UNIVERSITY OF CAPE COAST

CARCASS AND PRIMAL CUTS YIELD OF SELECTED LARGE WHITE BREED OF PIGS REARED AT THE UNIVERSITY OF CAPE COAST TEACHING AND RESEARCH FARM

ATSU CONQUER ADATOR

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BY

ATSU CONQUER ADATOR

Thesis Submitted to the Department of Animal Science, School of Agriculture, College of Agriculture and Natural Sciences, University of Cape Coast, in partial fulfillment of the requirements for the award of Master of Philosophy Degree in Animal Science

OCTOBER 2023

DECLARATION

Candidate's Declaration

I certify that this thesis is the result of my own original research and that no part of it has ever been submitted for credit toward another degree at this university or anywhere else.

Candidate's Signature…….. Date……

Name: ATSU CONQUER ADATOR

Supervisor's Declaration

I hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Supervisor's Signature…… Date……

Name: PROFESSOR MOSES TEYE

ABSTRACT

In Ghana, there is little or no data to empirically show the yield of pork for processors and marketers to effectively trade and market pork on primal cut basis. Information available on yield of pork for western countries maybe different from pork in Ghana, hence this study. This study was experimental, with a total of eighty (80) large white breed of pigs of six months from the University of Cape Coast (UCC) Teaching and Research farm were weighed and slaughtered, after which the yield of the primal cuts were assessed. A secondary data on the patronage of primal cuts was retrieved from the Meat Processing Unit of UCC and analysed using the one-way analysis of variance procedure under the Minitab Statistical Package to find out the rate of patronage of the various primal cuts. Tukey's Pairwise Comparison was used to separate means at 95% confidence level. The dressing percentage recorded for the animals ranged from 61.8 to 65.2%. It was realised that heavier animals produced better carcass weight and primal cuts. The yields of ham, shoulder, loin chop, spareribs and fillet ranged from 6.3 to 9.7, 8.4 to 11.9, 2.9 to 4.4, 0.5 to 0.8 and 0.2 to 0.4 kilograms respectively. Data on pork patronage revealed that, the ham and the shoulder are the most patronised primal cuts on fresh weight basis, implying that such parts are most preferred in the fresh forms. Butchers are advised to select heavier animals for slaughter, as these yield better dressing percentages. Further studies should assess the carcass and primal cut yields of different breeds of pigs reared in Ghana.

KEYWORDS

Primal cuts

Meat patronage

Pork yield

Dressing percentage

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To all the staff of the Meat Processing Unit, I say thank you for your immense help.

DEDICATION

I dedicate this work to my father, Alex Kofi Adator, my mother, Grace Sogbleame and my entire family.

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LIST OF ABBREVIATIONS

ADP	Ashanti Dwarf Pig
CCWT	Cold Carcass Weight
CP	Crude Protein
FAO	Food and Agricultural Organization
DFD	Dark Firm and Dry
LWT	Live Weight
MPU	Meat Processing Unit
ME	Metabolizable Energy
PSE	Pale Soft and Exudative
UCC	University of Cape Coast
USA	United States of America
WG	Weight Groups

CHAPTER ONE

INTRODUCTION

Background to the Study

According to Lawrie and Ledward (2006), meat is the flesh of animals used as food. This definition is often widened to include the musculature, and organs such as liver, kidney, brains and hide. Devi, Balachandar, Lee, & Kim (2014) also defined meat as "the muscle tissue of slaughter animals". In Ghana and in other African countries, several other parts of the slaughtered animal are also edible to a greater percentage of the general population. These parts include the internal organs. Meat is an indispensable product derived from livestock, and serves as the top-notch choice source of animal protein to many people. The total world production of the four main types of meat (chicken, pork, mutton and beef) in 1995 was 197 million tons (Clar, 2010). The largest meat type was pork, which stood at 83 million tons, followed by chicken 53.9 million tons, beef 53.2 million tons and 7 million tons from mutton. Between 1994 and 2004, the total global meat production increased by an average of 3.8% per year. The quantum of the increase differed among the four meat types. Over the ten years, beef production increased by 16% and mutton by 17%, whilst pork and chicken production increased by 41% and 72% respectively (Clar, 2010). Different weight ranges of primal cuts may be more price sensitive to market conditions than other cuts.

The optimisation of pork-production systems, including the evaluation of alternative management and marketing strategies, requires knowledge of the between-pig variation in primal and subprimal cut weights. The weight of yield from carcasses have been evaluated to estimate the variation and

relationships among the cut weights (Schinckel et al., 2013). However, there is limited recently published data on the variation in cut weight between either side of each pig. To effectively target cuts of specific weight ranges, the magnitude of all sources of variation must be evaluated and accounted for. The sources of variation in the primal and subprimal weights need to be evaluated. In the time past, there were controversies regarding quality simply because of the unavailability of a standard system of grading (Marcoux, Pomar, Faucitano, & Brodeur, 2007). The subjectivity was due to the contribution of the influence of the four main primal cuts and lack of measurement unit for each (Pomar & Marcoux, 2003). For optimum determination of the weight of carcass, each primal cut must be weighed and expressed as a percentage to the chilled carcass weight. Currently, the value estimation of carcass has no reference price tag for the individual primal cuts. The unique characteristics of each primal cut is factored into any system used to evaluate carcasses. The fat content of each primal cut and their market value are factored into new approaches used for grading. There is little data on the yield of animals reared in Ghana, thus, making it difficult for meat processors to estimate yield when purchasing live animals for slaughter as well as their profit (Adzitey & Nurul, 2011).

The inadequacy of the yield data of animals reared in Ghana often leads to time wastage and confrontations during purchasing decisions among farmers and meat processors. Whereas, the farmer perceives he/she is being paid lesser value for his animal, the meat processor also perceives he is paying too much for the animal and may incur losses. This results to price higgling and haggling between farmers and meat processors leading to time wastage

and mistrust. The imperfect knowledge of the expected yield from live animals will often pose a challenge to farmers and meat processors when it comes to pricing live animals (Ngapo, 2017).

This research sought to produce the yield information of pigs reared at the Teaching and Research farm of the University of Cape Coast which will serve as a guide to the meat industry in Ghana, especially farmers when pricing their live animals and to meat processors when estimating profit. Also, this study sought to provide information on the patronage of the primal cuts which will help meat processors to know the most demanded primal cuts as well as the less demanded primal cuts which may need further processing to add value and boost patronage.

General Objective

The main objective of this study was to determine the carcass and primal cut yield of the large white breed of pigs reared at the University of Cape Coast Teaching and Research farm in Ghana.

Specific Objectives

1. To document the market weight and age at which pigs from the University of Cape Coast Teaching and Research farm are sold.
2. To assess the correlation of live weight on the yield of primal cuts of pigs.
3. To evaluate the proportions of primal cuts from pigs in relation to the entire carcass.
4. To evaluate the rate of patronage of various primal cuts at the Meat Processing Unit of UCC.

Problem Statement

The production of sectioned and formed meat products have become increasingly more popular in the meat industry. These products have gained consumer acceptance and are manufactured by processes which are inherently advantageous to processors. In Ghana and Africa, there is little or no available data to empirically show the yield of slaughtered pigs for processors and marketers to effectively market pork on primal cut basis (Krauss, 2001). The scantiness of the yield data on pigs in Ghana makes it difficult for meat processors to estimate their profit margin before buying of live pigs. This research sought to fill that knowledge gap by finding out the yield that is to be expected when pigs of various weight ranges are slaughtered. Commercial pork producers need results of pork yield evaluation as a quality control measure to help assure customers that their stock will produce desirable market yield.

Justification

In Ghana, there is little or no data to show the expected yield on primal cuts basis that is to be obtained from carcass of pig. This problem necessitated this research to generate data and produce information on yield that can be gotten from slaughtered pigs based on the primal cuts in percentages. For instance, how many pigs should be slaughtered to obtain one tonne of ham? This will be very difficult to answer without knowing the carcass weight or dressing percentage and as such justify why this study need to be carried out. Knowledge from this study will help producers also to effectively combine resources and produce pigs to meet consumers expectation and help processors in their budgeting decisions. Information available on yield of animals for

Western countries will be different from animals in Ghana because of difference in growth conditions, therefore, the reason to estimate animal yield in Ghana. Information from this study will help processors estimate yield from the live weight of pigs and predict potential profit margin before buying an animal. Also, based on the data generated from patronage of the primal cuts, it will help processors to determine the most demanded primal cuts. This will boost patronage.

CHAPTER TWO

LITERATURE REVIEW

Yield of Pork

The primal cut weight and other cuts such as feet, jowl, kidneys, and spareribs, as well as the weight of meat, bones, and skin fat of slaughtered animals linearly increased with slaughter weight. These findings have similarly been recorded by Correa et al. (2006), in that the weight at slaughter and primal cut are positively correlated. Meat weight increases in slaughtered animals' cuts juxtaposed with the whole carcass derived in past studies agree with findings of Cisneros et al. (1996), who revealed an upsurge of 0.14 kilogram in the weight of meat per kilogram upsurge in weight at slaughter. Studies conducted by Johnson et al. (2004), pointed out that in relation to carcass weight, slaughter weight has no effect thereof. The weight at slaughter is thought to be insignificant on the yield of meat as reported by Correa et al. (2006). Conversely, studies by Johnson et al. (2004) and Cisneros et al. (1996) revealed a decline in yield of primal cuts. Possibly, due to differences in cut patterns, slaughter, weight ranges, nutrition, genetics, and feeding management used in the studies. Inverse relationship was observed between bone yield and weight, and weight at slaughter, agreeing to the findings of Johnson et al. (2004). To curb the undesirable situation of realizing lower yield from meat cuts due to lower weight at slaughter heightens the benefits of slaughtering heavier pigs, which insinuates that, at a reduced cost, more meat can be obtained per animal. Market surveys revealed that, adequate size of special cuts cherished by consumers, such as rump cap, tenderloin, boston butt, and topside are provided by heavier slaughter weights, but these surveys

also showed that traditional cuts, such as ham, loin, ribs, boneless loin from pigs slaughtered over 105 kilograms are often not preferred by consumers due to their large size. (Bertol et al., 2015). In general, conventionally-measured carcass traits and pork quality traits were moderate in magnitude with the exception of a few highly correlated traits. The genetic correlations estimated between pork quality and novel carcass traits, and between conventional and novel carcass traits, were moderate. Pork characteristics such as drip loss, ultimate pH (pH at 24 hours post mortem) and pork colour have strong correlations (Ouma et al., 2007) as when pH drops too low, pork that is pale in colour, soft and squishy in texture and highly exudative (PSE) can occur. Inversely, if ultimate pH is too high, pork that is dark in color, firm in texture and dry in appearance (DFD) can occur (Adzitey & Nurul, 2011). Both are detrimental characteristics for pork quality and should be avoided. It is common to see pig carcasses being graded based on lean yield across the globe (Pomar & Marcoux, 2003; Daumas & Dhorne, 1996).

For over the years, consumers taste, demand and preference has been on the ascendency for leaner pork cuts across the globe. As a result, lean yield was thought to be an important factor in carcass grading systems while thorough attention is being given to payment to producers by the consumers (Johnson et al., 2004). Placing a premium price tag on lean pork cut depicts a strong link between the economic value and leanness as a pork quality criterion. In order for producers to make available carcasses matching the taste and consumers admiration, price adjusting mechanisms were employed to serve as motivation (Cross & Savell, 1994). Consequently, carcass value is determined and lean yield estimated by the deploying of diverse dissection and

cut out techniques. A number of dissection techniques and cut out methods have been studied in France with the aim of standardizing and updating grading of carcass systems (Daumas & Dhorne, 1996). In order to settle on a dissection method to choose, several factors may have to be considered to define the leanness of yield in a unique way. A simple dissection method was developed through works of European union for the purpose to save cost cum time (Walstra & Merkus, 1996). For instance, determination of the value of carcass in America hinges on the harmonization efforts of carcass grading systems by players in the hog sector.

The Cut Prices and Trends in Pork

Season is found to influence the percentage economic contributions to the entire carcass market value; however, unstable price tags recur yearly. Spanning between 1999 to 2003, the economic contribution of belly to the entire carcass value surpassed that of ham and loin (Popescu, 2016). Since 1999, fair stability was recorded among trotters, the butt, and side ribs to the total economic market value. Time effects on the cuts of meat reveals the economic contribution to the market value on percentage basis. In order to get a representative price for the analysis, 2003 average data on prices was used in the computations and also because due to its availability although from 1999, the value of the belly keeps rising in a steady manner. The contribution of a low weight cut of meat to the entire market value will be minimised even if price upsurge in a kilogram of the meat is significant (Marcoux & Pomar, 2014). For heavier meat cuts, the opposite effect is true. The contribution of other cuts to the entire carcass value will change totally should there be a

change in one part since, there must be a total sum of one hundred percent if all parts are expressed as a percentage (Marcoux & Pomar, 2014).

