Ivoire and Togo (FAO, 2007). After few years of absence, the end of the third quarter of 2002 saw an emergence once again of African swine fever in the Northern region of Ghana. Before the end of the fourth quarter same year, an estimated 7,061 pigs had been on the death Rader resulting from this deadly disease. The outbreak also forced an estimated 1,743 pigs to be slaughtered and consumed by their keepers and family (Amponsah et al., 2015). The African swine fever disease is known to have been the number one most deadly and devastating swine disease recorded in the Ghanaian animal health books. It has become the major challenge facing the local swine industry as its surfacing can cause mortalities of up to 100 percent among the herds.

The outbreak in Zabzugu, one of the districts in Northern region of Ghana is said to have occurred or introduced from a small town called Bassare which borders Ghana and Togo about 30 km away. After several years of disappearance, the third quarter of 2018 saw ASF resurfaced in Cape coast, in the Central region of Ghana with a total of 898 pigs culled from the herds (FAO, 2019). The affected animals were low this time due to an early detection of the outbreak and the imposition of a ban on movement of pigs and their meat. These measures put in place during the 2018 outbreak served to minimise the devastating effects. Though the 2018 ASF outbreak has been the last case witnessed in the country, measures such as establishment of an ASF diagnostic unit within the Accra Central Laboratory and the provision of staff training, equipment and other consumables to help implement serosurveillance activities played a vital role in curtailing ASF.

On the other side, the true scale of affected animals which contracts ASF anytime there is an outbreak in Ghana cannot be gauged due to the lack of compensation for farmers, which further complicates controlling of the disease outbreak. Most Ghanaian pig producers become reluctant in reporting signs or incidences of ASF to Veterinary Service Directorate (VSD), knowing that their reporting will land them loosing pigs without compensation.

Other swine diseases before the insurgence of African swine fever in Ghana included pulmonary and enteric infection, skin and organ abscesses, foot and mouth disease, coccidiosis, and mastitis. The afore mentioned swine diseases have always been under control since time immemorial due to available vaccines, antibiotics and drugs that are administered as means of

curtailing the outbreak. The scavenging system of keeping animals mostly adopted by many swine producers especially by the small-scale producers, present substantial risk of exposure of the animals to diseases like African swine fever (ASF), Classical swine fever (CSF) and swine flu (FAO, 2017).

Table 5 comparing the differences and similarities relating to the health status of swine production in the three study countries.

Health status		
China	**Norway**	**Ghana**
ASF, AD, PRCV, PE, CSF, Mastitis, foot and mouth diseases and others occur just as in Ghana. ASF is the most fatal and deadly disease, killed a lot of pigs, caused a lot of pigs to be culled just as in Ghana. Use of antimicrobial drugs still occurs in China just as in Ghana. Disease surveillance, biosecurity measures, swine veterinary services do not match with that of Norway but better than Ghana. Scavenging feeding by pigs especially in peasant farming predisposes pigs to ASF, CSF and Swine flu just as in Ghana.	Swine disease-free except A(H1N1)pdm09. Non-use of antimicrobial drugs. Disease surveillance, biosecurity measures and swine veterinary services very vibrant, robust and excellent in Norway. Governmental support very high.	Transparency wise in terms of network distribution of livestock and their products, Ghana is better than China. Ghanaian outbreak of ASF did not occur through migration from wild boars.

Outbreak of ASF occur through migration from wild boars. Also, non-transparent distribution network of livestock and their products is another factor.		

4.2. Summary of health status

Comparing disease affecting swine in the study regions, Norway is nearing the end of the tunnel in the control and eradication of swine diseases, hence, the use of antimicrobial drugs is becoming a historical statement. In Norway, diseases such as Aujeszky's disease (AD), Porcine Respiratory coronavirus (PRCV), and Porcine Epidemic Diarrhoea (PE) have never been reported or recorded. The only disease of bother to this day is the A(H1N1)pdm09 disease of which its animal health directorate are fighting meticulously in curbing the menace. The prevention and control of swine diseases is transient and incomplete without the mediation of swine veterinary services.

A strong and robust veterinary service translates into increased and healthier pigs. Among the three countries, Norway boost of a vibrant, well established, well-resourced and well-coordinated veterinary service with Ghana being the least, hence, Norway is on the brink of eradicating swine diseases with the exception of A(H1N1)pdm09. The role played by veterinary services in curtailing swine diseases among the studying countries include design and delivering of food quality assurance and welfare certification programmes, ensure total adherence to implementation of new regulations or measures, design and implementation of biosecurity models, network with government institution/diagnostic laboratories/universities/pharmaceutical and boards of pork producing companies in the health and welfare of pigs. They also conduct disease surveillance, education and sensitisation of pig

producers on contamination by foreign animal diseases (cross boarder diseases) and carry out direct engagement to pig producers on their farms to identify farmer felt-needs.

In China, just as in Ghana, swine diseases such as ASF, CSF, Swine flu, Pseudorabies, AD, PRCV, and PED still persist. In Ghana, pulmonary and enteric infection, skin and organ abscesses, foot and mouth disease, coccidiosis, mastitis, anthrax, and anaemia are suppressed or under control because of availability of vaccines, antibiotics, and drugs to fight the diseases. In Ghana and China, the scavenging feeding nature of pigs especially in the peasant production level impede the fight against ASF, CSF and Swine flu. Like China, ASF is the most devastating and deadly swine disease in Ghana, but China was hit the hardest. In Ghana, the first and second waves of the disease in 2002 came from the neighbouring countries of Togo and Cote d'Ivoire, the third was internal (i.e. from Cape Coast in the Central region).

Economically, the outbreak of ASF caused a loss of $ 111.2 billion and also increased import of pork and pig products as in China. In Ghana, about 7,061 pigs died in 2002 and 1,743 pigs were forcibly slaughtered. In China, the outbreak of ASF, in majority, started with the indigenous pigs but in Ghana, it was the exotic breeds. The reason indigenous pigs led in the outbreak in China were that circular/peasant pig producers were many and there was non-transparency in the distribution network of livestock and their products. The local pig in Ghana is resistant to the disease. Currently, Ghana's Ministry of Food and Agriculture (Animal production section) has instituted preventive measures to deal with the ASF and the measures include ban on the movement of pigs and pig products of affected animals and setting up of surveillance and diagnostic unit.

5. MANAGEMENT

Strict adherence to good management practices in pig keeping will minimise or eliminate losses. A piggery set up would not be complete without a proper pig housing meant for keeping the pigs together. Good, efficient housing assures of easy control and guarantees a successful rearing of about 85% or more survival rate of all live born piglets from weaning to market weight attainment (FAO, 2009). Pig housing should provide different environments (temperatures), since pigs need varying environment at various stages of growth (FAO, 1990). Pigs may be kept in different pens, either individually or grouped in small units, depending on the space available.

Swine housing can be divided into three main apartments or units namely, a house to keep boars/gilts/dry sows/pregnant sows, a farrowing house, and a building to house growing pigs from weaning till they are ready for market (FAO, 1998). Pig housing can be situated on a high place with the flooring made of a tight but loose materials to allow for the smooth passage of pig waste into a sewer down below (Ariane et al., 2005). Due to the strong-bulky nature of pigs, their housing is supposed to be solid or strong to hold the pigs. Swine housing should provide adequate/clean waterers and feeders, must have high biosecurity structures in place and a conducive atmosphere to assure of good health and proper growth.

Swine housing located at ground level should be made of concrete and solid bearings to prevent pigs from escaping and bringing it down as well (FAO, 1990). A selected pig housing should perfectly fit into the surroundings where it is situated. For instance, housing needs to be kept distance apart from the water server in order to avoid pollution of the water body by the waste from the pens (Ariane et al., 2005; FAO, 1998). Due to the strong smell being emitted from the houses as a result of waste accumulation, pig housing should be situated far from human abodes (FAO, 2009).

In situation of an abundance space, enough room construction is ideal to accommodate increasing numbers from pig breeding, and to prevent pigs from cramming as well (FAWC, 2007). Pig housing should provide enough ventilation (natural or artificial ventilation through installed fans via ridge of the roof or sidewalls of the building). Standard pig housing must contain wallowing tank, loading ramp, holding area, manure pit, feed store, dipping tank, and crush for vaccination and treatment (Ariane et al., 2005; FAWC, 2007; FAO, 2009). Pigsty, its design and construction can vary from one region to another, most significantly must be able

to shelter the pigs, protect them from any harm, and protect from extreme temperatures and harsh weather (FAO, 1998).

5.1.1. Available housing systems in China

Both Chinese large and medium scale commercial pigs are housed in sties, often separated into one or more pens, and each pen is used to house either a single or group of pigs categorised according to age, sex, and purpose (Chen and Guo, 2009) . The pen size is dependent on the number of pigs and the floor area allocated per pig. Reason for partitioning/zoning of the Chinese pigsties into pens in a commercial piggery is to help gain easy control over the animals. Boar houses emanating under these system of production are designed to guard against extreme hot temperatures which could have a negative impact on production, by decreasing sperm fertility and libido (Chen et al., 2001). Most Chinese boar housing are strongly built to prevent potential boar escape and fighting.

Also, pig producers in China ensure that not more than twenty-four boar pens are placed under one roof, with not more than one boar per pen (FAO, 1998). Swine producers in China ensure there is enough boar sty floor to assure of better servicing, and floor must not be slippery (Chen and Guo, 2009). Most Chinese piggery do not have more than forty pens under a single roof for dry sows or gilts, with each pen accommodating not more than ten animals depending on the stage of growth (Tan and Li, 2010).

Different pig sty zoning or division to contain various categories of pigs according to their age, sex and purpose of production can be seen in the figure below.

Figure 8. A commercial pigsty in China showing different partitions (image courtesy: dreamstime.com)

Likewise with the dry sow/gilt housing, farrowing sties under Chinese commercial piggeries usually do not contain more than forty pens, with each pen sheltering one sow and her litter (Guo et al., 2007; FAO, 1998). The farrowing sty is built with enough resting space for the nursing sow and for the piglets to move around freely, and the presence of farrowing crates makes it easy for farrowing and keep the litters from being trampled upon (Tan and Li, 2010). Sties for holding weaner piglets under Chinese circles do not house more than thirty pens, with each pen housing between 10-20 animals from ages 2 to 6 months old (FAO, 2009). Commercial piggeries in China contain sty for sick animals, located at a distance from the others to ensure enough space is provided between healthy and sick animals (Chen at al., 2001). A creeping pen, clean waterers and feeders are also provided and in abundance to promote good welfare of the animals.