The carcass value variations are not only explained by the leanness of carcass as a characteristic explained by the diverse yield definitions. Market value and yield relationships are affected by fat removal and or trimming rate from meat cuts aside price of cuts and conformation. Defatting mostly happens to the loin during fabrication of meat on commercial basis as the recommended thickness of back fat should be below 9 mm (Popescu, 2016). Also, defatting is performed on the butt of the shoulder after a small amount of fat is trimmed off, leaving a 12mm thickness of fat cover. The front hock and the jowl are left intact and do not undergo any fat trimming. The ham and the belly undergo minimal defatting during the transition from primal cut to commercial cut. Several commercial cuts of meats have an amount of fat embedded within in order to increase their market value. This reality creates a missing link between carcass market value and yield. Therefore, it has become an albatross to state the ideal amount of fat to be contained in meat in order to meet producer price expectation and consumers taste and preference.

Evaluation of Carcass Value

In order to meet consumers demand, carcass evaluation systems are devised and its usage encouraged (Cross & Savell, 1994). The preferred quality criteria attract the expected price premiums (Pomar, Rivest, Jeandit, Bailleul, & Marcoux, 2001). Higher commercial value is attached to products that meet consumer's preference and taste. Trusell, Apple, Yancey, Johnson, Galloway & Stackhouse (2011), stated that fatty meat which are too visible to consumers makes such meat unattractive to consumers. As revealed by the

same authors, lean meat is always desirable to consumers than fatty meat and to get premium price for meat, effort must be made to trim off the excess fat from the meat. Majority of farmers in Quebec are now very careful to produce animals that produce lean meat always, and reports had it that this has been achieved (Le´vesque, 2003). The processing sector must also endeavour to employ methods that do not add excess fat to meat but rather improve the leanness. It therefore appears that the signal given via the current grading and payment system may not be the most important criterion to consider if one wants to reward the producer according to the market value of carcass.

A lot of factors affect pricing of meat and meat products an appropriate system of carcass evaluated need to be figured out and utilized. A major hinderance to a new carcass evaluation system is meeting the expectation of consumers and making a clear interpretation to producers vis a vis ensuring marketing and production are profitable and consumers needs also met. Andersen, Oksbjerg, Young, & Therkildsen (2005) pointed out that when it comes to meat quality, the perception of most consumers wavers regarding environment, welfare of animals, ethics, and this led to concept formulation for meat quality complex. Regardless, the price attached to different cut prices of meat reveals to consumers the quality status of meat and hence, their attractiveness to a particular meat cut. The production sector is being fed with indications from consumers. Premium prices are attached to loin muscle, while increasing the size as some Northern America companies offer has a weak relationship which cannot be justified (Pomar et al., 2001). It must be noted that increasing the area of a meat cut does not necessarily translate to its weight been increased and quality of such a meat is not even guaranteed

Węglarz (2011). The loin of pigs could be attached a premium since it offers tenderloin, side rib cuts and loin in much more quantity. Bacon is mostly processed from the belly in Northern America and side rib cuts, tenderloin are the parts that attract highest prices. There are differences in the value accorded to fat from animals based on the anatomical position of the fat in the animal. Commercially, bacon fat is at par with lean but fats been visible on meat cuts is not preferred by consumers (Brewer, Zhu, & McKeith, 2001; Ngapo & Dransfield, 2006). In order to find a mutual ground to satisfy producers and consumers, consideration to consumer preference must be factor into the evaluation system for pork and price adjustment made to producers who meet required standards. Consumer interest and producer expectations are always in contrast and need to be synchronized (Person et al., 2005). There should be niche markets to differentiate meats based on quality, and this must be a characteristic of a carcass evaluation system that is effective. Potential income will be maximised if carcasses with conformations are developed for diverse markets and marketing of meat products will also be boosted. Conformation criterion becomes important in the evaluation systems of carcass as it minimizes weight variations and ensures cuts that need to value high are catered for duly. For income to be maximized, evaluation systems of carcass is very essential. Using grading measurements such as fat, muscle thickness, warm carcass weight produces inadequate results therefore, price payment cannot depend on such. The four basic primal cuts affect carcass value and grading systems must take into account the proportion of each. The fat content must be determined taking into consideration ham, shoulder and loin as limited information is provided by whole carcass weight. In the same vein, to

estimate the carcass value will need a reference price from the market which is unavailable. A major challenge is to determine unique characteristics of the primal cuts as this poses a major hinderance to the evaluation systems of carcass in respect carcass value. An effective system will check out the lean and fat content of the shoulder, belly, ham and loin as well as their weights and determine the market value of each (Węglarz, 2011). Grading methods and current technologies will drastically change due to the need to determine leanness and weight at slaughter lines (Banson, Nketsia-Tabiri, Anno, & Dagbui, 2014).

The contribution of shoulder, loin, belly and ham influence the carcass value. The weight, monetary value on the market and leanness all have influence on their contribution factor (Marcoux, Pomar, Faucitano, & Brodeur, 2007).

Marketing of Pork

Despite the increasing price of pork, it remained the most consumed meat in Ghana (Osei-Asare, & Eghan, 2014). "Pork-show" which is a popular way of marketing pigs in Ghana is done by offering primal cuts such as the picnic, butt, loin, belly, head, legs, and offal near the producer's farm on a piece of trays. Demand for pork in Ghana and the production of pigs affect pork availability. Ghana's demand for pork outweighs her local production and therefore, import processed pork to cater for the demand deficit (Seré, Steinfeld, & Groenewold, 1996). A number of factors such as production systems, feed and breed affect growth rates and farrowing from one country to the other resulting to discrepancies in the gains made countries. A home-grown strategy by the Ghana government to scale up domestic production of pigs to meet her demand was improved pig breeds imported through the

Ministry of Food and Agriculture and distributed to our local farmers (Panel, 2020). Over the past decade, local production of pigs has been boosted and consumption of the same have also increased simply because, demand for pork is ever increasing. Products from pork which are value added such as bacons, sausages, pork chops and ham have been necessarily developed due to demand and marketing forces. A lot of adjustments and technologies have been employed in the pig production sector just so productivity will be boosted (Karlson, & Eidman, 1991). The impact of these technologies has well been felt in revenue increases and upsurge in production. For instance, increasing scale of production led to benefit in terms of cost due to economy of scale and its attended profit increase. Economies of scale in this context means the reduction in unit cost of inputs as the number of pig increases. More precisely, as the number of pigs increases the initial cost of investment is spread over the huge numbers leading to an increase in the return-on-investment (Banson, Nketsia-Tabiri, Anno, & Dagbui, 2014).

Overview of Pig Production and Breeds in Ghana

Food supply must be increased continuously as population across the globe keeps increasing in order to achieve food security (FAO, 2006). Hunger has been on the ascendency worldwide over the past three years consecutively. Reports indicated that eleven percent of the global population is undernourished, out of which 23.2% are based in sub- Saharan Africa and 15.1% are within western Africa. Nutritional wellbeing and a major protein source could be gotten from livestock (Komatsi & Kitanishi, 2015) and a good aspect of the pig industry is the prolificacy of the species, ease of management, and the myriad of farmers engaging in the sector on a small-

scale basis (Osei-Amponsah et al., 2017). Productivity could be boosted by the pig sector due to its shorter generational interval, fast growth rate, high litter sizes, good feed conversion efficiency juxtaposed to raising cattle (Mbuthia et al., 2015). However, a lot of study is needed about local pig farmers and their practices with the aim of providing guidance and technical expertise to boost local productivity and returns to the farmers (Adjei et al., 2015).

Conservation and improvement of pig production systems depends on their characterization. Breeding programmes thrive on information on production systems but this information is limited (Adjei et al., 2015; Ayizanga et al., 2018). When it comes to pigs, exotic breeds such as large whites and landraces, the local breed e.g Ashanti Dwarf pigs (ADPs), and crossbreeds which are crosses between local pigs and exotics are identified. Crossbred pigs are mostly kept by farmers as revealed by available data compared to the local and exotic breeds. Close to 95% of the pig farmers are into the production for meat and income (Fletcher, 2002). On the basis of preference for the traits, 49% of the pig farmers consider how fast the pig grows to choose them for raising and 30% chose body length and size to settle on which breed to raise (Mbuthia et al., 2015). Coat or skin colour is of no relevance to farmers when selecting breeds for raising (Mbuthia et al., 2015). A good number of the farmers provided some form of housing structure to their pigs (Komatsi & Kitanishi, 2015). However, few farmers do not have any structure for their pigs (Komatsi & Kitanishi, 2015). Kitchen left overs such as fish remnants, cooked cassava, soup and yam are with used to feed the pigs with quite a few farmers providing concentrates (Fletcher, 2002). Agro-industrial by-products (AIBPs) are used by a good number of farmers to feed

their livestock. Cost of feedstuffs are the major constraints to most farmers although the accessibility of such formulated feeds is available. When it comes to sourcing of breeding stocks, majority of the pig farmers depend on open markets, friends and family with a little of about 10% depending on breeding stations to provide their foundation stock (Aryee et al., 2019). Veterinary services are available and accessible to a little over 65% of farmers which made them to record low mortality rates (Aryee et al., 2019).

In the, Upper East, Volta region and Bono - East region women are the care givers to the pigs although ownership reside with the men (Aryee et al., 2019). This is to allow the men to take care of their crop farms. However, the narrative changed in the Western region where women possessed and manage their own piggery and engage in crop farming as well (Aina, 2007). FAO reports that, food processing, livestock farming and subsistence farming are mostly done by women indicating the pivotal contribution of women to agriculture (FAO, 2006). Some farmers in Upper East and Bono East did not have any formal education and this affects their management of the pigs but that of farmers in Western region, have had little formal education (Aryee et al., 2019). A considerable number of farmers in Africa have not gone to school and as such find it difficult to adopt new technologies in farming since no language could be written or read by them (Aina, 2007). As at the year 2010, lot of children below the age fifteen, fifty-eight percentage have not been enrolled in school, but government intervened with relevant policies and about 85% boost in children enrolment was recorded in 2017 (Aina, 2007). Possibly, the high involvement of women in pig farming may be due to the generally improved level of education among the farmers in the Western region (Aryee

et al., 2019). The ease with which farmers embrace new technologies in the farming was due to their comparatively high education background (Kimbi et al., 2015). Young adults between the age range of 20 and 50 forms the majority of farmers who are into pig farming. This is positive as agriculture development can be greatly enhanced if the youths are involved; there is a growing concern among agricultural developers and policy makers over the reluctance of the youths in rural areas to engage in agriculture. Unlike the past where farmers raise pigs on subsistence basis just for their families, now farmers are raising pigs to generate income and still feed their families (Ganaba et al., 2011). Farmers in Ghana largely keep Landrace, Large White, and Duroc as their pig breeds (Aryee et al., 2019). Crossbreeding is also been done by many of the Ghanaian pig farmers. Osei-Amponsah et al. (2017) found that farmers in their attempt to improve the productivity of their pigs engage in indiscriminate mating of exotic and local breeds which rather leads to low productivity due to inbreeding depression. As a result, reduced reproduction, distortion of adaptive features, poor health is recorded by the farmers instead. Ministry of Food and Agriculture has imported large white pigs being exotic and given to local farmers thereby contributing to the menace by encouraging farmers into cross breeding without due diligence to consider inbreeding depression (Aryee, Osei-Amponsah, Owusu Adjei, Ahunu, Skinner, Sargent, & Affara, 2019). Germplasms which are adaptive to local settings must be taken into consideration when interventions for the future are being planned. Traits of pigs which are of much interest to farmers must be thoroughly catered for when breeding programmes are being designed. Earlier studies revealed that valuable traits which farmers prefer are

heterogenous (Ouma et al., 2007). Fast growth rate is preferred by majority of farmers. Litter sizes, body length or size and good mothering ability are other traits preferred by some farmers. A few number of farmers value skin or coat colour (Aryee et al., 2019). Therefore, for a country like Ghana, all these traits must be given thorough attention when developing breeding programmes. Housing facilities also pose a great challenge to local farmers in that, shades, stalls and yards are temporally used to house pigs in contrast to commercial systems where permanent structures are used (Aryee et al., 2019).