Most Chinese pig houses are roofed with asbestos, clay sheets, clay tiles, and corrugated galvanised steel sheets, and in some cases, a layer of thatching or ceiling is used as an insulator to minimise the strength of heat in areas of extreme weather (FAO, 2009; Guo et al., 2007). Other pigsties in China especially those closed in on all sides contains ventilators (Chen at al., 2001). Single unit rain-proof or multi-storey buildings are used to house pigs under commercial production in China (Tan and Li, 2010; Lander et al., 2020). These commercial pigsties feature

all biosecurity protocols and other supporting structures such as wallowing ponds, holding areas, dipping tanks, feed store, and manure pit.

The figure below showing an aerial view of one of the multi-storey complexes built in China to accommodate or house thousands of pigs in a limited space.

Figure 9. Sample of a multi-storey pig housing at Yangxiang in China (image courtesy: pig333.com)

Aside the commercial pig housing types mentioned above, other forms of housing existing under Chinese swine production include open yard type with partial roofing, made of all sorts of materials, and mostly designated for boars. At the backyard farm level, some swine producers profit from the use of locally available materials at a cheaper cost to construct a simple pigsty of choice (Zhang et al., 1998). Most of these pigsties constructed from locally available materials are partitioned into multipurpose pens, designed for all categories of pigs, meeting standard floor space requirements, and supported with locally made feeding and watering troughs as well (Guo et al., 2007; Woolsey and Zhang, 2009). Though many producers under the backyard system use locally available materials for the construction of their pig housing, such housing assure of good ventilation and ample shade, devoid of overheating, and absence of bad odour and dampness in most cases (Chen and Guo, 2009; Lander et al., 2020).

5.1.2. Available housing systems in Norway

In Norway, a good welfare animal is recognised as the healthy and happy one as well. One of the topmost priority of the animal welfare agenda is the provision of sound and secure housing for all livestock of which pigs are no exception. With a ban imposed on restraining sow in Norway, one key feature of sow pigsty design is to ensure the animals have enough room or space to operate (Borgen et al., 2005). Provision of solid floors is a critical requirement to be fulfilled in Norwegian pig sties, as all animals should be able to lie on solid floors (Elvbakken, 1997) and provision of top-quality bedding material is of utmost importance in the pig house.

Use of fully slated flooring is prohibited in the pigsties. Space requirements differ among the categories of pigs, with some groups requiring greater space than others. Presence of rooting materials inside the pigsty is crucial as all pigs are entitled to its use to help them put up normal behaviour (Kyrre et al., 2004; Borgen et al., 2004). All commercial pigs in Norway are kept indoors with only a few commercial pig production practiced outdoors (approx. 20-30 holdings) (Fredriksen, 2005; Elvbakken, 1997). Sows under outdoor production are typically housed in huts on fenced pastures or mixed housing systems. Finishing herds are normally kept on fenced pastures or mixed housing systems as well (Jacobsen, 2003).

With the exception of the only few outdoor kept pigs, rest of the herds are housed in piggeries with well-equipped amenities in place to guarantee a better animal welfare and productivity (Borgen at al., 2005; Elvbakken, 1997). Norwegian pigsties are divided into multipurpose pens designed to hold distinct categories of pigs. Pig keeping practices such as the open yard type with partial roofing is not commonly found due to the extreme freezing conditions in this region (Jacobsen, 2003; Fredriksen, 2005). Norwegian pig housing comprises of the following components, namely waterproof roofing system, insulators provided in the form of ceiling or a thatching layer for maintaining warmth, ventilators, waterers and feeders, with sturdy and heated floors having slope away from the drain and easy to clean (Kyrre et al., 2004).

The image below showing a typical Norwegian pig sty with different partitions to hold various categories of pigs and with a proper insulation and ventilation systems in place to ensure the provision of thermoneutral zone.

Figure 10. Classical robust thermoneutral tempo sty for easy production (image courtesy: TopigsNorsvin.com)

Other compartments that can be found in a Norwegian piggery includes a farrowing sty for nursing sow and her litter, creeping pen with enough bedding for piglet holding, sty setup at a distance for holding sick animals, boar sty with enough space to allow for better servicing, farrowing crates for holding sow and her piglets, weaner piglet holding sty, and dry sow or gilt sty. As a standard practice requirement by the Norwegian Animal Research Authority, all pig producers or farmers must ensure their piggeries contain wallowing tank, loading ramp, holding area, manure pit, feed store, dipping tank, and crush for vaccination and treatment (Jacobsen, 2003; Borgen et al., 2005). Also, Norwegian pig producers ensure all biosecurity measures or structures are duly in place and strictly adheres to from both workers and visiting customers.

5.1.3. Available housing systems in Ghana

Pig housing in Ghana exist in diverse ways or forms, beginning from the Northern belt all the way to the Southern zone. The type of pigsty erected in a particular locality depends on a number of prevailing factors including land availability, purpose of production, number of animals, scale of production (large/medium and smallholder/backyard holding), religious dominance in the area, and last but not the least, the financial strength of the producer (Ayizanga et al., 2018). The basic goal of the farmer is to provide housing that will ensure animals are shielded and safe from sun, wind, and rains (FAO, 1998).

The housing structures are mostly built out of pallets, scrap woods, mud bricks, wooden stakes, cement blocks and concrete materials, galvanised roofing sheets, thatch roof, metal and iron pipes for gate construction, and wire mesh for fencing (Ayizanga et al., 2018; MOFA, 2013). Due to the extreme hot temperatures at certain period of the year, most Ghanaian pigsties are provided with wallowing ponds. In Ghana, commercial pigsties consist of multipurpose pens serving various categories of animals and studded with the standard basic amenities to promote good welfare and productivity (Amponsah et al., 2018; Ayizanga et al., 2018).

The demonstration of a typical tropical pig sty with the dwarf walls and either a wire netting or metal/iron fencing to ensure good ventilation through free movement of wind and also with a gabled roofing system to prevent rains from getting into contact with the animals as can be seen in the images below.

Figure 11. Samples of a standard Ghanaian commercial pig houses (images courtesy: pinterest.com, farmdreams.com)

One common structure dominant in the pig housing world in Ghana is the open yard type with fully roofed house(s) attached (Adjei et al., 2015). These houses are made from different material combination including cement blocks or concrete with galvanised roofing sheets or thatch, bricks without cement and roofed with thatch, mud bricks without cement and with thatch or mud roof, mud bricks but walls plastered with cement and roofed safely using galvanised sheets, and wooden stakes for wall construction with a thatch roof (Adjei et al., 2015; Ayizanga et al., 2018). The yards are constructed using wooden stakes, bricks or mud with or without cement, cement blocks or concrete, and wire netting with wooden stakes.

The images below depicting both wooden and concrete open yard pig sties with a fully roofed mini houses to protect against adverse or harsh weather conditions and enough space for exercise as well.

Figure 12. Open yard type(s) of pig housing by smallholder farmers in Ghana (images courtesy: agric.ug/org)

Pigs are normally produced under sheds, shades, yards, and stalls pertaining to backyard or smallholder settings compared with commercial rearing where permanent structures are erected to house the pigs (MOFA, 2013; Aboagye et al., 1995). Amenities such as wallowing pond, loading ramp, holding area, manure pit, feed store, dipping tank, and crush for vaccination and treatment are normally found in piggeries at Animal Research Stations, Breeding Stations, and University Farms, though other large scale commercial farms do have these fully installed and operational in their farms (Karnuah et al., 2018). Most of the afore mentioned amenities are completely lacking under smallholder/backyard settings.

The figure below shows the pig housing structure at the time when the study was carried out with about a third of pig farmers (35%) in Ghana having permanent housing structures, a whopping 36% of the farmers keeping their animals under sheds, followed by those under stall/shades making up about 26% of the total, and lastly, with 2% each representing pig farmers with no housing and those under yards respectively.

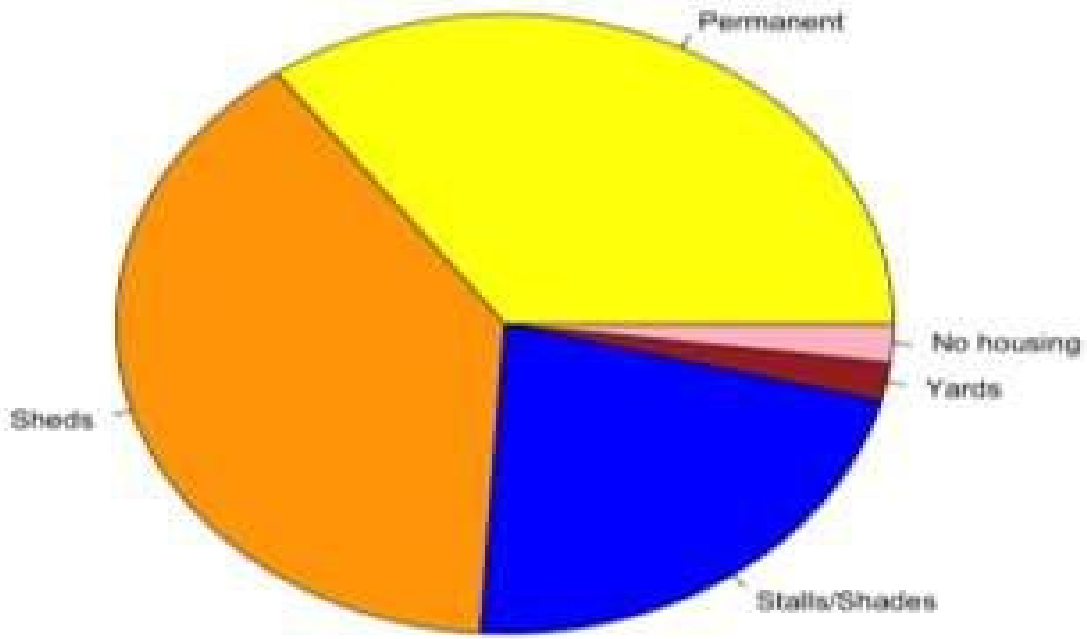

Figure 13. Pie chart showing various composition of Ghanaian pig housing systems (image courtesy: researchgate.net)

5.2.1. Selection of housing for commercial production in China

Prior to 1995, majority of pigs reared in China was from backyard operations. The insurgence of commercial pig farms in China over the past two decades has been phenomenal with many commercial operations producing between 50 to 1000 herds (NBSC, 2020). Some of these Chinese commercial operations can produce tens to hundreds of thousands of pigs annually. This shift in production require the use of specialised built housing units to contain or manage the growing pig herds. The choice of pig housing and its design is central in determining the growth and development of pigs, as poorly designed pigsty can promote disease contraction and even escalates it further (Zhang et al., 1998).