Under the local conditions, it is easy to get the housing materials and easy to afford hence, many farmers resort to shades, stall and yards (Karnuah et al., 2018). Pig farmers also have as one of their biggest challenge feed availability and cost. Studies revealed that feedstuffs are readily available but very expensive. Consequently, majority of the farmers do not use concentrates but resort to agro-industrial by products and kitchen wastes to feed their animals. Record keeping by the local farmers is almost lacking but compared to commercial farmers, they earn less (Karnuah et al., 2018). The inadequate income generated by the local farmers may be due to the poor-quality feeds they depend on to feed their animals as Karnuah, Dunga, & Rewe (2018) pointed out that formulated feeds and concentrates cannot be afforded by local farmers and this affect the productivity of the animals and their accrued income. Friends, families serve as the source of breeding stocks to most farmers due to closeness of their farms. The few farmers who source their breeding stock from breeding stations do engage in crossing for families and friend and consequently lead to inbreeding depression (Ouma et al., 2007). Due to this, there is a high possibility of indiscriminate crossbreeding among

pigs in the communities studied. Finally, with regards to litter size, disease resistance and mortality experienced on farm, these pig farmers do not keep records on their farms, but concluded that local pigs had smaller litter sizes and were resistant to most endemic diseases. Most farmers said they have access to veterinary services but are not able to purchase commercial drugs. Nonetheless, they record low mortality on their farms. This result agrees with reports that, local pigs are hardy, disease resistant and are able to survive drought incidence in Ghana (Adjei et al., 2018; Osei- Amponsah et al., 2017; Ayizanga et al., 2018). Fifty (50%) of the national population of pigs in Ghana is made up of the Ashanti Black Pig (ABP) and it is the predominant indigenous breed of pig in Ghana (Adjei et al., 2018). This pig breed is hardy and thrive well under poor nutritional and husbandry practices, able to withstand the heat strokes from the sun in the tropics and very resistant to adverse conditions making it very adaptable to tropical conditions (Barnes & Fleischer, 1998). Trypanosomiasis never attacks this breed of pig due its resistance to the disease (Ayizanga et al., 2018). The bulwark of the Ghanaian pig industry depends on the Ashanti Black Pig since, it is a carrier of a vital genetic resource that need to be harnessed and utilized after characterization and improvement is done to it. Nonetheless, the local pig must be preserved if genetic diversity is to be maintained.

Growth Characteristics and Performance of Pigs

The decision to cull sows always borders on their inability to reproduce and this is usually done at early parity. Every farmer desires among many other things to have sows that are highly productive and can have several parities in order to maximize gains economically (Engblom et al.,

2007). In the industry of pig production, litter size is very desired for economic reasons. Higher birth weight, high survivability and fast growth rate are other vital traits being sought after by pig farmers. Among the many factors that regulate the growth of piglets, both the gene of the sow and that of the piglet are pivotal in regulating the growth of piglets (Grandinson, 2005). To develop breeding programmes that are very effective, impact of genetic effects need to be holistically considered because of the antagonistic effect reported in earlier studies (Holm, Bakken, Klemetsdal & Vangen, 2004). A good performance indicator of a sow is seen in the early growth of the piglets and considered as fast growth rate to justify future performance of sows (Ayaz, 2000). Solanes et al. (2004) posited that, piglet weight needs to be taken at four instances in order to declare a positive relationship among direct effects. Consequently, a higher milk producing sow is needed to match up the large litter size and rapid growth rate of the piglets. Grandinson (2005) revealed that, there are discrepancies in the weight of lactating sows. Faster growth rate piglets and high survivability piglets are always produced by sows that use their body reserves during lactating periods as revealed on genetic and phenotypic levels than sows that could mobilize less reserves in the body (Grandinson et al., 2003; Valros et al., 2003). Within a week post weaning, sows are to come back on heat as is the expectation. The sows choose to invest the limited reserve in the body to maintaining its own body cells and tissues, its growth other than survival of the offspring and reproduction (Beilharz et al., 1993). The problem of nutrient allocation between the needs of the sow and that of the offspring is paramount conflict encountered by sows that are primiparous. To avoid culling, the sow must return to heat for continuity of

reproduction despite its own need of adequate resources for growth (Whittemore, 1996). Luteinizing hormone which is a reproductive hormone will be negatively affected by large litter as luteinizing hormone ensures follicle development. The duration for sows to return to oestrus after weaning will take longer time than normal because of the rate of depletion of body reserves of the sow having large litter size (Sterning, Rydhmer & Eliasson-Selling, 1998). In the same vein, Tholen et al. (1996) revealed that, the resumption to heat among primiparous sows is longer. Sterning et al. (1998) also revealed the relationship that exist between reproductive traits and production traits. The relationship between litter weight gain and return to oestrus is low for sows that shows standing heat. The relationship between weaning interval and return to oestrus and the loss of weight during lactation is high. Lactation length and feeding strategies which are among managerial factors could be used to explain the phenotypic differences.

Season and climate which are environmental factors are also plausible to cause phenotypic changes. Proper management could lead to the impact of production demand not to be felt by the sows despite differences in the traits. The explanation of these genetic correlations is based on a possible genetic antagonism between backfat thickness measured at selection day and longevity after farrowing. Difficulties in sows becoming pregnant due to a negative energy balance is a possible explanation for the unfavourable relationship between backfat thickness and longevity, since reproduction problems are important reasons for culling (Valros et al., 2003). The influence of backfat thickness on longevity could also be explained through leg weakness syndrome as a consequence of lower backfat thickness as has

previously been described by other authors. Petracci, Bianchi, Cavani, Gaspari, & Lavazza (2006) found that Landrace boars with lower fat levels developed leg weakness earlier in life. Tholen et al. (1996) also reported that pigs with better legs were fatter and Marahrens, Von Richthofen, Schmeiduch, & Hartung (2003), estimated an unfavourable genetic correlation between lean percentage and leg weakness score in Landrace. In this respect, Petracci, Bianchi, Cavani, Gaspari, & Lavazza (2006) opined that selection for leaner pigs, like the sows in a study, leads to the loss of adequate front-leg structure in Duroc swine.

Management of Pigs

It is in agreement with the unfavourable genetic correlations between backfat thickness and the exterior traits of gait and swinging of back. An extensive discussion of pigs' management and breeding have been done by Tholen et al. (1996). Foundation stocks are usually gotten from weaners aged 2 to 3 months old. A typical pig farm will compose of gilts and boars serving as the foundation stock. Structures, well-constructed and having wallows are used to shelter the pigs. Formulated feeds, diets which are cereal-based, grasses are used to feed the animals. Periodically, treatments which are prophylactic in essence are administered to the pigs to guard against parasites and infections. For gilts to be considered matured for breeding purposes and to be mated, it must be aged 7 to 8 months and having 55 kilograms to 60 kilograms body weight. When parturition is due of about a week time, thorough grooming and deworming is done to the sows and the farrowing pen adequately disinfected. Straws are used as a bedding material to insulate the new born piglets against cold stress. In the first week of parturition, iron

dextrin injection of 2ml is given to the piglets and each clearly identified. (López-Serrano et al., 2000). Until weaning from the time of farrowing, lactating sows are fed with ration composed of crude protein (CP) of 16% ad-libitum. Ration made up of 20% crude protein is used to creep feed piglets 3 to 4 weeks postpartum. Weaning is carried out on an average of 6 weeks and the weaners identified with ear tags. To hasten the return of heat period in sows, flushing is done by feeding a high energy and protein ration made of metabolizable energy of 13.5 MJ/kg and 18% protein which is crude after two weeks of weaning the sows. Until the animal is disposed of, an up-to-date record is kept on them. Feeding systems and management practices pose opportunity to enhance productivity of the Ashanti Black Pigs and conservation done to them. Appropriate breeding schemes and proper selection methods taking into consideration the traits which are of economic importance to farmers can help improve the genetics of the pig. To monitor genetic progress and performance, the above-mentioned parameters are very essential to predict the selection response. Due to differences in environment, the genetic parameters in pigs elsewhere may not be applicable to the Ashanti Black Pig because it is specific to that population. Hence, to develop a breeding programme for the Ashanti Black Pig, estimation of genetic parameters need to be specifically done for it (Darfour-Oduro et al., 2009). Estimate for growth traits through direct heritability are said to be low by Cassady and Robinson (2002). Piglets pre-weaning traits are directly inherited during lactation and also during gestation because of the potential for growth of the embryo (Kaufmann et al., 2000). However, maternal effect and random effect have similar heritability for birth weight directly (Knol et al., 2002)

Relationship between Heritability and Pig's Live Weights

Kaufmann et al. (2000) posited that the direct heritability of birth weight is widely low after maternal heritability and direct heritability have been estimated. Undoubtedly, birth weight to a larger extent determines early post-natal survival among piglets. According to Kaufmann et al. (2000), "maternal genetic effects are presumably caused by genetically controlled components of uterine nutrition, uterus capacity and milk production". A lot of variation exists in the determination of weaning weight, pre-weaning weight and birth weight with regard to maternal heritabilities in literature. The reduced level of cross-fostering for Ashanti Black Pigs may have accounted for the difference in the estimated maternal heritability for the traits. Maternal effects are expected to be high in piglets at Babile because, sows suckle their own off springs. Reports by Kaufmann et al. (2000), "There is relatively high direct heritability of weaning weight as compared to birth weight in studies involving Large White pigs". Piglets weaned from their mothers till 180 days showed a clear maternal additive genetic decline. Milk quality and production which are traits associated with sows will not be tampered with if improvement with regard to prior weaning management of Ashanti Black Pigs is to be done because, positive direct maternal correlation exist between piglets pre-weaning daily average gain, birth weights and weaning weights. According to Grandinson et al. (2003), however, "observed significant negative genetic correlations exist between direct and maternal effects for daily gain from birth to weaning". Two traits been determined as a single gene is an indication of a perfect direct genetic correlation. However, according to Lynch and Walsh (1998), "a perfect correlation is equivalent to an absolute

evolutionary constraint, since no change can occur in either character without a parallel change in the other". The implication is that, heavier pigs will be weaned from pigs having heavier birth weight. Same gene may have influenced both pre-weaning average daily gain and birth weight due to the observed direct genetic correlation in a study. There will be high pre-weaning growth rates and heavier pigs at birth in the litters due to the positive maternal correlation that exist between pre-weaning average daily gain and birth weight. Also, heavier pigs will be weaned from heavier pigs with high pre-weaning average daily gain due to the positive maternal genetic correlation between pre-weaning average daily gain and weaning weight. In this literature, estimated direct genetic correlation for other traits were higher than the positive direct genetic correlation between post-weaning average daily gain and pre-weaning average daily gain. The lower genetic correlation of piglets may be as a result of the stress associated with weaning pigs at the initial post weaning periods juxtaposed with other genetic correlations estimated in this literature which were direct-direct. Grandinson et al. (2003) recorded for post-weaning average daily gain and pre-weaning average daily gain a value close to zero for direct-direct genetic correlation. There is a good genetic capacity for post weaning average daily gain as well as high pre weaning average daily gain among piglets for which the direct genetic correlation estimation was done in this literature. According to Darfour-Oduro et al. (2009), "sows with genetic capacity to give birth to piglets with high growth rate before weaning have a poor growth rate in their litters after weaning as maternal genetic correlation between pre- and post-weaning average daily gain was negative". In expectation of positive response of growth traits to selection, there has been

variation according to the obtained heritability estimates in this literature. However, in regard to weaning weight at 180-day weight, weaning weight and pre- and post-weaning average daily gain, positive response should be expected as well as faster progress. Growth traits are influenced largely by maternal additive effect. Hence, the growth traits are influenced by same genes to a large extent due to the moderate to high genetic correlations recorded in this literature.

Factors that Affect Pork Quality

Technological Quality

The quality of pork is a function of diverse characteristics on which its display in retail shops, processing into various meat products and storage depend whether it is suitable for purpose or not. The determining characteristics which consumers base their decisions on are but not limited to uniformity and oxidative stability, fat content and composition, colour and water holding capacity. One major criterion for assessing meat quality is its technological quality. As a matter of fact, technological quality is a multivariate and complex index of meat, with myriad of factors interacting and having influence on it (Grandinson et al., 2003). These factors comprise of storage and chilling conditions, genotype of the pigs, feeding regime, breed, stunning, pre-slaughter handling and the slaughter method. Feeding strategy and genotype directly affect oxidative stability and uniformity, fat composition and content whereas the remaining factors affect the colour and water holding capacity of the meat (Rosenvold & Andersen, 2003). For some length of time now, the quality of pork has received thorough attention with regard to firmness, fatness, colour, structure and marbling. The processing

characteristics of meat from pale, soft and exudative pork have been studied by Grandinson et al. (2003), Berg & Allee (2001) and (Stahl, Allee, & Berg, 2001). The relationship between yield of processed pork and fatness of the animal has been reported by Gallo, Lizondo, & Knowles (2003). Studies were conducted and revealed the impact of supplementing feed with creatine monohydrate up to slaughter on technological quality of pork (Berg & Allee, 2001; O'Quinn et al., 2000; Stahl, Allee, & Berg, 2001). The motivation for such a study was necessitated by supplementing human diets with creatine monohydrate which was proven to result to a 20% load increase in intramuscular creatine (Greenhaff, 1996) and lean body mass also proven to be increased by same (Balsom, Soderlund, Sjodin, & Ekblom, 1995). Retention of water was also seen to have been improved by supplementing diet with creatine monohydrate (Juhn, 1999). Study also has showed, just as phosphocreatine leads to upsurge in muscle energy stores when supplemented in feed, creatine supplementation does same (Casey, Constantin-Teodosiu, Howell, Hultman, & Greenhaff, 1996). This explains why pH fall in the muscle of pig post mortem is retarded since there is enough energy stores. There is delay in pH decline as the metabolism of the energy store takes comparatively longer time. Cooking loss decreases by the supplementing feed for five days with creatine monohydrate as well as gain in weight and decreased pH fall post mortem (Berg & Allee, 2001; Maddock, Bidner, Carr, McKeith, Berg, & Savell, 2000). Evidentially, pigs fed with the supplemented feed reduced the prevalence of the occurrence of pale, soft and exudative meat (Maddock et al., 2000). In contrast to the gains made, technological quality of the meat will be negatively affected if the supplementation duration is

extended from ten to fifteen days (Stahl et al., 2001). Nonetheless, O'Quinn et al. (2000) reported that pork quality will never be affected by the supplementation with creatine monohydrate. Creatine monohydrate supplementation was found to reduce the occurrence of pale, soft and exudative meat (Maddock et al., 2000). This could be that most of the pigs carry the gene known as halothane and the impact of supplementation is felt more in carrier pigs in their meat. However, an alternate study by Maddock et al. (2000) reported that technological quality is never affected by creatine monohydrate supplementation.

Feeding Impact on Pork Quality

The kind of feed given to pigs have a direct effect on pork quality because they are monogastric animals. The fat tissues and muscle components are derived from the kind of feed given to the pigs. The composition of the fatty acid is a direct function of the composition of the feed (Wood & Enser, 1997) as well as the mineral and vitamin composition will be impacted by supplementing their feed with vitamin E (Buckley et al., 2001). Fish meal as a component of feed is been found to give off-flavour (Gallo, Lizondo, & Knowles, 2003). In addition, through feeding, manipulation can be done to muscle glycogen stores at slaughter (Rosenvold, Lærke, Jensen, Karlsson, Lundstrom, & Andersen, 2001; Rosenvold, Lærke, Jensen, Karlsson, Lundstrom, & Andersen, 2002) and thus, technological pork quality and pH decline post mortem will be affected. It must be noted that dietary fatty acids are incorporated into tissue lipids from the intestine where absorption takes place. In situ synthesisation of linolenic and linoleic fatty acids which are polyunsaturated fatty acids is not possible, therefore, dietary changes quickly

affect the concentration of the fatty acids in tissues. On the contrary, diet rarely affects the concentrations of the monounsaturated and saturated fatty acids since they are mostly synthesized (Pariza, Park, & Cook, 2001). Due to the concern of too much fat in human diet, attempts have been made to use feeding to control fat deposition in pigs and other animals i.e., to get an ideal ratio among polyunsaturated, monounsaturated and saturated fatty acids (Jakobsen, 1999). However, meat will be considered inferior if there is a high level of polyunsaturated fatty acids in it as the incidence of pale, soft and exudative meat is highly possible to occur (Cameron, Penman, Fisken, Nute, Perry, & Wood, 1999; Hays & Preston, 1994; Warnants, van Oeckel, & Boucque, 1996). For this reason, in the United Kingdom, formulating feed uses 16 grams linoleic acid per kilogram of feed serves as the common threshold (Wood & Enser, 1997). It must also be known that, reduced shelf life is highly possible for a product which has higher amounts of polyunsaturated fatty acids due to susceptibility to oxidation (Sheard, Enser, Wood, Nute, Gill, & Richardson, 2000). Also, there exists an inverse relationship between the concentration of polyunsaturated fatty acids and amount of fat in animals (Wood & Enser, 1997). Consequentially, improved oxidative stability and higher concentrations of polyunsaturated fatty acids in meat products have been achieved during processing due to demand of carcasses which are lean. It is possible not to affect oxidation of lipid negatively and still use feeding strategies, rightly to improve the nutritional value of pork regardless of the problems listed above (Riley, Enser, Nute, & Wood, 2000; Sheard et al., 2000). There is a swift change to vegetable fat which is more unsaturated from animal fat which is saturated more with

regards to the source of dietary fat. Pork quality may resultantly be changed owing to the change. The firmness of pork fat could be achieved by feeding animal fat to pigs at the finishing stage (Warnants, van Oeckel, & Boucque, 1996). Most attention has been given to conjugated linoleic acids as a result of the interests sparked by the effects of dietary lipids. In the mid-1980s, the importance of conjugated linoleic acids has been identified (Dunshea & Ostrowska, 1999; Pariza, Park, & Cook, 2001). An increase in lean meat content has been identified in pigs due to conjugated linoleic acids in their diets as well as reduction in fat content (O'Quinn et al., 2000; Swan, Parrish, Wiegand, Larsen, Baas, & Berg, 2001; Thiel-Cooper, Parrish, Sparks, Wiegand, & Ewan, 2001; Wiegand, Parrish, Swan, Larsen, & Baas, 2001). However, few contrasting results have been reported with regard to conjugated linoleic acids (O'Quinn et al., 2000; Ramsay, Evock-Clover, Steele, & Azain, 2001). The ratio of unsaturated or saturated fat in muscle, intramuscular and adipose tissues is found to be increased due to conjugate linoleic acids as well as the improvement in firmness of the belly with regard to meat quality (Dugan, Aalhus, Jeremiah, Kramer, & Schaefer, 1999; Eggert, Belury, Kempa-Steczko, Mills, & Schinckel, 2001; Joo, Lee, Ha, & Park, 2002; O'Quinn et al., 2000; Ramsay et al., 2001; Thiel-cooper et al., 2001; Wiegand et al., 2001). In addition, O'Quinn et al. (2000) recorded an increase in water holding capacity as well as pH_{24}, but eating quality has being judged to be inferior in light of tenderness, flavour, overall acceptability and juiciness as a consequence of feeding with conjugated linoleic acid (D'Souza & Mullan, 2002).

Vitamin E and Other Antioxidants Utilization for Feed Supplementation

Originally, when it comes to nutrition, normal reproduction was the only role thought to have been played by vitamin E as dietary factor of nutrition. Far more than that, vital role in life processes, protection of the integrity of tissues and significantly, a radical chain breaking antioxidant are proven to be the importance of vitamin E (Buckley, Morrissey, & Gray, 1995). Functions such as protein kinase C inhibition, growth of certain cells, transcription of some genes and radical scavenging ability were found to be performed by vitamin E aside its primary role of being an antioxidant (Azzi & Stocker, 2000). Pork products and fresh pork are protected from lipid oxidation when 200 mg per kilogram of feed contains vitamin E which is above the level of dietary requirement (Asghar et al., 1991; Buckley, Morrissey, & Gray, 1995; Jensen et al., 1998; Lauridsen et al., 1999; O'Sullivan, Kerry, Buckley, Lynch, & Morrissey, 1998). Primarily, pork quality is jeopardized by microbial spoilage and lipid oxidation upon which shelf life of pork and pork products ultimately depends. Odour and off-flavours are produced by the influence of oxidation (Morrissey, Buckley, Sheehy, & Monahan, 1994) and toxic compounds are potentially formed. The composition of the meat in terms of fatty acid and the concentration of vitamin E determines the extent and rate of lipid oxidation within the meat. Meat discoloration is believed to be a function of the enzymatic and oxidative processes as well as systems to reduce metmyoglobin in the meat (Faustman & Cassens, 1990). Stability of fresh beef and colour improvement have all been achieved by the supplementation with vitamin E. However, an inconclusive result has been recorded when the same strategy was used to improve the

colour of pork (Faustman & Wang, 2000). Vitamin E supplementation has been reported by several studies to improve colour stability (Asghar et al., 1991; Monahan, Gray, Booren, Miller, Buckley, Morrissey, & Gomaa, 1992). On the contrary, colour stability and vitamin E supplementation has been reported by several other studies to be independent of each other or otherwise, colour stability is not been affected by the supplementation with vitamin E (Cannon et al., 1996; Rosenvold & Andersen, 2003; Zanardi, Novelli, Ghiretti, Dorigoni, & Chizzolini, 1999). Improvement in water holding capacity has been widely believed to be the impact of vitamin E supplementation. In order to come to such a conclusion of improved water holding capacity due to supplementation with vitamin E, there was a comparison between meat from pigs fed with diets devoid of E vitamin and meat from pigs fed with 100 to 200 mg vitamin E/kg of feed (Monahan et al., 1994). By the prevention of the oxidation of membranal phospholipids by vitamin E, muscle cell integrity is been maintained as previous studies suggested (Asghar et al., 1991; Cheah, Cheah, & Krausgrill, 1995). However, water holding capacity is never affected by tocopherol being an antioxidant as other studies revealed (Corino, Oriani, Pantaleo, Pastorelli, & Salvatori, 1999). Cheah et al. (1995) reported that pigs that carry the halothane gene are proven to show a decline in the incidence of the occurrence of pale, soft and exudative meat if given feed supplemented with 1000 mg/kg of feed known as supra-nutritional vitamin E supplementation. In pigs, vitamin E is been shown to increase the store of glycogen (Lauridsen et al., 1999). Water holding capacity and juiciness have been reduced in pigs stressed prior to slaughter due to vitamin E supplementation on a supra-nutritional level as revealed by a study. Higher

glycogen muscle stores prior to slaughter have been linked to such occurrence (Rosenvold et al., 2002). An ideal level of vitamin E supplementation therefore exists owing to the above findings reported by previous studies. Studies is therefore needed to find such a threshold for vitamin E supplementation of feed. Natural foods and plant extracts such as tea catechins have antioxidant potential (McCarthy, Kerry, Kerry, Lynch, & Buckley, 2001). Vitamin E can effectively be alternated with dietary tea catechins in chicken to play the same role (Tang, Kerry, Sheehan, Buckley, & Morrissey, 2001). However, a confirmation is needed for the dietary effect of such supplements for pork.

Impact of Genetic Make-Up on Pork Quality

Variations among breeds and the variations among animals within of the same breed impact pork quality and thus form the components of genetics. There is a multifactorial background to meat quality traits that are of interest. Therefore, these variations are polygenic effects meaning, a large number of genes each having little impact caused these variations (Andersson, 2001). However, monogenic effect can possibly affect pork quality. Monogenic genes that cause an impact on pork quality are called major genes (Sellier & Monin, 1994). The development of pale, soft and exudative meat is been link to the halothane gene since the 1960s (Briskey, 2001). Muscle degeneration was the term used first to describe pale, soft and exudative meat (Henson & Northen, 2000). A high temperature coupled with low pH post mortem trigger extensive denaturation of protein and mainly cause the development of pale, soft and exudative meat (Briskey, 2001; Henson & Northen, 2000). Reports had it that breed such as landrace has a larger proportion of animals prone to pale, soft

and exudative meat but not so in other breeds of pigs. Henson & Northen (2000) firstly proposed that stress susceptibility existed among animals which variation is monogenic. Lindeman & Vaananen (2000) later revealed that, reaction to halothane gas is possible by pigs which possess homozygous halothane gene. Few countries such as Sweden, Netherlands, Switzerland and Denmark have been able to eliminate from their selection lines the Halothane gene many years ago. It was beyond 1990s that this elimination of halothane gene from their selection line was decided and done by known international companies that are into breeding. The relationship between meat quality and performance and halothane gene has been extensively researched into, and discussion about same briefly will be discussed here. Largely, there is a higher lean percentage and carcass yield in pigs that possess heterozygous and homozygous gene for halothane gene (Aalhus, Jones, Robertson, Tong, & Sather, 1991; Garcıa-Macıas et al., 1996; Pedersen et al., 2001; Larzul et al., 1997). Performance of pigs is positively impacted by halothane gene but colour and water holding capacity is negatively impacted by the halothane gene. Carriers of the gene are highly susceptible to stress as the other name of the gene which is porcine stress syndrome indicates. Pigs that have heterozygous or homozygous for the porcine stress syndrome have post mortem glycolysis rate been higher despite humane handling pre slaughter. The little pre-slaughter stress is enough to trigger fast rate post mortem breakdown of glycogen. (Lundstrom, Essen-Gustavsson, Rundgren, Edfors-Lilja, & Malmfors, 2001). Consequently, pale, soft and exudative meat develops because of the high temperatures coupled with low pH immediately

after slaughter which led to protein denaturation (Bendall & Wismer-Pedersen, 2001).