In China, the choice of housing for keeping pigs commercially are determined by a number of factors. Some of these factors include placing of pigsty at an elevated heights to stop flooding during torrential rains, sufficiency of providing shade from sun and ample fresh air, location must be easily accessible, and of regular supply of power and electricity (Chen and Guo, 2009; Tan and Li, 2010; Zhang et al., 1998). Again, selected housing for commercial purposes should guarantee optimum temperature through provision of right ventilation techniques or installations at all times (FAO, 2009). Also, housing should provide enough feeding and

watering troughs. Selected pigsties should contain dip tanks, holding area and footbaths as part of the biosecurity control measures. With regards to backyard production, selected housing should guard against rains, wind, and sunshine, provide enough space for feeding and watering, and contains some biosecurity measures to help minimise disease outbreak and its spreading as well (Guo et al., 2007).

5.2.2. Selection of housing for commercial production in Norway

The architectural design of Norwegian pigsties with its long, narrow buildings with the long axis running from east to west, makes it feel cooler during summer and warmer in winter. This pigsty design makes it an ideal choice for keeping pigs as the thermoneutral zone which helps in promoting productivity and welfare is maintained (Borgen et al., 2005). Also, the Norwegian housing type provides optimal temperature balance required by piglets as they tend to suffer most from cold. On the other side, older and larger pigs suffer from rising temperature, with temperatures above 27°C not considered suitable for growers, finishers, and breeders (Kyrre et al., 2004; Fredriksen, 2005). Access to good connecting roads, stable supply of water and power, distance of farm from human abode, and positioning of these houses at elevated places to keep them out of flooding, are all deciding factors in settling for choice of commercial pig housing in Norway.

These type of housing are also selected for commercial purposes based on ability to provide dry solid floor that can easily be warmed, presence of dry straw or untreated wood shavings as insulators for piglets, presence of ventilators and insulators to remove water vapour, carbon dioxide, ammonia, bacteria and odours, whiles controlling heat gain or loss by conduction (Elvbakken, 1997; Jacobsen, 2003). Another feature which makes these pigsties a preferred choice is the presence of adequate feeding and watering facilities. Also, selection of these pigsties for commercial production is highly based on associated strict biosecurity protocols. These biosecurity protocols help prevent diseases among the herds, promotes good animal welfare and productivity (Ritzmann et al., 2008).

5.2.3. Selection of housing for commercial production in Ghana

In Ghana, the choice or selection of a commercial pig housing is dependent on a number of factors including climate, local prevailing practices, environmental considerations, government regulations, and cost (Karnuah et al., 2018; MOFA, 2013). Standard pigsty with concrete floors, open yard type with building completely roofed, and wooden pigsty roofed with galvanised sheets or thatch, are all housing types used in producing commercial pigs (Ayizanga et al., 2018). The choice or use of each type depends on the availability and cost of building materials, number of pigs to be kept, land size and location, purpose of production, and financial muscle of the intended producer (Adjei et al., 2015; Aboagye et al., 1995).

Also, the use of each type of housing for commercial production is dependent on a number of factors such as access of the site to motorable roads, adequate supply of water and electricity, source of good ventilation and ample shade, site should be away from residences, and should be of an elevated height to prevent flooding by rainwater. Overall, selected housing for pig keeping being it large/medium scale or peasant/backyard should provide shield against wind, sun, and rain, balanced air flow especially in enclosed spaces, presence of enough feeders and waterers, and assure of high biosecurity standards in prevention of diseases, and promotes good animal welfare (Karnuah et al., 2018; Ayizanga et al., 2018). In hot climatic zone like Ghana, presence of wallowing pond in a piggery is one crucial element of consideration to help the animals cool off or maintain thermoregulation.

5.2. Reasons or advantages of selected housing over the other systems

Many factors account for the type of swine housing situated in a particular location and reasons for selection as well. Choice of housing design depends on the purpose and scale of production, land availability, climate, material cost and availability, and financial resources of the intended keeper. Overall, pig housing should not be draughty, prevents enough bright sunshine and rain from entering, provide slight variation in terms of temperature inside the pen, should be simple and easy to clean, possess slopy but not slippery floor, and make provision for manure storage, litter and run-off for later use.

5.2.1. Chinese choice over other systems

Being home to half of the world's pig population, pig housing design and construction in the form of multiple storey building is crucial to contain the huge herd numbers. Contrary to conventional low buildings, pig skyscrapers in China help slow down the risk of pathogens spreading from one pig farm to the next through ventilation (Zhang et al., 1998). Moreover, a sudden outbreak of disease will stay isolated only to the attacked floor, whiles the cooling pads, virus filters and air conditioning installations all contribute significantly to prevention of a disease outbreak (Tan and Li, 2010).

Other forms of commercial pig housing aside the multi-storey are chosen due to better ventilators, insulators, well layered feeding and watering system, and other biosecurity protocols in place, which helps protect pigs against extreme temperatures, diseases outbreaks and other adverse weather conditions such as heavy rains and cold winds (Guo et al., 2007; FAO, 2012). Use of sturdy local materials in construction of pigsty especially by backyard swine keepers with all growth promoter components in place help to significantly reduce the cost of production in terms of housing (Woolsey and Zhang, 2009). The open yard system widely used in some Chinese provinces also help the animals express their full potential without being restricted or confined to a provided space.

5.2.2. Norwegian choice over other systems

Due to the extreme cold temperatures during the winter, the design and use of Norwegian pig housing with an orientation such that the openings under the roof can be closed completely to prevent piglets from catching cold becomes an ideal one. During summertime when temperatures are higher, same housing orientation allows the top section of the walls to be opened to cool in, and later closed again nearing the evening to keep warmth in (Borgen et al., 2005). The ventilation and insulation fittings on the walls and roof of Norwegian pigsties help create thermoneutral zone irrespective of the time of the year and also, help the herds to grow and produce properly.

The long, narrow pig housing design with the long axis running from east to west helps maintain warmth during winter and cool in the summer (Kyrre et al., 2004). The design of the pigsties also allows for carefully and controlled feeding/watering routines to be conducted, especially feeding designed to cater for different groups of pigs (Elvbakken, 1997). The types

of pig housing found in Norway make good hygiene practising easier, thus contributing positively to the health of the pigs. Weaning and heat controls can be executed at the right time and in the right way due to the design.

5.2.3. Ghanaian choice over other systems

In hot, humid or damp locations like Ghana, breeze and shade are crucial factors of consideration with regards to pig housing. Ghanaian pigsties are mostly designed to be as open and airy as possible. The walls of the pen allow enough wind to pass freely through good ventilation, which helps in reducing rate at which infectious diseases can spread rapidly. Tropical pigsty as found in Ghana ensures that daytime temperatures are kept as low as possible, and that young pigs can be kept warm enough during the nights and cool periods. Ghanaian pig housing are mostly orientated lengthwise from east to west, surrounded by trees which provides shade, absorbs and screen a good amount of heat to help in providing thermoneutral zone for the herds (Adjei et al., 2015; Aboagye et al., 1995).

The roof of many Ghanaian pigsties are slopy enough with the longest slope facing prevailing wind and rain direction to help prevent it from getting into direct contact with the animals (Ayizanga et al., 2018). The thatch or grass roof insulates well against heat and cold, reason they are added on top of corrugated iron or aluminium sheets. Indoor housing system protects the herds from wild sun and heavy rains, whiles at the same time increasing survivability rate of piglets under safe, warm and healthy surroundings (MOFA, 2013). Other Ghanaian systems of housing such as the open yard type or free-range housing, provides pigs some level of freedom to select for the optimum micro-climate, thereby exercising control on their living conditions.

Table 6 describing or comparing various housing structures used in keeping pigs in the three study regions.

Management (housing)		
China	**Norway**	**Ghana**
The use of skyscrapers to house pigs is exclusive to China. The use of ventilation and insulation fittings on walls and roof of houses are exclusive to China and Norway. Use is made of fully-slated floors (exclusive to China). Commercial farms use complete houses, strongly built and roofed with waterproof material in China and Norway. Some peasant farmers used open yard houses with partial roofing just as in Ghana.	All the standard biosecurity protocols namely holding area, crush, dipping tank, wallowing pond, feed stores, footbaths, manure pit and others are pursued/carried out in all the three regions. The diligence of carrying out biosecurity protocols is more elaborate and consistent than China and Ghana. Non-use of Open yard houses with partial roofing. Use of solid floors which can be heated or warmed. These prevents piglets from catching cold.	Commercial farms use dwarf walls with wire netting or metal/iron fencing above and roofed with waterproof material. Use of shades, sheds, stalls and yards exclusive to Ghana. Not all biosecurity protocols are diligently carried our under the peasant farm setting, but provision of wallowing tank is a must to because of the high temperatures in most times of the year.

5.3. Summary of Management (Housing)

Pig housing is key to proper management, growth, development, health and productivity of pigs. The housing used must ensure that all or most of the biosecurity measures can be undertaken. In the three study regions, pig sties used ensure safety/protection and security of the pigs, the proper/optimum temperature for the survival of the animals, animals are not affected by floods from heavy rains and also shielded from sun and wind, and sties are readily accessible to reliable source of electricity and water. It must also ensure inclusion of loading

ramp, footbaths, manure pit, feed store, crush for vaccination and treatment, dipping tank, wallowing tank, feeding and watering facilities.

The construction and design of pig sty depends on varying factors relating to the country under consideration and include capital and land availability, number of animals involved, availability of local materials, prevailing climatic/environmental conditions, religion and culture of the people and others. At the peasant or local level, local materials in the region concerned such as bamboo, thatch, wood, and bricks are used foremost for the safety and security of the animals and also to reduce cost. In Ghana, the open yard house with fully or partially roofed house is the most common. Others such as sheds, shades, yards and stalls are available.

Ghana being a tropical country does not suffer from extreme cold or hot conditions, hence, the use of dwarf walls and roofing which is gabled respectively to allow in enough wind through good ventilation and prevents fast disease spread and excessive rains from getting into direct contact with the pigs. This is in sharp contrast to Norwegian housing where due to extreme cold temperatures in winter and hot temperatures in summer, the open yard type is not common. The solid floor is also heated or warmed electrically to cancel the extreme cold effect. Also in Norway, pig sty is oriented in a manner such that long axis run from east to west. This alignment makes it possible for openings under the roof to be closed completely to prevent piglets from catching cold and dying in the winter.