Muscle Glycogen Manipulations

Dark, firm and dry (DFD) meat which is an undesirable meat quality characteristic has been found to be associated with feeding digestible carbohydrate in higher quantities to animals. The condition of meat been DFD occurs because of reduced lactate acid formation within the muscles after slaughter because, creatine phosphate and glycogen levels are low in the muscles (McCarthy & O'Reilly, 2000), possibly resulting from pre-slaughter chronic stress such composing of chasing and fighting. The pH_{24} h can be reduced if for few days to slaughter, digestible carbohydrate and sucrose have been fed in higher levels to animals or feeding same to them whiles in lairage can increase their muscle glycogen store (Briskey, Bray, Hoekstra, Phillips, & Grummer, 2001; Fernandes, Smith, & Armstrong, 2002; Sayre et al., 2004). Data by Fernandez, Tornberg, Magard, and Goransson (1992) pointed out that the effects of sugar feeding could be eliminated by overnight fasting of the animals as the observations made earlier have short-term impacts. Hampshire crossbred pigs noted to the porcine stress syndrome gene in higher frequency have been used for a later study. Pethick, Warner, D'Souza, and Dunshea (1997) in their nutritional manipulation of meat quality review reported a possible decrease in the occurrence of dark, firm and dry meat in contrast to pale, soft and exudative meat which may possibly be on the rise for halothane gene carriers which are sugar fed.

Production Systems of Pigs

Production systems used in the past took into consideration several factors to suit the diversification of local condition. Among the factors were vegetative characteristics of the farming location, soil, climate, socio-economic environment, technology employed and breeds reared. Current production systems are devoid of such pertinent considerations and the associated impact is not felt as a result of countries collaborating and exchanging genetic material (Singh, McPhee, & Kopinski, 1995). Pork quality is gaining more homogeneity due to production systems becoming homogenous because of world market prices affecting feeding strategy (Nardone & Valfre`, 1999). Sensory characteristics of meat, animal welfare, organic farming and ethical production of animals have been of most over the past decade. Therefore, North American and European meat industries are targeting alternate systems of production such as the free range under the extensive system to afford pigs access to natural feeds (Bridi, Muller, & Ribeiro, 1998; Dworschaak et al., 1995; Enfalt, Lundstrom, Hansson, Lundeheim, & Nystrom, 1997; Lebret, Massabie, Juin, Mourot, Chevillon, & LeDenmat, 1998; Sather, Jones, Schaefer, Colyn, & Robertson, 1997). Beside the few surviving traditional production systems, such as Iberian pig production in. Although, La Dehesa has traditional systems of production which are few (Lopez-Bote, 1998), a major challenge such as space among many others will be encountered if there is to be a total shift from free-range system to other environmentally friendly system of production (Jakobsen & Hermansen, 2001; Nilzen, Babol, Dutta, Lundeheim, Enfalt, & Lundstrom, 2001; Lopez-Bote & Rey, 2001).

Pigs raised under the traditional system has less of unsaturated fatty acid compared to those from organic raised and free-range system (Nilzen et al., 2001), of which lipid oxidation in the former will be more and its quality lower compared to the later (Warnants, van Oeckel, & Boucque, 1996). An increased vitamin E level as well as decreased vitamin E levels is gotten from pigs raised under free-range system, therefore, the high level polyunsaturated fatty acids cannot be compensated for by the increase vitamin E level and its associated oxidative stability been less. Lean yield is more in organically raised pigs (Danielsen, Hansen, Møller, Bejerholm, & Nielsen, 2000; Sather et al., 1997) as well as a better carcass value owing to the fact that, compared to their counterparts from the confinement raising system, pork from pigs raised organically have heavier loins, ham and butts (Sather et al., 1997) whereas there is higher intramuscular fat distribution known as high marbling score in those raised under the confinement system. In recent studies, Beattie, O'Connell, and Moss (2000) compared extensive and intensive system of raising pigs and reported that there is a high pork quality in the extensive system compared to the intensive system because of reduced cooking loss experienced with it. Studies by Sather et al. (1997) also revealed that there are many other pertinent factors such as feeding, pre-slaughter handling and genetic factors aside the fundamentally known factor which is the new production systems are also responsible for the pork quality differences. Therefore, to sum up there should be quality assurance systems in cooperated into the new production systems to meet consumers taste and preferences.

Pre-Slaughter Fasting of Animals

In order to reduce cross-contamination by microbes and to reduce the amount of waste in the gastro-intestinal tract especially, large intestine, many countries restrain animals from feed but give them water for 12 to 15 hours prior to slaughter. In addition, studies revealed pigs with full gut do have high mortality in transit (Warriss, 1994). Colour and water-holding capacity have been improved due to increased pH_{24} using fasting. In order to see any significant change in meat quality, more than 24 hours fasting is needed (Eikelenboom, Bolink, & Sybesma, 1991; Fischer, Augustini, & McCormick, 2005; Wittmann, Ecolan, Levasseur, & Fernandez, 1994). Nonetheless, other consequences may result if lairage holding is extended. Mixing different pigs in terms of age and different locations or pens lead to fighting and their welfare compromised (Murray, Robertson, Nattress, & Fortin, 2001). Also, it must be noted that a reduced carcass yield is possible if lairage holding period is extended (Eikelenboom et al., 1991).

Handling of Animals Prior to Slaughter

A series of activities such as loading, holding in lairage, transportation, mixing unfamiliar animals constitute pre-slaughter handling of animals. In one way or the other, a physical or psychological stress may be induced by these prior handling. The stress imposed on animals prior to slaughter is deemed a quality issue as well as welfare issue since pork quality is adversely affected by it (Callow, 2012; Fernandes et al., 2005). Two broad categorization is been given to pre-slaughter stress thus, chronic stress or long-term stress due to mixing, transport and loading and acute or short-term stress, which comes about by driving to the stunner and lairage conditions. Although, dark, firm

and dry meat is associated with long term stress and pale, soft and exudative meat been associated with the short-term stress, the two categories of stress should not be viewed as separate identities. Pre-slaughter stress is a function of bad on farm handling or in otherwise, pre-slaughter stress is bound to occur when there is poor on farm handling (D'Souza, Warner, Dunshea, & Leury, 2000). There is higher incidence of the occurrence of pale, soft and exudative meat and dark, firm and dry meat with mal-handled animals prior to slaughter due to depletion of muscle glycogen stores as well as lower pH_{24} hours after slaughter. Under no circumstance should unfamiliar animals be mixed together as this has severe effect on welfare and meat quality (McCarthy & O'Reilly, 2000; Karlsson, & Lundstrom, 1992). A stable social hierarchy is developed and maintained among familiar group of animals and such social stability is disrupted when unfamiliar groups are mixed together, to develop such dominance order again takes frequent fighting among animals to establish (Warriss et al., 1998). This fighting leads to commercial losses since bruises and lacerations are developed on the skin and the carcass value diminishes (Faucitano, 2001). Again, the resultant effect is high ultimate pH emanating from depleted glycogen reserve due to fighting among pigs (Warriss & Brown, 2006). Warriss and Brown (2006) also pointed out that, the probability of pale, soft and exudative meat occurring is very minimal and should not be expected at pH_{45} minutes since, fighting has no impact on it. Aggression and fighting among pigs could be reduced by reducing the group size if it becomes critical to mix animals. Current findings showed that, calmness and resting behaviour are promoted if the group sizes are 15 pigs regardless of the pigs been mixed up juxtaposed to group of larger pigs. Generally, it has been agreed that the

two aspects of transport which impose the most stress on animals are off-loading at the abattoir and loading in the farm (Gade, 2008).

Stocking density, ventilation and the quality of the vehicle as well as the distance to be covered contribute immensely to the stress level imposed on the pigs (Faucitano. 2001). The stress level in pigs has been shown to be impacted by the period of holding in lairage (Faucitano, 1998). Two (2) to 3 hours of holding animals in lairage is optimal (Milligan, Ramsey, Miller, Kaster, & Thompson, 1998; Van der Wal, Engel, & Hulsegge, 1997; Warriss, Brown, Edwards, & Knowles, 1998). Fighting stops and calm is restored at an average time period of 2 hours in the lairage among pigs (van der Wal et al., 1997; van der Wal, Engel, & Reimert, 1999). Nonetheless, there is increase in the occurrence of dark, firm and dry meat as well as proportionate skin damage resulting from depletion of glycogen, consequential of fighting (Costa, Fiego, Dall'O- lio, Davoli, & Russo, 2002; Warriss et al., 1998). The occurrence of pale, soft and exudative meat will be high due to short holding in the lairage or immediate slaughter after delivery (Eikelenboom & Bolink, 1991). In any case, factors such as the stress intensity meted out to the animals, the pen size been a lairage condition and unfamiliar animals been mixed will strongly determine the ideal lairage period. Recently, research shows that lairage time has no effect the quality of pork from pigs that do not carry the porcine stress syndrome known as the halothane gene in the presence of low pre-slaughter stress (Aaslyng & Barton-Gade, 2001). Lower pH amidst high temperatures post-mortem is due to acute or short-term stress prior to slaughter (Brown, Warriss, Nute, Edwards, & Knowles, 1998; D'Souza, Warner, Leury, & Dunshea, 1998; Henckel, Karlsson, Oksbjerg, & Petersen,

2000; Rosenvold et al., 2002; Støier, Aaslyng, Olsen, & Henckel, 2001; van der Wal et al., 1997). In live pigs, pH reduces when pre-slaughter stress is meted out to them (Enfalt et al, 1997; Henckel et al., 2000). Water holding capacity reduces when high temperatures and unfavourable pH conditions occur in the stress pigs (D'Souza et al., 1998; Rosenvold et al., 2002; Støier et al., 2001). The implication thereof is that, temperature and post-mortem pH must be carefully handled in pigs that are not even carriers of the halothane gene simply because of the impact of the above two factors on meat capacity to hold water (Schafer, Rosenvold, Purslow, Andersen, & Henckel, 2002). Later studies explained variation in drip loss of 2% in meat by using pH_{24} hours. Moreso, there is an increase in pH_{24} of pigs stressed to unstressed pigs however, water-holding capacity is higher in stressed pigs post-slaughter (Rosenvold & Andersen, 2002; Støier et al., 2001). Lower creatine phosphate levels in pigs may account for the observed higher pH_{24} hours values in the stressed pigs prior to slaughter. Reduced concentration of ATP as well as low levels of creatine phosphate led to increased metabolism of glycogen during stunning of stressed pigs in contrast to pigs which have not been stressed and therefore depend on their store of creatine phosphate amidst stunning (Henckel, Karlsson, Jensen, Oksbjerg, and Petersen, 2002). In brief, pH_{24} hours cannot be a good determinant of water-holding capacity. Also, acute stress prior to slaughter has been proven to affect the stability of colours (Van der Wal et al., 1999). Humane slaughter practices to ensure minimal stress to animals prior to slaughter have successfully being used (Støier et al., 2001). Among many other things, a lower stocking density during transport and lower temperatures immediately after slaughter to positively impact on water-

holding capacity and meat quality in general have been involved in the system (Støier et al., 2001).