However, the top section of the walls are open to cool in and later closed again in the evening to keep warmth in. The ventilation and insulation fittings on the walls and roof are used to create thermoneutral zone irrespective of the season to help herds grow and produce properly. In Ghana, the east to west style orientation surrounded by trees provide shade, absorbs and screen good amount of it to provide the thermoneutral zone for pigs. Daytime temperatures are minimised as much as possible, thus, pigs are kept warm during the night and cool periods. China also uses the open yard type style with partial roofing to allow the pigs to exercise their bodies.

Commercially, China uses multi storey sties to accommodate their larger population of pig on a small land or space. Also, such a sty ensures that the risk of pathogens spreading from one farm to another through ventilation is reduced drastically. Disease transmission and spread are also reduced, and such a sty also eases the observance of biosecurity protocols. The wallowing pond or tank is a very necessary biosecurity measure in Ghana since Ghana is in a hot location.

Hot temperatures may kill the pigs due to overheating, hence, the importance of wallowing tank, especially in the dry season. The pursuance of biosecurity protocols is highest in Norway and least in Ghana and the observance of these protocols in Ghana is more pronounced on university farms, research stations, demonstration farms and other commercial farms owned by individuals as against peasant farms.

6. ECONOMY

Comparatively, pork is the most widely consumed meat worldwide, with huge volumes of the consumption centred around Europe and Southeast Asia. This fact exist as pork is considered too low expensive than other meat sources which is a major boost for its high consumption globally. Aside being a cheap meat product, its consumption is highly influenced by its palatability, fat content and texture that fascinate consumers (FAO, 2021). Some of the factors promoting high demand for pork includes growing disposable income, changing consumer preference/taste and larger part of the population turning into the middle class (USDA, 2021).

According to a report by Alltech (2021), swine feed marketing is highly concentrated in huge pork production and consumption areas such as found in the developed regions of North America, Europe and some parts of Asia. A survey by Livestock and Poultry World Markets and Trade of the USDA indicates that, total global pork production volume in 2021 amounted to 105 million metric tons (USDA, 2021). Out of this figure, a whooping forty-three million metric tons came from China, followed by the European Union with 24 million metric tons, and the United States came third with 12 million metric tons (FAO,2021; USDA, 2021). Other larger pork producing countries include Brazil, Canada, Mexico, South Korea, Japan, the Philippines and Hong Kong.

Table 7. Leading global pork producing countries and their production volumes (Table courtesy: USDA)

Pork Production – Selected Countries Summary
1,000 Metric Tons (Carcass Weight Equivalent)

Countries	2019	2020 Apr	2020 Jul	2021 Apr	2021 Jul
China	42,550	36,340	36,340	40,500	43,750
EU	23,956	24,150	24,267	24,500	24,800
USA	12,543	12,843	12,845	12,832	12,776
Brazil	3,975	4,125	4,125	4,250	4,280
Canada	2,000	2,130	2,130	2,130	2,225
Mexico	1,408	1,451	1,451	1,495	1,495
Korea	1,364	1,403	1,403	1,354	1,375
Japan	1,279	1,298	1,298	1,300	1,300
Philippines	1,585	1,115	1,115	1,000	1,000
Hong Kong	74	63	63	70	70
Others	11,291	11,559	11,780	12,050	12,050
Total	**102,025**	**96,698**	**96,817**	**101,481**	**105,121**

Source: USDA

A market report by USDA indicated that, global consumption of pork is projected to be up from 117.35 metric kilotons in 2017 to 131 metric kilotons by the end of 2027. In terms of leading market for pork consumption and production, Asia region occupy the top spot with more than half of the world's production (FAO, 2021). This status makes the Asia-Pacific region the largest market hub for swine feed products. Southeast Asia dominates in the production and exports of pork followed by Europe and North America respectively (FAO, 2021). A USDA report in 2021 also projected an upward movement of 2% to 11.8 million tons on higher estimates for major exporters.

Chinese imports continually surpass others with a 3% increase to five million tons. Following China on the import ladder includes Japan, Mexico and South Korea respectively (IMARC, 2021). Regarding global pork exports, European Union remain on top with an average of 4.4 million tons, followed by the United States with over three million tons, with Canada and Brazil occupying the third and fourth spot respectively (FAO, 2021). According to a 2020 Alltech Global Feed Survey, pig feeds assumed the second position in global compound feed preparation (1.126 billion metric tons) with a 21.4% of the share displayed. The Asia-Pacific regions alone contributed 120.6 million tons of pig feed production out of 286.3 million tons

globally in 2020. Occupying the second spot came European Union with 72.9 million tons, followed by the North America with 53.9 million tons (Alltech, 2021).

The survey also showed a downwards movement in pig feed production of about 11% resulting from an outbreak of African swine fever (Alltech, 2021). The effects of ASF caused the primary producing regions to experience the biggest decline of 26%, with China being the biggest casualty (-35%) decline (USDA, 2021; FAO, 2021). Comparing the decline in feed production due to an ASF, Europe, North America, Russian Federation and Latin America experienced a moderate production expansion within percentage points, partially offsetting production losses elsewhere (FAO, 2021). Talking from a tonnage standpoint, Africa is considered small, but showed a substantial increase of 29% in swine feed production during the same period (FAO, 2021).

The spreading of more retail outlets and easy accessibility of pork products through different sales channels, makes its purchase easy and convenient for consumers, which becomes the primary force behind the higher sales figures recorded annually across board (USDA, 2021).

6.1.1. Chinese swine market

Chinese pork industry have witnessed a dramatic quick recovery after a devastating outbreak of African swine fever in 2019, and this recovery becomes evidential from sharp drop in prices of pork products during the first half of 2021 (USDA, 2021). Majority of backyard or smallholder farms doubled their effort by quickly restocking their barns to be able to cash in from the extremely soaring prices post ASF pandemic. Unfortunately, current factors such as falling producer prices and rising commodity prices which has a negative consequence on farm's profitability helped shuttered the dreams of taking advantage of the soaring prices by smallholder pig farmers (FAO, 2021). Such development later forced small farms to reduce their inventories, resulting in a one-off increase in domestic supply, with large scale swine productions on the increase due to support or subsidies received from various governmental bodies or agencies (FAO, 2021).

China's pork production was estimated to hit forty-eight million tons by the end of 2021 with imports down at 10% since summer of 2021 compared to 2020 (USDA, 2021). Though production is expected to fall by 13% between 2021/2022 production season, import is expected to see an upward movement with figures exceeding five million tons. Despite import

figures surging upwards, Chinese government's desire to stabilise prices will make it unlikely for the value of imports to surpass that of records high in 2019 and 2020 (FAO, 2021; USDA, 2021). Chinese pork imports fell by 35% between June and July 2021. This reduction forms part of the government plans to curtail inflation and also, led to an increase in domestic supply. Chinese imports of pork especially carcasses, boneless parts, and ribs have dropped significantly, whiles imports of loins, bacon, and fat is on the increase surpassing that of 2020 together with stable demand for offal (USDA, 2021).

The current decline in demand for pork from China is leading to a shifting of flows towards the intra-European market (USDA, 2021). As a diversionary tactics to get pork prices down on the international market, China has decided to diversify its supply of protein sources as means to add to the pressure. Chinese hog prices has seen a downwards movement of 23% over the past year following an aggression on expansion of the herds after the industry got struck by ASF (Statistica, 2021). Though China's hog prices is on the rebound following prolong collapsed, current constraints or happenings including covid lockdowns in world's biggest pork consumer makes it far from calling it a turning point (FAO, 2021). The prospects for demand for pork products looks glimmer as a result of covid lockdowns and has led to a dietary switch towards poultry meat, affecting pork price gains.

6.1.2. Norwegian swine market

The swine production in Norway and other inland agriculture production is regulated by the government and the production volume is meant to cover the demand of the food industry. The price of pork is regulated each year through negotiations between the government and the Norwegian farmers organisations. There has been a variation in pork market prices over the years in Norway based on production volume. Prior to 2019, a kilo of pork was sold for $1.99 in 2017 and $2.03 in 2018, but due to a change in an export price, a kilo was sold at $2.56 in 2019, showing a percentage increase of about 25.9% (FAO, 2021). The exports of Norwegian pork to neighbouring Sweden, the Netherlands, Denmark, Spain and Ukraine in 2019 accounted significantly for the high growth recorded by the export sector. Currently, a kilo of pork in Norway cost between $2.56 and $ 2.03 or NOK 21.28 equivalent depending on the kind of market and locality (Statistica, 2021).

In 2015, the Norwegian pork market saw an upward movement by 4.7% to $430 million, being a second time in succession in terms of an increase after thirty-six months of decline (Statistica,

2017). Overall, pork consumption recorded an appreciable fall. The year 2007 became an outstanding year where pork consumption reached the record highs at an estimated $541 million and since that time, lower figures regarding consumption have been recorded (Statistica, 2009). In value terms, an estimated export figures regarding pork rose to $412 million in 2015, though overall production continues to show a decline (Statistica, 2017). Norwegian swine production hit the peak level in 2008 with a total volume of $635 million (FAO, 2010).

Relating to pork imports in Norway, it is described negligibly small in comparison to the production figures. Pork import numbers have been on a fluctuation lane from 2013 to 2021 (FAO, 2021). In 2012, imports amounted to nearly 2,000 metric tons and showed a massive growth the following year by hitting over 4,000 metric tons (Statistica, 2013). The subsequent years saw a reduction in import figures below 3,000 metric tons. A sharp increase in pork exports at more than 14,000 metric tons was achieved in 2021 (Statistica, 2021). The above export figures makes the import share of the market seen to be absent or hidden in both volume and value terms. The above Norwegian swine market statistics describes how robust the domestic pig production has been and remained over the course of time.

6.1.3. Ghanaian swine market

Pork imports into Ghana amounted to over $2 million in 2020, making it the 108th largest pig meat importer in the world. Under the same year, pig meat occupied the 506th position in terms of the most imported products into the country (FAO, 2021). Most of these imports were sourced from the Netherlands, Poland, Canada, South Africa and France with corresponding import figures of $1.03M, $493,000, $215,000, $66,000 and $61,000 respectively (FAO, 2021). Since 2008, pork prices have been rapidly souring in Ghana at an average of 15-20 % causing a kilogram of pork to cost between $2.1 to $2.53 depending on maintenance cost (Statistica, 2010).

The last decade has seen the Ghanaian pork market risen sharply above all other livestock products due to their high preference rate. The increase in widespread acceptance of pork and its products is fuelled by choice of dietary patterns with more consumers shifting from red meat consumption to that of white meat (FAO, 2012). A decade spanning between 1999 to 2009 saw Ghanaian pork production increased from 11, 173 metric tons to 17, 512 metric tons respectively, with a year-to-year corresponding pork production index ranging from 98 to 154

(FAO, 2010). Pork imports witnessed a sharp increase from 3,583.1 metric tons in 2000 to its peak of 13, 290 metric tons in 2006 and later showed a downwards movement to 3, 150 metric tons in 2009 (Statistica, 2010).

In 2021, pork exports shrunk significantly at 35-40%, almost similar to that of the preceding year (FAO, 2021). In Ghana, excluding the year 2012 where over one thousand metric tons of pork were exported, the subsequent years till date have all shown a reduction or contraction in terms of pork exports. Cote d'Ivoire has over the years been adjudged Ghana's biggest pork export destination and still continues to occupy that position with approximately 76% share of total exports. The role of Cote d'Ivoire as the major pork export destination has placed them in a position to decide or determine pork prices on regular trading periods. Pork imports from abroad experienced a downward turn in 2018, hence, bringing an end to a two-year upward trend (FAO, 2019). Overall, pork imports experienced a dramatic expansion with 2020 being the peaked year with imports reaching 18, 371 metric tons (Statistica, 2021).

6.2. Pork marketing channels

These channels determine how the distribution of pigs, pig meat and by-products from the pig farm reach the final consumer. Some swine producers use the traditional routes or channels by either selling their live animals directly to the buyers with or without the involvement of intermediaries or some choosing to add value to their pork and sold through brand names or through retailer chains or directly to the consumer. Other producers also have a direct link to pork processing companies which convert the meat into assorted products in different forms under various packaging and storage. Other marketing route involves direct marketing of pork products by the producer through establishing and expanding on the niche to market pork directly to consumers through the use of their own websites (online marketing), skipping traditional marketing channels.

6.2.1. Chinese pork marketing channels

In terms of Chinese marketing, the meat market comes second in the country's retail food market with pork being the most sought after and consumed meat in China (Zhang et al., 2021). In China, processed pork products are sold to Supermarkets and Hypermarkets whiles fresh pork is mainly found in the Streets or Open market (Lander et al., 2020). Due to urbanisation

and increasing purchasing power of urban dwellers, these markets (Supermarkets and Hypermarkets) have become number one retail outlets for their processed pork (frozen and chilled products). This condition has come into being due to the willingness of these dwellers to buy expensive cuts of meat, boosting high production of animals and to increase demand for variety in relation to quality product (Zhang et al., 2021).

Most of the large-scale pig farms in China are either owned by a pork processing company or the farms have their own processing setup, hence, do not resort to selling or marketing of their animals to the outside market (FAO, 2020). Other large-scale farms which do not have their own processing facility or not a subsidiary of a pork processing company, offload their stock into the market by selling them to some of the big processing companies which offer higher returns (FAO, 2021). Some medium scale productions market their animals by directly engaging the major processing companies or slaughterhouses and others also employ the services of intermediaries in achieving same goal (Lander et al., 2020).

Also, other medium scale producers deal with all manner of firms or people (slaughterhouses, abattoirs or individuals) regarding marketing of their herds, provided their price demands can only be met. The backyard or smallholder swine producers which constitute the majority of producers in China, use various avenues or channels to offload their stock unto the market. Most of the producers involve the services of intermediaries or sell directly to middlemen during the marketing period (FAO, 2021).

Other backyard producers slaughter and sell their pork directly in the Open/Street market without the involvement of intermediaries, with others also turning or preparing them into favourite local pork delicacies and sold to recoup their investment and make profit as well (Zhang et al., 2021). Another way and a modern one of course to which processed pork and products are marketed in China involve the use of online marketing platforms, as most Chinese people are always looking for products to buy online.

6.2.2. Norwegian pork marketing channels

Demand for pork meat in Norway turns out to be very low compared to the demand in China, but yet, swine producers are able to make good returns due to a stable market. In Norway, pigs from large-scale farms, medium scale farms and few backyard farms ready for market are sold directly to the slaughterhouses/abattoirs or processing companies which converts them into

different meat and meat products (Bente, 2005). Majority of the pork products from these processing entities end up in the Supermarkets as a chilled or frozen product, with only few ending up in the meat shop. Fresh pork meat can only be bought in Norway through a designated or specified meat selling outlets (Borgen et al., 2005).

The Open or Street pork market does not exist in Norway due to food safety and hygienic issues which is a top priority of "Nortura" an entity that regulates slaughterhouses and other processing plants related to meat and eggs. Swine producers in Norway have a body which determines and regulates the price at which a pig ready for the market must be sold according to an established procedure (Borgen et al., 2005). Through the workings of this body, a stable and good returns on producers investments are assured 0ocompared to other areas or places where it is done otherwise. The price determination ranges according to stage of the animal, purpose of purchase, carcass yield or percentage and the final weight in relation to mature or finished pigs. Also, the presence of this body do not give room for the functionality of intermediaries at all stages regarding the selling of pigs in Norway.

6.2.3. Ghanaian pork marketing channels

In Ghana, pigs grown in between 24 – 28 weeks with heavy yielding carcasses and weighing between 60 to 80 kg, without any health deformities and ready for slaughtering are sold. Some of these pigs are sold for export purposes especially to the neighbouring countries and others to pork processors for the usage of hotels, restaurants, food joints and individual homes (Banson, 2014). Pigs at different ages or stages of growth can also be bought from colleague producers by others and used for the intended purpose at a bargained price. With the Ghanaian economy characterised by not many meat processing companies, pigs from large-scale productions, university farms, research stations and demonstration farms are mostly sold to the slaughterhouses/abattoirs or processing companies for slaughtering, meat cutting and further processing due to the vast numbers involved and the purpose of production as well.

Aside one-third of the whole pig being sold as fresh meat in designated meat shopping centres, the remainder is further processed into ham, bacon and sausages, which end up in various cold stores and supermarkets for sale (Akwetey et al., 2013). In Ghana, the primary medium through which fresh pig meat and other meat sources are sold is via meat shopping centres, usually set up close to the slaughterhouses or abattoirs (FAO, 2010). Some of these centres are well fenced and gated buildings with elevated level of hygienic protocols in place. Others could be found

in the open and on the streets as well. Also, other pork selling joints or mediums have been categorised into groups including a group of butchers numbering between 2 to 5 with a meat stand set up somewhere within a city or community and also, individual butchers with a single stand within same city or community.

In localities where the butchers are in group, various kinds of meat can be found ranging between beef, poultry, chevon, mutton and pork. Regarding the individual butcher set up in Ghana, usually the person/seller specialises in the selling of a particular meat. Excluding large-scale pig producers, both medium scale and backyard pig producers directly involve the services of intermediaries in offloading their stock unto the market. Some farmers or producers take their animals directly to the intermediaries in the market for them to function as brokers or do bargaining on their behalf after which they are paid commission. In other instance, some intermediaries visit the farm and buy the animals ready for the market themselves.

Also, other producers especially from backyard or smallholder background, kill and prepare the meat into various local pork delicacies (grilled/roasted pork, fried pork and pork soup) and sold to the public. Most of the small pork joint owners also buy the animals from the producer, kill and make an ends meet from selling them.

6.3. Potentials/opportunities in pork marketing

In pig marketing, a valuation of a potential revenue for a particular product out of a whole pig is crucial to the growth of the industry. Knowledge of the overall market potential will help to maximise sales and also, directly corelates with the expansion of the swine enterprise. These potentials/opportunities are not static or permanent and can quickly change when laws change or even some simple adjustments can have a prolonged effects. Hence, swine marketers must be proactive and dynamic as well, in order to make the most out of the available potential/opportunity.

6.3.1 Marketing potentials/opportunities in China

With regards to food safety and health issues, China's use of Open or Street meat market must be reduced or discouraged as it could be a potential source of disease outbreak. Instead, the use of butcher houses or meat selling joints, well-constructed with hygienic protocols in full force must be encouraged or promoted. Also, a regulatory body to look into meat pricing must be set up by the Chinese government which will include the producers, to curtail the surge in the cost of China's staple meat recently. Most swine and other meat producers stoke gains by restricting output or hoarding in anticipation of higher prices, and the existence of such body will help check this practice. Moreover, some pork sellers in the Open/Street market can widen their daily sales and make fortune at the same time by way of targeting online shoppers through the use of hygienic packaging and technological tools. In this way, the elite pork lovers or consumers which can pay more per kilogram of meat will not be missed out.

6.3.2. Marketing potentials/opportunities in Norway

The Norwegian pig marketing body (dominated by pig producers) which determine and regulate pricing of pigs must be strengthened to ensure pig farmers continue to enjoy stable market and good returns as well. The ties regarding export of Norwegian pigs to neighbouring countries such as Sweden and Denmark and other European countries including the Netherlands must be maintained and strengthened, as it is a source of foreign exchange to boost livestock production especially swine production in Norway. The funding allocated to "Nortura" must be consistent and increased as well, so that Norwegians can continue to enjoy healthy and hygienic meat under the health and safety food programme.

6.3.3. Marketing potentials/opportunities in Ghana

In Ghana, the establishment of pig marketing board involving producers, buyers and processors to determine and regulate prices at which pigs ready for the market must be sold will become beneficial to all the stakeholders in the industry. The setup of such a body will help to a greater extent eliminate or reduce the activities of intermediaries, with many of them ending up bagging higher profits than the actual producers. Also, the setting up of more slaughterhouses/abattoirs or pork processing plant across the length and breadth of the country

will help convert other usable parts aside the carcasses that are normally thrown away or considered as waste under the traditional slaughtering system into useful products.

Moreover, meat from slaughterhouses or abattoirs are hygienically superior compared to those from the traditional or local slaughtering system. Better and proper pork meat or butcher houses must be featured at all levels with hygienic protocols in place, as many customers are attracted to and prefer buying from such facilities than those in the open or unhygienic places. Also, more programmes such as annual "Pork Shows" must be encouraged or promoted, as the last one held in Ghana helped increased pork patronage and consumption.

Table 8 is a summary of the differences and similarities existing in the marketing of pigs and pork products among the three countries.