Temporal Holding in the Lairage

Welfare Quality refers to the following four areas relevant to farm animals' welfare: good feeding, appropriate behaviour, good health and good housing (Holmes et al., 2020). These are also relevant for pigs at arrival at the slaughterhouse, during handling and moving in lairage and for comfort around resting in lairage pens. Pigs shall be unloaded as quickly as possible from trucks aligned with legal animal welfare requirements to prevent prolonged periods on trucks and the associated risk of an increasing degree of distress. Arrival management must be managed accordingly. Concerning animal-human interactions, pigs should be handled as sentient beings, thus respecting their behavioral needs and the stress they are coping with on the day of slaughter. Respectively, the layout and construction of lairage should encourage pigs to move freely within lairage passageways and races to the stunning area. The size of groups being moved, ramps for unloading, the layout of lairage, lighting management, surfaces of floors, the level of noise and airflows and handling of animals are significant for pigs' ease of movement. Mixing or regrouping pigs with unfamiliar conspecifics in lairage can lead to a high level of stress due to fighting and can cause skin lesions (Aaslyng et al., 2013), resulting in pain and fear. This applies especially to entire males (Gade, 2002) and adult females. The damage based on skin lesions is particularly severe in mixed groups with an increased proportion of boars due to the higher risk of fighting (Popescu, 2016). Fighting may be associated with the development of dark, firm and dry (DFD) meat due to

glycogen depletion (Čobanović et al., 2017). Skin lesions also may increase in lairages due to inappropriate management procedures and the use of sticks while moving the pigs (Faucitano, 2010). If sows or piglets are housed in lairage pens, they will usually be mixed with nonfamiliar animals, leading to an increased risk of aggression. Fighting may have considerable consequences in terms of skin lesions, which can be assessed as an animal-based indicator amongst other for fighting and biting. After pigs have recovered from transportation and handling, usually after 2-3 hours, their activity level in lairage pens will increase. Depending on mixing, the duration of deprivation of food or water, rooting material and space allowance, agonistic behaviour may increase over time. Longer duration in lairage pens, especially overnight, are associated with an increased incidence of skin lesions due to fighting (Faucitano, 2010; Dokmanović et al., 2014; & Čobanović et al., 2017). High pitch vocalisation can indicate fighting and aggression in lairage pen.

Stunning Method

Considering welfare concerns and humane slaughter practices have been on the ascendency, it is required legally that, animals due for slaughter are made unconscious and insensitive to pain till complete exsanguination takes place (Støier et al., 2001). The meat industry considers it a great loss when fracture of bones and blood patches are observed in slaughtered animals meant for meat as these factors decrease the quality of the meat. A lot of evaluation has been given to the methods employed in stunning animals. Electrical and carbon dioxide method of stunning are the two mostly used stunning methods for pigs. There is also the use of captive bolt stunners. Studies show a fast decline in pH as well as poor water holding capacity in the

muscles of electrically stunned animals compared to muscles from pigs that have been stunned with carbon dioxide (Casteels, van Oeckel, Boschaerts, Spincemaille, & Boucque, 1995; Channon, Payne, & Warner, 2002). The implication of the above finding is that, an increased physiological stress is accompanied with electrical stunning than carbon dioxide stunning which catalysis post mortem metabolism of glycogen due to heightened activity within the muscles (Troeger & Woltersdorf, 1990). Additionally, the incidence of blood splashes is minimal with carbon dioxide stunning than compared to electrical stunning (Channon et al., 2002; Velarde, Gispert, Faucitano, Manteca, & Diestre, 2000). It is certain which stunning method is best ethically after so many efforts (Gregory, 1994; Lambooy, 1990). Bertram, Stødkilde-Jørgensen, Karlsson, & Andersen (2002) found that, the use of captive bolt method, carbon dioxide and electrical method of stunning induce different levels of physiological stress on the animals more than anaesthesia. Going into the future, efforts are needed to figure out stunning methods which impose minimal physiological stress on the animal like anaesthesia or even lesser as quality parameters such as water holding capacity, colour, and oxidative ability will be enhanced.

As a humane slaughter practice and ensuring welfare of animals due for slaughter, unconsciousness is conferred on the animals through the process of stunning to ward off undue pain and suffering to the animals just before exsanguination at the point of slaughter. All over the world, the practice of stunning animals before slaughtering is done owing to the numerous benefits associated with the practice. The accompanying struggling with animals is catered for if stunning is done. Injury to personnel by the animal and the

animal itself being hurt and bruised which will lead to low quality meat is also prevented when stunning is done. For stunning to be perfect, rhythmic breathing must stop, the animal must collapse immediately after slaughter with extended neck and no blinking of the eyes are the requirements. The underlying principle for stunning is that, the animal must not feel pain when the neck is being slitted since animals are sentient and are able to experience sensation and feel. Therefore, until the animal died out completely through bleeding out, it must be in a state of unconsciousness as stipulated by most welfare regulations and guidelines on the stunning methods used for the diverse animal (Berg & Raj, 2015).

Electrical Stimulation

Cold shortening which has effect on water holding capacity and tenderness is brought about by accelerated chilling as pointed out in the previous discussion. Mutton and beef are electrically stimulated to improve tenderness by accelerating the post mortem muscle metabolism to avoid cold shortening (Bowker, Wynveen, Grant, & Gerrard, 1999; Maribo, Ertbjerg, Andersson, Barton, & Moller, 1999; Taylor & Martoccia, 1995; Taylor, Perry, & Warkup, 1995). However, Faucitano (2010) reported that the rate of occurrence of pale, soft and exudative meat becomes higher when electrical stimulation is done because, it hastens pH decline post mortem. The above findings were supported by Bowker et al. (1999); Maribo et al. (1999); Taylor, Nute, & Warkup (1995), and Warriss et al. (1995). However, combination of accelerated chilling and electrical stimulation improve water holding capacity and tenderness of meat whether low voltage stimulation (Taylor & Tantikov,

1992) or high voltage electrical stimulation is used (Taylor & Martoccia, 1995).

Exsanguination

Effective bleeding of animals is important and is a component of humane slaughter as it determines the timing of abattoir operations (Faucitano, 2010). Aerobic metabolism is terminated by the exsanguination of skeletal muscles and the biochemical conversion of muscles to meat depends on it. Blood is highly nutritious and is a good medium for bacterium proliferation. Therefore, effort must be done to ensure the animals bleed adequately so the rate of meat spoilage in the abattoir will be drastically retarded. Lactate acid production occurs during anaerobic metabolism just after the seizure of aerobic metabolism (Dokmanović et al., 2014). The degree of lactate production and its rate influence pork quality as pH activities revolve around it. Meat that is being poorly exsanguinated is relegated or condemned or pushed to a lower market value (Santhi et al., 2008). The exsanguination technology has a bearing on the collection of blood with the intent of using its protein content.

Singeing

The risk of heavy metal contamination in meat is of great concern for both food safety and human health because of the toxic nature of these metals at relatively minute concentrations (Santhi et al., 2008; Mahaffey, 2000). Instances of heavy metal contamination in meat products during processing have been reported (Santhi et al., 2008; Brito et al., 2005). The treatment of carcass, thus, is an important factor affecting meat quality in Ghana. Slaughtered ruminants such as goats, sheep and cattle are normally singed to

get rid of the fur. Singeing is largely favoured in many respects in African countries as it maintains the carcass hide for consumption and evokes flavours in meat that are highly acceptable by the local populace (Santhi et al., 2008). Traditionally, singeing proceeds in open fire using firewood as fuel. But the relative scarcity of firewood lately has resulted in local butchers using scrap tyres as alternative source of fuel to singe slaughtered livestock (Obiri-Danso et al., 2008). The practice, though unconventional and potentially dangerous, is increasingly favoured by local butchers; reasons being that fire from the scrap tyres is able to selectively burn off the animal fur without cracking the hide (Obiri-Danso et al., 2008).

Evisceration

Avoiding bacterial contamination of carcasses and meat is the most important hygienic challenge in meat industry. Evisceration carries a high probability of carcass contamination due to knife cuts and perforations resulting in leakage of the intestinal content (Čobanović et al., 2017). Good Hygiene Practise for evisceration includes ensuring that the probability of perforating the viscera, alimentary tract, uterus, urinary bladder, and gall bladder is minimised during separation cuts. In addition, and regardless of accidental knife perforations, the two ends of the gastrointestinal tract are potential sources of carcass contamination. Evisceration and other dressing must be carried out without undue delay and in a manner that avoids contaminating the meat (Alvseike et al., 2020).

Chilling Rate

Pork quality is affected by the chilling rate as it hinges on temperature and pH of the muscle (Bendall & Swatland, 2001). These effects have been investigated by several studies. Støier et al. (2001) found that the occurrence of pale, soft and exudative meat is prevented by the use of liquid nitrogen chilling and variations in pH_{24} hours are not observed. Later, Taylor and Dant (2003) also showed that water holding capacity is enhanced due to accelerated air chilling as confirmed by other studies (Bertram, Dønstrup, Karlsson, Andersen, & Stødkilde-Jørgensen, 2001; Kerth et al., 2001). In contrast, no effect on water holding capacity due to delayed or accelerated air chilling as has being reported by other studies (D'Souza et al., 1998; Jones, Jeremiah, & Robertson, 1993; Long & Tarrant, 1990; Milligan et al., 1998), although, colour improvement was also identified by few studies as well (Long & Tarrant, 1990; Jones et al., 1993; Milligan et al., 1998). Cold shortening is possible with accelerated chilling due to rapid temperature fall while there is still high energy level in the muscle. Honikel, Kim, & Hamm (2004) have found that there is a positive correlation between water holding capacity and the length of the sacomere. As a matter of fact, toughness was identified in rapidly chilled meat compared to meat that has been chilled conventionally of which is dependent on cold shortening (Jones et al., 1993; van der Wal, Engel, Beek, & Veerkamp, 1995). It must be noted that, cold chilling has positive effect on denaturation of protein in meat but this may be counter balanced by the negative effect of same on the water holding capacity of the meat (Støier et al., 2001). The water holding capacity remained unperturbed in studies by carriers of the halothane gene in pigs (D'Souza et al., 1998; Long & Tarrant,

1990; Milligan et al., 1998). The presence of the halothane gene could account for many variations in meat (Jones et al., 1993; van der Wal et al., 1995). This assertion was supported by Kerth et al. (2001) who found that, instead of pale, soft and exudative meat to occur in pigs that carry the halothane gene, accelerated chilling rather reduced the incidence of pale, soft and exudative meat from occurring. Pre-slaughter handling and prevailing temperature post mortem has direct consequence on glycogen store in the muscle and thus, affect pH decline after slaughter.

Most post-mortem chilling processes of livestock carcasses are primarily employed to ensure food safety, maximize shelf-life, and reduce shrinkage with less emphasis on maintaining tenderness and color factors of the finished product. Throughout the centuries, more sophisticated means were developed to reduce the heat from freshly slaughtered animals. Today, advanced refrigeration systems are used throughout most parts of the world to accomplish the task of chilling carcasses during the critical time period after slaughter and through the development of rigor mortis. The efficiency of heat removal became so great that a half century ago, it was discovered that the process of chilling could negatively affect the eating quality of beef and lamb (Owens, & Sams, 2000). Conversely, with increases in pork carcass weights and mass over the years, the challenge often for this species is to get the product chilled more rapidly to reduce problems associated with temperature/pH relationships. These two examples reflect the importance of developing and implementing chilling systems that are neither too severe nor too mild for the particular species involved (Savell et al., 2005).

Freezing

Freezing, a storage practice, is one of the oldest and most common methods to increase the safety and shelf life of meat products. Freezing and thawing, however, can negatively impact product quality compared to meat that is never frozen (Leygonie et al., 2012). Major meat quality attributes affected by the freezing and thawing process include water loss (Vieira et al., 2009). Thawing of meat is an integral part of all meat processing firms. It involves defrosting ice from a frozen product. The choice of a thawing method depends on a number of factors such as: ease of usage of the method, cost of operation, labour availability, practicability of the operations as well as sustainability (Schulte et al., 2019). Thawing prior to processing prevents excessive shattering of meat, and wearing of equipment during cutting. To thaw a product is more difficult than to freeze it simply because of the fact that, the thermal conductivity of water is much lower juxtaposed with the thermal conductivity of ice (James, James & Purnell, 2017). As the product begins to thaw and ice melts, the liquid around the product forms a barrier to heat flow into the product to be thawed thereby making thawing a very slower process than freezing a product (James, James & Purnell, 2017).