Economy(marketing)		
China	**Norway**	**Ghana**
Imports more pork than she exports. No governmental involvement in the production and pricing of pig/pork just as in Ghana. Use of Open/Street marketing of fresh pork, sale of processed pork to Super and Hyper markets just as in Ghana. Online sale of pork just as in Ghana. Middlemen/intermediaries are involved in the sale of live pigs just as in Ghana. Peasant farmers and other individuals prepare pork into	Exports more pork than she imports. High governmental involvement, hence, market is stable because of the setting up of Nortura. Fresh pork is only sold at designated points or outlets. No online sale of pork. No involvement of middlemen/intermediaries in the sale of live pigs. Peasant farmers and other individuals do not prepare pork into various delicacies as it does in China and Ghana.	Imports more than she exports (feet and legs takes about 80%). Local delicacies sold on funeral grounds, durbars, workshops and other social gatherings. Exclusively, Ghana promotes the production, sale and consumption of pigs through "PORK SHOWS" organised yearly on the first Friday of December.

various local delicacies just as in Ghana. Bargaining and sale of live animal to slaughterhouses, abattoirs, firms, institutions by medium scale and some peasant pig producers in all the three regions. Commercial and medium scale pig producers with processing units, process and sell same themselves across the three regions.	Mature pigs are sold to processing companies/firms by commercial and medium scale pig producers in all the three regions.	

6.4. Summary of swine economy

Swine market has never been static in these three study countries due to diseases, consumer preference, pricing/cost of pork and production volume. The incidence of ASF dealt a heavy blow to the pig industries in Ghana and China but not to Norway. Production volumes of the animals in China and Ghana, were accordingly reduced which translated into large imports of the meat. In Norway as against China and Ghana, government regulation and control of production volume and pricing of pork has stabilised the swine market. Because of the keen involvement of government/government agencies in the pig industry coupled with the absence of ASF in Norway and the fact that the domestic pig production is robust, and fluctuations in production volumes and pricing is minimal, Norway exports more than she imports pork as compared to China and Ghana.

China was seriously affected by ASF. Even though the pig industry bounced back after the pandemic, the increase in production was short-lived because governmental bodies and agencies assisted only commercial pig producers and left the peasant farmers. Chinese hog price has seen a downward movement, but the rebound suffered sustenance on the price increase due to dietary switch towards poultry meat by consumers. China, like Ghana is a net importer of pork. Ghana is a net importer than exporter of pork because the incidence of ASF, the lack of or poor governmental control and regulation of peasant pig production which affects total production volume and consumer preference for the imported pig legs more than pork from Ghana, has led to Ghana being a net importer of pork. The main export destination of Ghana's pork is Côte d'Ivoire, and this has led to a situation where Côte d'Ivoire dictates the price of pork and push it down and this affects the foreign exchange earning of Ghana.

The three countries have certain channels in common. These include commercial and medium scale pig producers who have processing plants process, and sell themselves, commercial and medium scale producers without processing plants sell mature animals to processing companies, and some medium scale producers and peasant farmers bargain with and sell the pigs to slaughterhouses, abattoirs, firms and individual. Common channels in China and Ghana only are employment of intermediaries in arranging for sales or purchases of pigs by buyers and/or buying and selling the animals themselves, use of online platforms to sell live animals, sales of fresh pork in Open and Street markets, sale of processed pork in Supermarket and Hypermarkets, and lastly, peasant farmers slaughter and prepare pork into various local delicacies.

Exclusive to Norway, fresh pork meat is only available at designated or specific places well-constructed and secured with all the necessary hygiene protocols. Also, Nortura in Norway regulates and determines recent prices for pigs, truncates activities of intermediaries and sustain the swine industry. In Ghana, pork is prepared into different delicacies and sold on funeral grounds and other social gatherings. Some pig producers only buy young pigs from farmers (commercial, medium scale and peasant), reared them into marketable stages and sells them alive or slaughter them for sale. Others buy the already matured animals, keep them in their pens and sell them later or slaughter them to the market.

In Ghana, there is low patronage for fatty pork and people take advantage of this and buy such animals/pork cheap and extract the fat for oil by heating the pork in iron pans and sell. Demand

for pork in Norway is lower than that in China and Ghana but because the swine market is stable, pig farmers and producers are not disadvantaged, and they make good returns in Norway. Many of the potentials of the three countries are similar and these include the setting up of regulatory/marketing boards to bargain and determine realistic pig or pork prices, to sideline intermediaries and to stabilise the swine markets. In Norway, the already existing Nortura must be well strengthened and resourced.

Regarding Chinese and Ghanaian Open/Street pork market, sales points and food joints must be well protected, secured and health wisely accepted to prevent disease infection and pest infestation through regular and routine hygienic protocols. This will attract more consumers for better and higher patronage. Also, institution of online shopping to bring buyers and sellers together will promote faster business and realisation of better and improved prices. In Norway, trading/marketing ties with the Netherlands, Sweden, Denmark and other European countries which are the export destination of Norwegian swine should be strengthened to increase the foreign earnings of the country.

In Ghana, farmers day observed annually on the first Friday of every December can be used to create more awareness on pigs and pork by awarding swine producers to serve as production incentive. Pork shows should be organised on districts/constituency basis to expose the public to the importance of the swine industry. More slaughterhouses, abattoirs and processing plants or firms should be setup to make up for the shortfalls compared to those found in China and Norway and to make access to pork easier as well.

7. DISCUSSION

7.1. Breeds/breeding

The Ashanti Dwarf pig is the most dominant and the best local breed in Ghana because of its outstanding characteristics such as hardy and disease resistant, more resistant to heat strokes, able to survive under poor supervision and management, able to digest high fibre etc. Also, the exhibition of some traits that can be found in both European and Asian pig breeds make ADP the most celebrated local pig breed. The most celebrated exotic pig breeds in Ghana are the Landrace and Large white. Both foreign breeds are hardy, able to withstand variations in climate, able to do well under all sorts of environmental factors and have excellent mothering abilities.

Moreover, the ability of both breeds to survive under both intensive and free-range farming systems coupled with being good for commercial production as well as ability to use them to improve other local pig breeds make them the most celebrated in Ghana. The exotic breeds in the three study countries are similar. The Norwegian Landrace and the TaiHu pigs are the most dominant local pig breeds of Norway and China respectively. The Norwegian Landrace is rated highly efficient in terms of feed conversion efficiency and has high potential growth rate whiles the TaiHu breed possesses extra teat and highly fertile as well.

Consider purebred local ADP as A, purebred exotic Landrace as B and purebred exotic Large white as C. The crossbred obtained from crossing A and B will have good attributes (physiologically) such as ability to withstand harsh environmental conditions, be resistant to local diseases, more resistant to heat stroke, has high digestibility for crude fibre, hardy, has a high survival rate under poor management and supervision, has excellent mothering ability, has less back fat and lard, and has lean carcass than meat. Also, the mature crossbred boar weighs around 350 kg and that of the crossbred sow weighs around 320 kg and it produces a large number of piglets at farrowing (i.e. the crossbred is prolific) and lastly, the crossbred is easily manageable (docility). The crossbred has better and tender quality meat.

From the above, the crossbred from crossing purebreds of ADP and Landrace will have the good physiological qualities of ADP and Landrace with lesser or reduced poor qualities. From the above also, crossbred from purebreds of ADP and Landrace is used to produce pigs with less carcass than meat and also with less backfat and lard. Crossbred from A and C will have good characteristics of the two purebreds reinforced as highly productive, highly efficient

together with the qualities of ADP listed. Crossbred of the local and exotic breeds in Norway and China will also lead to the crossbred having the good qualities reinforced.

The semen from crossbred boars can be imported to improve pigs in the country of concern. For example, semen from purebred Meishan can be imported from China and used to successfully inseminate ADP sow in Ghana on heat which will lead to the production of a hybrid of higher level of heterosis, produce large litter size, produce pigs with a lot of quality tender meat reinforced with the good qualities of ADP including disease and pest resistance, environmental adaptation and excellent meat. It should be noted that the conditions/factors which kick against production of purebred animals should be improved or looked at critically, especially in Ghana to ensure production of more and proven purebreds.

Another way of promoting or improving upon the above breeding programmes especially in Ghana is to ensure that proper records of intended animals should be kept on the animals, and also target beneficiaries or farmers should be featured during such improvements. The government should also come in to support financially and logistically so that farmers do not become scared of the use of such improvements. The negative effects of inbreeding outweigh that of the positive and therefore inbreeding should be reduced as much as possible through proper examination of relatedness allowed in mating, selection within the families, critical examination of the number of progenies per male and female to be selected and the keeping of proper records on the animals. However, indiscriminate crossbreeding should also be tackled seriously to avoid extinction of animals under use or the animals becoming endangered. The success of crossbreeding rests on successful pure line breeding, hence, all efforts must be enforced to promote these breeding practices to ensure the sustenance of the swine industry.

7.2. Feed and feed ingredients

The importance and contribution of nutrition in the pig industry cannot be underestimated or overlooked since nutrition accounts for about 60% of the cost of livestock production. Feeds prepared hygienically for pigs must be nutritious and balanced for proper growth, breeding, fattening and should also be cheap and low cost as well as good for lean meat production. Peasant pig producers in the three countries form the majority in the industry but some are not able to afford the cost of commercially prepared feed and therefore prepare their own feed from locally available materials which are cheaper, available and affordable.

Cheaper sources of feed material for swine feed preparation especially by peasant or backyard producers in both China and Ghana include rice bran, broken rice and maize, damaged fruits (from poor handling, transportation and storage), pito mash, kitchen waste from households/restaurants/food joints as well as scraps from fruits and vegetables properly treated or cooked.

Peasant farmers in Ghana normally feed animals with fresh cassava peels because it is cheaply obtained from households and chop bars. The feeding of pigs with a lot of fresh cassava peels result in the animals building or accumulating a lot of fat under their skin and this affect their market value. Also, the over dependence on certain household and industrial waste in feeding the animals in Ghana results in the animals growing too fatty. Typical examples are the peels of yam and pito mash. Consumers of pork do not patronise pork which has a lot of fat, and this leads to the producers incurring losses which is a disincentive for the production of pigs. If the peels are piled up or stocked for more than 24hours, they decay, rot or ferment producing a lot of heat, gases and even alcohol as well as other toxic substances and this becomes contaminated.

Additionally, the untreated peels may contain foreign materials such as broken bottles, plastic and metallic objects and these can cause pigs to emaciate or even die. Some of these materials contained in the peels can even block the digestive system, reducing appetite and this may also lead to animals growing emaciated and that result in death in most cases. In Ghana, the leafmeal from baobab tree (*Adansonia digitata)* is another source of cheap local feed material, especially in the Northern part of Ghana. The leafmeal is an excellent source of protein containing all the essential amino acids, has high content of minerals (Ca, P), vitamin A and C (Heuzé et al., 2011).

To enable swine producers at various production levels to make use or patronise commercial feeds at reduced prices, certain ingredient inclusion (serving as generous safety margins) can be removed without affecting the quality of the feed or certain ingredients can be substituted for others to cause price reduction. For example, lactose for feeding piglets to survive post-weaning can be substituted with other simple sugars such as molasses, dextrose and sucrose. The use of Yeast with about 40% of protein in fishmeal and soybean to substitute fishmeal is also a means of reducing feed cost. Also, to produce cheaper and nutritious feed for pigs especially fatners, soybean and other grass protein sources can be considered. The benefit of quality feed and water for pigs is only realised if feeding is done in a hygienic and

contaminated-free environment, hence, profiting from quality feed and water for pigs correlates with the provision of contaminated-free feed and hygienic environment.

Pig producers/farmers/nutritionists in all the three study regions should also note that pig feed made from a mixture of animal protein by-product (meat or bone meal) and grain (corn) will perform inferior to corn-soybean diet and such diet can be improved by including tryptophan or its supplements. Inclusion of antibiotics, enzymes, and microbial supplements (prebiotics and probiotics) considered as non-feed elements are able to catalyse efficiency of weight gain and improves digestibility, hence, swine feed formulators should take a keynote. Clean and sufficient amount of water is also important in pig feeding for good gut health in the pigs. Feed formulators or producers in the study countries should note that feed consumption in pigs reduces voluntarily if excess fat inclusion is made in energy diets, hence, their avoidance.

Reduction in feed consumption will lead to loss in weight and lactation/milking which will make the animal more susceptible to diseases and pest. Farmers are advised to provide those amino acids that cannot be synthesised by pigs themselves in their diets. Lysine, tryptophan, methionine and threonine must always be provided in commercially prepared diets. Amino acids are important for tissue and muscle growth, foetus development and milk production in lactating sows. Calcium and phosphorus should be included in higher levels for young pigs but lower in finishing pigs to prevent osteoporosis. To promote nutrient absorption, electrolyte balance and pH regulation, formulators or nutritionists must ensure optimum amount of salt in swine diets.

Also, for the proper functioning of the enzyme systems and formation of haemoglobin for the prevention of nutritional anaemia, it is advisable for swine producers or farmers to ensure diets meant for their herds contains enough iron and copper. To prevent or minimise the occurrence of post weaning diarrhoea in piglets, their diets must be fortified with zinc oxide (zinc). Finally, commercially prepared feeds must be fortified with vitamins (fat and water soluble) which are very essential in pig diet. For example, vitamin E acts as natural antioxidant and prevents feed from going bad and also boost boar semen quality just as the addition of 0.5ppm selenium does. Vitamins A,D and K are responsible for good vision, proper bone formation and maintenance of normal blood clotting, respectively.

7.3. Health status

The African swine fever is a fatal and deadly disease in China and Ghana. The ability of the causative virus to survive at fifteen weeks at room temperature, months at 4°C, surviving for more than three months in meat and offal in the raw form and indefinitely when frozen makes its fighting and control more difficult for producers/farmers and veterinarians. Additionally, the contraction of the disease through urine and faeces makes its prevention more cumbersome. For best control or to avoid the spread of the disease, swine farmers/producers in affected regions must strictly adhere to measures such as destruction of the affected animals and products and proper disposing off and culling of affected animals as well. Also, observance of all biosecurity or hygiene protocols on the farm would help prevent or reduce the spread of ASF in case of an outbreak.

Other swine diseases such as Aujeszky's, coccidiosis, swine flu, classical swine fever and others have never been reported in Norway due to the seriousness the government attaches to disease surveillance and control, safety of food and strict adherence to biosecurity measures. Measures like these in place accounts for Norwegian swine keeping becoming devoid of the use of antimicrobial drugs and close to eradicating swine diseases. The only swine disease of concern to the Norwegian swine industry is A(H1N1)pdm09 which they are tackling headlong due to structures and programmes put in place. Lack of capacity of peasant or backyard farms to prevent and control infectious diseases like ASF contributed significantly to the huge losses incurred in China and Ghana during an ASF outbreak. The institution of measures like delineating of quarantine zones for infected animals and the rigorous culling of infected animals contributed enormously to bringing both the number of cases and dead/culled herds down to the level it was before August 2019.

Though huge losses were incurred by both countries during the outbreak, China was hit the hardest losing millions of pigs through culling/killing as compared to Ghana. Ghana lost less than ten thousand pigs. Another effect of ASF on Chinese economy was the loss of over $ 100 billion during the outbreak and the surge in import of pork and pork products. For any meaningful impact to be made in the control and eradication of swine diseases, there should be a properly working swine disease surveillance and control unit or system, properly working food safety authority, properly working veterinary services, strict observance of all biosecurity protocols and proper housing and feeding.

In China, just as in Ghana, swine diseases like coccidiosis, mastitis, foot and mouth disease, skin and organ abscesses and pulmonary and enteric infection still persist but they have been suppressed/subdued or under control due to the availability of vaccines, antibiotics and drugs to fight the diseases. The surest way to deal with swine diseases is to prevent their occurrence through efficient quarantine measures, properly disposing off all animals suspected or showing disease symptoms, proper and routine inspection of animals, routine medication and deworming as well as culling/isolation of infected animals. Of specific mention in ensuring the above-mentioned measures is the role of veterinarians. Designing of biosecurity models, prevention and control of infectious diseases, and simplifying of complex data and information into usable forms for easy comprehension and dissemination to target users or farmers are some of the major tasks executed by veterinarians.

7.4. Management

Like feeding and disease control, good housing is particularly important and guarantees a successful production of substantial number of pigs including their survival from weaning to the market weight point. Because there is pressure on land for various uses such as crop farming, industrialisation and residential accommodation, consideration should be given to the use of multi storey buildings as used in China. The multi storey building ensures that large population of pigs is kept on a small piece of land, reduce overcrowding, ensures effective monitoring/supervision/management of the animals, eases the execution of management practices such as disease and pest control, provision of food and water, and finally, reduces labour cost since few workers can be employed to manage the animals. However, if there is a disease attack especially if the attack is vertically transmitted, the effect can be disastrous.

The study revealed that, better housing conditions including pens/sties being spacious, floors being solid, availability of wallowing tanks, feed storerooms and sick pens must be provided to promote proper growth and function of the herds. The above provisions is eminent since it makes it easy for pig to move freely and develop more natural behaviour, for longer storage of feed as well as preventing it from going bad/mouldy and to house or isolate sick animals from the healthy ones. Wallowing tank is of utmost importance especially in the tropics to help animals cool their body temperature in the wake of high temperatures. Also, cooling down their body temperature is physiologically important because elevated temperatures cause the animals to be overheated and overheating causes a slowing down of physiological processes which lead

to low productivity and even death. The pens should be well ventilated and tidy to help prevent disease outbreak and spread as well.

Evident from figure 13, excluding the large-scale commercial farms, medium scale farms and few smallholder farms which housed their animals in permanent housing facilities, the remaining pig farmers or producers who form the majority do not house their herds in permanent structures but instead resort to use of sheds, stalls, shades and yards. This condition may be as a result of how cheap, easy and accessible the materials used in constructing these houses (shed, stalls, shades and yards) can be obtained, compared to those used in constructing permanent housing structures. Moreover, majority of the farmers who house their animals under shed, stalls, shades and yards are from peasant or backyard backgrounds and cannot afford the cost involved in the setting up of permanent housing structures.

From the study, housing made and used in each of the three countries depends on varying factors including prevailing conditions which would cater for the welfare, security and comfort of the animals. The use of thermoneutral tempo sty is the ideal housing for keeping pigs in Norway and China since it help the pigs to maintain their normal body temperature. Unlike Norway and China, Ghana, being a tropical country experiences elevated temperatures at certain periods of the year. Following from this, the commonest pig sty adopted is the Open yard type, which provides good ventilation and reduces overheating.

In the commercial pig keeping, the permanent house attached to the yard is fully roofed to serve as a sleeping or resting place which provides warmth and also, protect the animals against sunburns, heavy winds and rains from getting into contact with them. The house is usually made of cement blocks/concrete/bricks with or without cement with walls plastered with cement, and strengthened to provide protection against escape, adverse weather conditions and prey attack. The roofing is either made with galvanised sheets or thatch. In the designing of a wooden yard, the wooden sticks involved are generally treated with chemicals for prevention of termite attack, with or without wire netting. Consideration is given to the choice of roof selected as decision is purely geographical, with the thatch being the most dominant and preferred in the Northern region due to the extreme hot temperatures. The galvanised sheets are predominantly found in the Southern and the middle belts where temperatures are somehow cool to reduce or minimise heat effect, as heating can have a devastating effects on the herds.

Comparatively, housing for commercial pig farms in Ghana consist of only the permanent house with dwarf wall and wire netting or metal/iron fencing used above the wall. The

permanent house is zoned into pens to accommodate the various purposed animals in order to meet their production goals. In the case of backyard swine production, most of the pigs are produced under sheds, shades and stalls due to the lack of capital to help producers put up permanent housing. From the study, determinants including financial strength of the intended keeper, land availability, purpose of production, number of animals and the availability and cost of materials influenced the choice or selection of pig housing in the three countries. Norway and China are in the temperate regions where temperatures are low. The adoption of their housing style in Ghana will not promote higher production and productivity of the animals. For example, heat strokes, inability of boars to produce viable sperms and other factors will not make the adoption of their housing style applicable in Ghana.

Likewise in Norway and China, the adoption of Ghanaian Open yard type or sty made of dwarf wall with wire netting or metal/iron fencing above the wall will be catastrophic especially in the winter season as many piglets will die from catching cold. Biosecurity protocols or measures and their observance has become a subject of importance due to the emergence and re-emergence of several diseases difficult to eradicate or control. A typical example of such diseases is African swine fever. From the study, biosecurity was found to be in full force in commercial/large scale farms and some medium scale farms across the three countries, but less effective among peasant or backyard farms. The massive fatalities or deaths recorded under peasant/backyard productions anytime there is an outbreak of disease could be attributed to the above scenario, since biosecurity helps to avoid transmission either between farms or within farms.