Summary

The quality of pork is affected by a number of slaughter and production practices pointed out in previous discussions. Although, manipulations can be done to get the desired quality of meat. Most of the studies done in recent years were to figure out the impact of two or more factors on meat quality. Therefore, going into the future, slaughter and production factors that affect meat quality and their interaction effect need to

be studied and ways to avert it developed. Beyond this, the demand for quality pork and market standards for it will be maximally achieved. Efforts are being made to reduce the Halothane gene proven to cause PSE condition in pork and subsequently, although water holding capacity remains highly variable (Purslow, 2001). A gene pool which is unique will be created if among commercial pig populations the RN and Halothane genes are eliminated. Meat science will therefore be ushered into a new kind of intellectual revival as the new genetic pool will have a different response to post mortem factors and production factors with regard to pork quality. The Halothane gene otherwise called the RN gene prevents the effects of slaughter and production factors which may be relevant to pork quality. Comparatively, earlier researches have shown that the effect of the Halothane gene on pork quality is far greater than pre - slaughter handling. Moreover, should the Halothane gene be eliminated, factors such as the addition of creatine or magnesium monohydrate, vitamin E which impact the quality of meat may become highly negligible (James, James & Purnell, 2017). Nonetheless, confirmation to this assertion must be proven. Pigs that carry the Halothane gene have been shown in some of the previous studies to be the only victims to the effect of accelerated chilling (Kerth et al., 2001), in direct contrast to pigs that do not carry the Halothane gene proven to be the ones rather affected by the accelerated chilling (Bertram et al., 2001). Currently, pre – slaughter handling methods such as stunning can reduce the environmental impacts on pork quality and reveal other genetic conditions which may be of significance (Støier et al., 2001). The need for a complete study into the phenomenon is indispensable. Energy metabolism after slaughter is far less when the stunning is done with carbon dioxide compared

to stunning with electrical current, therefore, a lesser impact on meat quality is gained by the use of carbon dioxide stunning to electrical stunning method.

However, anaesthesia method of stunning is better than both the electrical and the carbon dioxide method of stunning in terms of imposing physiological stress on the animal (Bertram et al., 2002). Going forward, the stunning method that reduces the physiological stress on the animal need to be figured out just so the technological component of meat could be enhanced comprising of colour and water holding capacity. Meat quality to a larger extent is dependent on the amount of glycogen stored up in the muscles (Ciobanu et al., 2001). Regardless, there is a weak comprehension of how muscle glycogen store works physiologically, particularly in post mortem muscles as there is a great bias in research geared towards post mortem muscles to muscles in living animals (Graham & Adamo, 1999). A better understanding is however gotten now by the realisation of a major enzyme called glycogenin and the revamped energy into studying macroglycogen and proglycogen as the two glycogen forms (Kerth et al., 2001). In addition, the discovery of new alleles responsible for glycogen stores in pigs and manipulation of feeding strategies have been found to be beneficial to meat quality (Ciobanu et al., 2001). The relationship between pork quality and muscle glycogen metabolism will now be understood more due to these discoveries. The oxidative stability of meat may be seriously affected likewise the fat composition of meat due to an increasing use of vegetable oil during processing and the introduction of free – range systems of producing animals. Therefore, to guard against negative consequences that jeopardize meat quality such as reduced oxidative ability, the introduction of these two systems must

be coupled with research to find mutually beneficial grounds. Conclusively, at least one factor is widely known to play major influence on meat quality. Rather than fundamental comprehension, this knowledge is empirically backed by evidence. Finally, the employment of alternative systems of production, and demand for quality meat, warrant the need for a complete and holistic research to comprehend the impact of post mortem factors and diverse systems of production on the quality of pork.

CHAPTER THREE

METHODOLOGY

Introduction

This chapter presents the steps and procedures followed to collect data, through to the data analysis to achieve the set objectives of the study. It includes description of the study area, the research design used, sample size and sampling procedure, data collection instruments, data collection procedures, data processing and analysis.

Study Area

The study was conducted at the Meat Processing Unit (MPU) of the School of Agriculture, University of Cape Coast, Ghana. The MPU is managed by the Animal Science Department and headed by a coordinator, who oversees the day - to - day administration of the Unit. There are state – of – the – art slaughter facilities at the Unit to ensure the safe and hygienic slaughter, processing, and marketing of meat to the University community and the entire Cape Coast Metropolis. Among the facilities present are: cold room for preservation of the meat, slaughter slab, a lairage for temporary holding of animals due for slaughter, captive bolt stunners for the humane and ethical slaughter of animals. The MPU produces meat products like sausages, burgers among many others. Slaughter services are done to the general public at an affordable fee. There are technicians and workers who are engaged in the daily activities such as slaughtering, records keeping, accounting and processing of meat into the various products.

Management of Pigs Kept at the University of Cape Coast Teaching and Research Farm

The breed of pigs kept by the farm is the large white. The sty is constructed with cement blocks to a height of about two metres, and a metallic wire-gauze is fixed on top of the walls to ensure adequate ventilation. The floor is concreted and the entire housing unit roofed with aluminium sheets. Formulated feed specifically, Koudijs concentrate was purchased and used to feed the animals, and the quantity and frequency depend on the growth phases of the pigs. The nutrient composition are as follows: 46% protein, 1,536 kcal of metabolizable energy, 3% fat and 3.4% crude fiber. A space dimension of four by seven metres was used for fifteen growers. For the weaners, less than twenty kilograms of liveweight were fed ad-libitum. Those between the liveweight range of twenty to fifty kilograms were given one or one and half kilogram(s) of feed two times daily. The average weight of pigs sold from the University of Cape Coast Teaching and Research Farm is fifty (50) kilograms, and the age is twenty – four weeks old. Antibiotics and dewormers were occasionally given to the animals. The piglets were occasionally treated with iron dextran injection to prevent anaemia. Water provision to the pigs has been ad-libitum, through the nipple drinkers' system installed in every sty. Prior to slaughter of the animals, a qualified and certified veterinary officer inspected the animals and passed them fit for consumption before slaughter. There was a post-mortem inspection of the carcass by a certified meat inspector.

Research Method

Within the context of this study, the method used was experimental study. Efforts have been made to gather information and collect data so as to

quantify the yield of pork and describe the phenomenon of pork patronage. Although, there are other designs, this was chosen over all others because there is the need to discover whether there is a relationship between two variables, that is, live weight and yield of pork.

Sample and Sampling Procedure

The sampling method used in this research is non – probability sampling because the student researcher picked data on animals to be slaughtered on a given date. The researcher had no control over animals selected for slaughter. The sampling techniques used specifically were convenient and cluster. Convenient because, large white breed of pigs was used due to their availability at the study area and preference for pigs to suit the purpose of the study. Cluster because all available pigs within the period were used for the study. A population size of eighty (80) pigs were used for the study.

Data Collection

The data were collected by weighing the pigs on scales and at other times too, direct observations of the slaughter processes were done to gather relevant information for the studies. Where the workload was seemingly burdensome, the student employed the services of other students and workers to assist, usually during taking of live weights of pigs, hot and chilled carcass weights. The various items or parameters on which data were collected were live weights of the pigs, hot carcass weight, chilled carcass weight, weight of the primal cuts, dates and quantities of primal cuts purchased. These parameters were taken with the objectives of the study in view.

Data Collection Procedures

At every slaughter section, an average of twenty (20) pigs were slaughtered. The student researcher went to the sty at the Research Farm of the University of Cape Coast early morning to take the live weight of pigs to be slaughtered, using Osborne's innovative ACCU-ARM® scale model from the United States of America. A permanent marker was then used to identify each of the pigs. Thereafter, they were transported in a vehicle from the farm to the slaughter house where the pigs were kept in a lairage. In turns, the pigs were stunned with a captive bolt stunner and slaughtered. After slaughtering, they were then singed using liquified petroleum gas as fuel, carcasses were washed and then eviscerated. After the evisceration, in turns, the hot carcass weights were taken and recorded, labelled with a masking tape so as to prevent mixing up during the time of chilling. The carcasses were then hoisted in the cold room at 2ºC for twenty-four (24) hours, after which cold carcass weights were taken. The carcasses were then sectioned into the various primal cuts; ham, shoulder, loin chop, spareribs, and each part was weighed.

Figure 1: Osborne's innovative ACCU-ARM® scale used to weigh the live pigs

Specifications on the Scale Used

The scale used to take the hot and chilled carcass weights and the weight of primal cuts has its model name as Nops® from the United States of America. The maximum and minimum weights is 200 kilograms and less than a kilogram respectively.

The Slaughter Processes

Temporal Holding in a Lairage

The pigs brought to the slaughter unit were kept in a pen called lairage to rest before they were slaughtered. In the lairage, they were sprayed with water to keep them relaxed and clean.

Stunning

The method of stunning used was the captive - bolt method. The stunning was done to one pig at a time. The pigs were kept in a restraint box

for stunning. The captive - bolt stunner was then positioned on the forehead of the pig in between the eyes and the ears and stunned.

Exsanguination

Right after stunning, a sharp knife was used to slit the throat of the pigs to cut the jugular veins. The pigs were left to bleed adequately, before the next activity was performed.

Singeing

The method of singeing was by the use of liquified petroleum gas flame and a blow pump because that was readily available. The burnt hairs were scrapped off using a coarse sponge, and the carcasses were then washed.

Washing

After singeing of the carcass, copious amount of pipe borne water was poured on the carcasses and with the use of a hard brush, thorough washing was done. This was necessary to remove dirt and sooth from the skin surface and remnants of the singed fur from the carcass. The hooves were also removed at this point during the washing.

Evisceration

The carcasses were opened by the use of a sharp knife at the ventral side. With the help of another person holding the fore legs, the viscera was pulled out comprising the large and small intestines, heart, lungs and liver, after which the warm carcass weights were taken.

Chilling

The carcasses were hoisted with a stainless-steel hook and kept in a cold room of temperature 2ºC for 24 hours. An identification label was then

put on all the carcasses to differentiate them. The carcasses were then grouped into various weight categories; Thus, 36-40kg, 41-45kg, 46-50kg and 51-56kg.

Cutting into primal cuts or parts

After the 24 – hour chilling, the carcasses were removed from the cold room and cut into the various primal cuts by the use of a stainless-steel meat saw. The parts include: the ham, shoulders, spare ribs, loin chop, feet, belly and fillets. The definition of these primal cuts has being stated under results and discussion.

Scaling

After cutting into primal parts, each part was then weighed on a scale and recorded. The brand name for the scale used is Escali Primo Digital Scale from the United States of America.

Packaging

For the purposes of convenience and marketing, each primal cut was further sectioned into units of one kilogram, and packaged according to consumers preferences and purchasing ability.

Freezing

After the packaging into units of one (1) kilogram, the meat was stored in freezers and sold on retail basis.

Secondary Data

The daily record of sales was collected from the MPU and data on patronage of the various primal cuts of pork was retrieved. Data was collated on weekly basis over a period of two (2) years, spanning from January, 2019 to December, 2021 to ascertain the trend of patronage. The details of the secondary data were presented in tables three (3) and four (4) under the

results. The festive months considered were: April, September, December. The non – festive months considered were the rest of the months except April, September and December.

Analysis of Data

Data generated was subjected to the one-way analysis of variance procedure under the Minitab Statistical Package. Where differences in means were identified, means were separated using Tukey's test at 5% level of significance.

CHAPTER FOUR

RESULTS AND DISCUSSION

Table 1: Absolute values (kilogram) of primal cuts of pigs in different weight groups

Parameters	Weight Groups				Stan Dev	P. Value
	WG1	WG2	WG3	WG4		
Live wt(kg)	39.2^{d}	43.1^{c}	48.6^{b}	53.1^{a}	1.320	0.000
Hot carcass wt(kg)	24.2^{c}	25.9^{c}	30.0^{b}	34.7^{a}	2.457	0.000
Cold carcass wt(kg)	23.6^{c}	24.7^{c}	29.2^{b}	33.5^{a}	2.506	0.000
Ham (kg)	6.3^{c}	6.8^{c}	8.5^{b}	9.7^{a}	1.227	0.000
Shoulder (kg)	8.4^{c}	8.7^{c}	10.4^{b}	11.9^{a}	1.221	0.000
Loin chop (kg)	2.9^{b}	3.2^{b}	3.6^{b}	4.4^{a}	0.617	0.000
Spareribs (kg)	0.5^{b}	0.5^{b}	0.6^{b}	0.8^{a}	0.137	0.000
Head (kg)	2.9^{b}	3.0^{b}	3.0^{ab}	3.1^{a}	0.097	0.001
Belly (kg)	1.2^{b}	1.4^{b}	1.5^{b}	2.0^{a}	0.401	0.000
Fillet (kg)	0.2	0.2	0.4	0.4	0.259	0.075
Trotters (kg)	1.0^{b}	1.0^{b}	1.2^{b}	1.4^{a}	0.169	0.000

Means in the same row that do not share the same superscript are significantly different ($p<0.05$). StanDev. = standard deviation. WG1, WG2, WG3 and WG4 = the various groupings of weights of the pigs thus, 36-40kg, 41-45kg, 46-50kg and 51-56kg respectively. wt = weight. Kg = kilogram

Table 1 presents the yield values in kilograms. This is important because, it helps farmers to easily quantify the expected yield from animals with a given liveweight. As has been presented in Table 1, not all farmers can relate and understand the values in percentages. Therefore, the implication for presenting the yield values in kilograms is that, even uneducated farmers can easily determine expected yield from animals on their own without seeking for help which may come at a cost.