7.5. Economy

According to the study, Chinese, Norwegian and Ghanaian pork market have relatively not been stable as a result of variation existing in terms of consumer preference, pricing/cost of pork, the presence or absence of a particular swine disease and the overall production volumes. The occurrence of ASF in both China and Ghana led to a sudden increase in pork prices domestically due to production shortfalls or shortages and a surge in the importation of pork products, whiles pork prices/cost in Norway continued to remain relatively stable due to the absence of ASF over the same period. Also, due to the robustness of Norwegian domestic pig production, fluctuations and production volumes as well as pricing of pork continue to be minimal.

The latter statement is in sharp contrast to the case in China, where more pork imports are required to compensate for the shortfalls in demand as a result of the local production alone not being able to meet consumer demands, resulting in use of foreign exchange which ends up causing fluctuations in pricing or making it highly unstable.

As pork consumption continues to gain the momentum or surge in China due to the preference of the meat over others, elsewhere in Norway, consumption continues to see a decline with consumers citing production, welfare and sustainability issues. Ghanaian pork market has enjoyed relatively fair or stable market with not so much price adjustments regarding domestic production over a period of time. This condition is caused by a lot of interest or preference consumers place on imported pork especially the legs than pork from Ghana, making cost of imported pork products higher than the locally produced ones. Pork consumption by Norwegians has been on a decline in decades now because more pork consumers have shown meat-reducing attitudes citing production, welfare, health and sustainability issues.

In China and Ghana, the occurrence of continuous fluctuation/variation in pricing of pork can be attributed to the lack of governments regulation and control of pork pricing, giving Norway the edge to continue enjoying stable pricing/cost of pork due to the governments regulation and control of production volumes and pricing. Another revelation from the study which gives Norway an edge over its two other comparing countries in pork marketing is that Norway exports more pork than it imports as against China and Ghana, which imports more pork than they both export. Relatively, this translates into more foreign exchange earnings by Norway than what is earned by China and Ghana. Ghana even becomes more disadvantageous relating to its foreign exchange earnings from pork exports, as the prices at which pork is sold is determined by its biggest export destination partner being Cote d'Ivoire.

Judging from table 7, China's pork production volume almost doubled to that of the European Union and thrice that of the United States post ASF, and this growth could be attributed to the Chinese governments stimulus measures that were put in place after the pandemic. Measures like the ordering of local governments by the Ministry of Agriculture and Rural Affairs to provide financial incentives for pig farmers to step up production to the standard accounted for the sudden growth. Regarding how fresh pork marketing is done in the three countries, more efforts and improvements will be needed in the area of Open/Street marketing of the produce as practised in China and Ghana. The use of better and hygienically improved structures for the marketing of pork should be of critical consideration in both China and Ghana.

The use of Open/Street market could be a potential source of disease outbreak and spread as well. Use of highly protected and hygienic structures for the marketing of fresh pork as used in Norway prevents possible disease outbreak and spread, hence, it should be encouraged or promoted for the well-being of the pork industry in Ghana and China. It also helps in boosting the sale of pork as consumers or lovers of pork are enticed or attracted to buy from such facilities, hence, increasing revenues of producers and marketers as well. Finally, the institution/implementation and strengthening of measures like online pork shopping across the study regions helped a lot not only in terms of profits but it also harnesses better cooperation between buyers and sellers for the betterment and growth of the pork market industry.

8. STRENGTH AND WEAKNESSES IN THE PRODUCTION SYSTEMS

The following conclusions can be drawn from the study. Native or local pig breeds found in the three study countries have peculiar and distinct characteristics/features/traits, which make them unique from one another, thrive and produce successfully, and promote their quick and easy adaptation under various environmental conditions. Also, some of the traits (disease resistance, higher growth rate, high feed conversion efficiency, larger litter size etc.) considered important and useful can be transferred or improved upon through the use of particular breeding programmes/practices and technological advancement such as artificial insemination. The semen of boars such as ADP of Ghana, Norwegian Landrace and Chinese TaiHu can be used through artificial insemination to inseminate mature sows on heat in the same region because of their pedigree records.

Likewise, semen from a targeted boar with desirable characteristics/traits in another country can be imported and used to successfully inseminate sow on heat to produce a hybrid or progeny with higher heterosis. Inbreeding should be avoided because of its negative effects through proper examination of relatedness, keeping of proper records on the animals and other factors. Crossbreeding should be pursued vigorously through production of pure lines and indiscriminate crossbreeding should be relegated completely. The study also shows that Chinese and Norwegian crossbreeding techniques are the same or similar and more enhancing than Ghana, hence, Ghanaian breeders need to emulate the techniques used by Chinese and Norwegian breeders in order to produce better crossbreds.

Exotic swine breeds such as Landraces, Large whites, Duroc and Hampshire have scattered all over the study regions due to how easily they lend themselves to adaptation and commercialisation and also, ability to use them to improve upon local breeds in selected country. To ensure better and improved breeding practices by peasant/backyard producers, factors such as improper records keeping, considering of certain breeding programmes as costly and cumbersome, sidestepping of backyard/peasant producers of the animals, and restriction of the improvement programme to research stations/university or demonstration farms and large commercial farms must be discontinued or relegated, since they result in low or poor breeding outcomes.

Commercial swine feed produced to fulfil various production purposes or goals in the three study countries are the same or similar relating to ingredient composition, nutrient availability

and their specific quantities in the diet. At the peasant level, various differences exist among the three countries pertaining to combination of ingredients, nutritional value and specific amounts used during formulation. According to the study, a lot of the ingredients used locally are cheaply obtained, easily accessible and considered nutritionally balanced to feed pigs. Exclusive to China and Ghana, peasant or backyard producers make significant use of household/restaurant/kitchen waste and scraps from fruits and vegetables properly treated or cooked to feed their herds.

Use of soybean meal and other plant protein sources is on the increase in Norway as a potential replacement for expensive fishmeal in swine diet formulation. Barley, corn and wheat are among the dominant ingredients found in the local Norwegian pig feed, whiles in Ghana and China, ingredients such as maize, broken rice, rice bran, sorghum, soyabean, yam peels, and pito mash dominate. China and Ghana should start intensifying the use of soybean meal and other plant protein sources considered as the least cost and highly nutritious in place of the expensive fishmeal in swine feed formulation. Overfeeding of certain household and industrial waste such as peels of yam and pito mash led to the production of fatty pork, which has low consumer acceptance especially in Ghana, hence, moderate use of such materials would be profitable as it will help to prevent production of fatty pork. Also, the study revealed that baobab leafmeal commonly found in Ghana especially in the Northern region can be used as a protein substitute during formulation of swine diets.

Inclusion of DDGS is on the increase in both Chinese and Norwegian commercial pig farms which has helped reduce feed cost significantly, but it does not exist or totally absent in Ghanaian swine diets. Attention and focus from Ghanaian swine feed formulators should be shifting towards the use of DDGS and its benefits nutritionally, as it also help to reduce feed cost significantly. Health wisely, Norway is almost at the verge of eradicating swine diseases from its entire pig population as a result of stringent measures effected by the disease surveillance and control unit under the animal health directorate. From the study, Influenza A(H1N1)pdm09 has become the major swine disease of bother till date in Norway and both veterinarians and virologists are working meticulously to bring it under control or eradicate it completely from the swine population.

In China, just as in Ghana, the persistency and presence of swine diseases such as ASF, CSF, Swine flu, mastitis, anaemia, pseudorabies, foot and mouth disease and others continue to have a devastating effect on the swine industry, leading to heavy losses economically. In China and

Ghana, the disease surveillance and control units and the veterinarians divisions of the animal health directorate must be reinforced or strengthened with all the needed resources and tools in order to fight and eradicate or eliminate diseases from their swine population as compared to Norway. The study also revealed that swine diseases in China in particular are transboundary in nature. Disease surveillance and control in Norway is at its peak because the country has a strong and robust veterinary services which is vibrant, well-resourced and coordinated and this explains why Norway is at the verge of eradicating swine diseases from the swine industry.

The design and construction of pig houses are different in the study regions and for all commercial houses or sties, the following standard components must be available – manure pit, wallowing tank, dipping tank, holding area, feed store, crush and loading ramp. All pig sties no matter the design and construction must address the following: proper sheltering and prevention of escape of animal, protection from harm, protection from diseases and pest, protection from extreme temperature and bad weather and ensure the comfort and safety of the animals. The type of pig sty located or situated in any of the study countries under any production system is determined or influenced by factors such as capital and land availability, number of animals involved, prevailing climatic/environmental conditions, availability of local materials and purpose of production.

At the end of the study, it became evidently clear that the sole aim of putting up or mounting these houses in the various study regions is to ensure safety/protection and security of the animals. Also, peasant/backyard producers made use of local materials dominant in their region to construct simple pig sties to foremost provide safety and security of the animals and also to reduce cost as well. Open yard type of housing with fully or partially roofed houses is the most dominant in Ghana because Ghana is in the tropics and does not suffer from extreme cold or hot conditions. Shades, sheds, yards and stalls are also used in housing pigs in Ghana especially among producers who cannot afford to raise permanent housing structures. In Norway, just as in China, the type of commercial pig sty and its use with fully installed insulation and ventilation fittings is an ideal choice since both countries are in the temperate zone with extreme temperature conditions.

The design, orientation of the buildings and the installations ensure safety/protection of the herds, prevents piglets from catching and dying of cold and finally, promote growth, development, health and productivity of pigs. The variation in relation to the swine market continue to widen among the three study countries due to the persistence of diseases, consumer

preferences, pricing/cost of pork and production volumes. Norway continues to enjoy a relatively stable swine market as a result of governmental regulation and control of production volumes and pricing. In China and Ghana, swine market continue to be unstable because production volumes and pricing are not regulated by government. Governmental involvement or regulation of pork production as well as pricing of the commodity in China and Ghana will help bring stability in the swine/pork market just as in Norway. The robustness of the Norwegian domestic pig production has credited the country as an exporter of pork but not an importer as compared to China and Ghana.

The study revealed that the Open/Street pork markets in China and Ghana are not up to standard hygienically and thus, not enticing enough to customers/consumers compared to Norway where fresh pork is sold only at designated places well secured with hygienic protocols. Norway does not involve middlemen in the swine market chain as against China and Ghana. The actions of these intermediaries/middlemen sometimes go to the detriment of the producers, as many of them end up bagging higher profits than the actual producers. The use of the Open/Street pork market in China and Ghana should be critically reviewed and restructured to meet all the standard hygienic protocols. Also, the employment of the services of middlemen/intermediaries in both Chinese and Ghanaian swine/pork marketing chain must be discontinued or relegated as the negatives of their services far outweigh the positives.

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