Among the price list, the shoulder just ranks a little above the trotters and the head which are the least priced cuts and it is not economical to keep selling it on fresh basis. The yield of loin chop from Table 2 ranged from 2.9 kilograms to 4.4 kilograms which is in line with that reported by McCarthy

(2000), where he recorded 2.9 to 4.3 kilograms. In terms of patronage, the loin chop ranked the third most patronised primal cut and it is the third highly priced primal cut from the price list. This increment in the weight of the loin chop will inure to an increase in the profit to the meat processors and the meat producers because sales is on weight basis. A higher weight of the loin chop will attract a higher price and vice-versa. Richardson, MacFie, & Shepherd (1994) reported the loin chop to be one of the most preferred primal cuts among pork consumers, and thus receives higher pricing. Therefore, meat vendors should make available this primal cut to consumers always and earn higher profit. Also, should any primal cut be opted to be used for other meat products due to low patronage, the loin chop should be exempted. The yield of spareribs figures in this study ranged from 0.5 kilograms to 0.8 kilograms which are lower, compared to that reported by Willson, Rojas de Oliveira, Schinckel, Grossi & Brito (2020) who recorded the yield of spareribs to be 1.09 kilograms to 2.42 kilograms. The lower values recorded in this study could be attributed to the younger age of the pigs used in this study. This low yield will be to the detriment of meat processors because, the higher the weight of the yield, the higher the price and vice versa. The spareribs also is the fourth most patronised primal cut from Table 3 and the fourth highest priced primal cut per the price list of the meat processing unit. Meat processors are therefore to note the expected yield from this primal cut and to use it in estimating their profit margin and overall planning. It is also recommended to meat processors to consider using this primal cut for further processing in order to add value and increase the price at which it is sold other than selling on fresh cut basis. The aim is to boost the gains of meat processors and meat

dealers. Animal producers in Ghana are also implored to use best practices in raising the animals so that their yield data will match those from the Western world which will certainly inure to their benefit in terms of higher selling prices.

The fillet yield in this study ranged from 0.2 kilograms to 0.4 kilograms. The fillet is highest priced primal cut. In as much as the fillet is the highest priced primal cut, its demand is not always being met because, its yield when animals are slaughtered is very limited. The yield result of the fillet in this study is in contrast to the result recorded by Khanal, Maltecca, Schwab, Gray & Tiezzi (2019) who documented 0.28 kilograms to 0.74 kilograms in their study for the fillet. The comparatively lower values recorded in this study for the fillet could be attributed to the difference in the raising environment in terms of the housing unit. Though, the price of the fillet is comparatively the highest, it is the leanest part of pork and consumers are admonished to purchase and make use of it more for health benefits of consuming lean meats (Kim, Jeong, Hur, Yang, Jeon, & Joo, 2010). The yield of the belly in this current study ranged from 1.2 kilograms to 2.0 kilograms which is not different from the result recorded by Issanchou (1996). The belly has been reported to be the fattiest part among the primal cuts of pork (Collewet, Bogner, Allen, Busk, Dobrowolski, Olsen, & Davenel, 2005). Therefore, it has always been processed into bacon which is highly valued. This could translate in higher profit margin to meat producers if this primal cut is made available to consumers readily. The trotters and the head are the least priced parts. The yield of the head ranged from 2.9 kilograms to 3.1 kilograms which is in agreement to earlier report by Trusell, Apple, Yancey, Johnson, Galloway &

Stackhouse (2011). The head is not an economical part as most people do not like patronising it. Besides, it is the least priced primal cut together with the trotters therefore, it is recommended that, the head and trotters be processed into brawn, meat jelly and can also channelled to the pet feed and bone meal industry.

The yield of the head showed a trend in that, the lower the live weight of the pigs, the higher the weight of the heads in proportion to the entire carcass. This trend should serve as a guide to live animal purchasers in their decision to buy animals. A heavier head of the pig could not translate to a higher price since the head is the least priced cut. The trotters, just like head are the least priced cut among all the primal cuts of pork. The yield of the trotters ranged from 1.0 kilogram to 1.4 kilograms, which agrees to report by Eggert, Belury, Kempa-Steczko, Mills & Schinckel (2001). The trotters ranked the fifth in terms of patronage but this does not make economic gains to meat processors as its price tag is the lowest. The lesser the live weight of the animal, the lesser the yield of the trotters as is the trend revealed by Table 2 in regard to the trotters. This trend should inform animal dealers and meat processors in their selection of live animals to purchase in order to maximise profit.

Table 2: Means showing percentages of the parameters against the weight groups of pigs

Parameters	Weight Groups				Stan Dev	P. Value
	WG1	WG2	WG3	WG4		
Dressing%	61.8^{ab}	60.0^{b}	61.7^{b}	65.2^{a}	4.390	0.001
%Ham to LWT	16.2^{ab}	15.8^{b}	17.6^{ab}	18.3^{a}	2.501	0.005
%Ham to CCWT	26.8	27.5	29.2	29	3.376	0.186
%Shoulder to LWT	21.4^{ab}	20.2^{b}	21.4^{ab}	22.4^{a}	2.359	0.024
%Shoulder to CCWT	35.5	35.4	35.6	35.5	2.280	0.997
%Loin chop to LWT	6.8^{d}	7.2^{c}	7.9^{b}	8.4^{a}	0.337	0.000
%Loin chop to CCWT	9.9^{c}	11.1^{b}	12.6^{a}	13.0^{a}	1.012	0.000
%Spareribs to LWT	1.2^{ab}	1.2^{b}	1.3^{ab}	1.4^{a}	0.267	0.011
%Spareribs to CCWT	2.0	2.1	2.1	2.3	0.441	0.317
%Belly to LWT	3.2^{ab}	3.2^{ab}	3.1^{b}	3.7^{a}	0.770	0.030
%Belly to CCWT	5.3	5.3	5.6	5.9	1.297	0.324
%Fillet to LWT	0.5	0.6	0.7	0.8	0.510	0.300
%Fillet to CCWT	0.9	1.0	1.3	1.2	0.783	0.390
%Trotters to LWT	2.7	2.5	2.5	2.5	0.326	0.241
%Trotters to CCWT	4.4	4.4	4.1	4.2	0.587	0.200
%Head to LWT	7.4^{a}	6.9^{b}	6.2^{c}	5.8^{d}	0.236	0.000
%Head to CCWT	12.0^{a}	11.6^{a}	10.1^{b}	8.9^{c}	0.923	0.000

Means in the same row that do not share the same superscript are significantly different ($p<0.05$). StanDev. = standard deviation. WG1, WG2, WG3 and WG4 = the various groupings of weights of the pigs thus, 36-40kg, 41-45kg, 46-50kg and 51-56kg respectively. LWT = live weight. CCWT = chilled carcass weight.

Dressing Percentage

From Table 2, it was observed that, the dressing percentage of the pigs increased as slaughter weight increased with exception of group one pigs (36 to 40 kilograms). This was possibly due to the sex of the animals in group one, all being females. Sex has been reported to influence dressing percentage, in that male animals tend to have higher dressing percentage than their female counterparts of the same age, because male animals tend to lay down more muscles which is heavier compared with female animals which tend to lay down more fat (Jaturasitha et al., 2006; Trezona et al. 2011). Heavier pigs at

slaughter may provide a higher dressing percentage (Álvarez-Rodríguez & Teixeira, 2019).

The implication of a higher dressing percentage is that, the proportion of the yield of saleable parts of the carcass is higher than the parts considered as waste. Therefore, a pig producer who produces pigs with higher dressing percentage will have a higher yield to sell and make much profit than a pig producer who produces pigs with a lower dressing percentage. In contrast to high dressing percentage, a lower dressing percentage means the proportion of the yield of the saleable parts of the carcass is lower than the parts considered waste, which are of less economic value. Therefore, a farmer who produces animals with lower dressing percentage will incur losses because, the yield proportion of saleable parts of such animals will be less than the parts of the carcass considered as waste. Some saleable parts of pigs include but not limited to ham, shoulder, fillet, loin chop, and that of the parts considered waste are but not limited to the bones, fats, gastro-intestinal tract. These findings were in agreement to Correa et al. (2006) who reported significant increases in dressing percentage as liveweight at slaughter increased. Bertol et al. (2015) reported an increase in the dressing percentages as live weight increased. The recommended range of dressing percentage for pigs is 68 to 77% with an average of 72%. In this study, the dressing percentages were below the optimum, and could possibly be due to the breed of pigs used in this study (large white), which is mainly raised for reproductive functions such as large litter size (Domański & Więcek, 2019). Generally, age, breed and muscle fatness are some other factors that influence dressing percentage (Trezona et al., 2011).

Ham

The ham is meat from the upper part of a pig's hind or back leg. In this study, the estimation of the primal cuts to the live weights on percentage basis saw a trend in which as the slaughter weight increased among the pigs, the yield of ham also increased alongside, similar to report by Bertol et al. (2015). Therefore, it implies that, slaughtering heavier pigs could yield higher percentage of ham, and as such, meat processors, butchers, live animal buyers are advised to go in for heavier animals when buying, in order to get higher yields in terms of primal cuts. However, the recorded yields of the hams in this study which ranges from 16.2 to 18.3% were lower compared to the 23 to 25 percent recorded by Crome et al. (1996) who used large white pigs of twenty four (24) weeks old. These comparatively low values of the ham from the pigs in this study could mean that, the animals may have been stressed through improper feeding, which may have caused stuntedness and consequently reducing their yield. At heavier live weights, pork quality is rated higher in terms of juiciness, flavour and tenderness (Piao et al., 2004) which, according to Hugo et al. (1999), would be attributable to differences in intramuscular fat composition.

Shoulder

As the liveweight increased, the yield of the shoulder muscles also increased. This trend corresponded to findings by Bertol et al. (2015), who reported an increase in the weights of primal cuts as live weight increases. The percentage values for the yield of the shoulders in this study ranged from 20.2 to 22.4% which is not very different from 21.09 to 21.72% recorded by Crome et al. (1996). The importance of these values is that, the shoulder being the

second most demanded primal cut, will likely generate more profit to the meat dealers (Jaturasitha et al., 2006).

Loin chop

The loin chop is the section of the back from the shoulder to the hip of pigs. It is the third highest valued primal cut after fillet and ham. The recorded percentage yield of the loin chops in this study ranged from 6.8 to 8.4% which is lower, compared to 19.47 to 20.24% recorded by Bertol et al. (2015). The lower values of the loin chops in this study could be attributed to stuntedness in growth of the pigs used in this study, possibly resulting from poor feeding or disease condition. The age of the pigs used in this study was twenty-four weeks old, which is lower than the recommended maturity period of at least twenty-eight weeks (Akridge et al., 1992). Therefore, the implication of the lower age of the animals could lead to obtaining a more tender and leaner meat relatively, since, fat deposition and development of connective tissues increase with age of animals.

Spareribs

The spareribs are taken from the belly side of the rib cage, below the section of the back ribs, and above the sternum. The values obtained for the spareribs in this study showed a trend in that, as the liveweight increased the yield of the spareribs also increased. This trend corresponded to results from Boler et al. (2014), who reported an increase in the weights of primal cuts as live weight increased. The percentage values for the yield of the spareribs in this study ranged from 1.2 to 1.4% which is not very different from 3.63 to 3.81% recorded by Unruh et al. (1996). The lower values of the spareribs may be due to improper feeding of the animals used in this study which made them

stunted as well as, the breed used which is large white noted for reproductive functions. The meat obtained from these animals may be leaner and tender since fat deposition increases with age as well as the development of connective tissues which make meat tough also increase with age. The importance of the increasing trend in the values of the spareribs is that, a higher profit will be accrued by meat dealers as the spareribs is the fourth highest valued primal cut after loin chops (Bertol et al., 2015).

Belly

The belly muscle is located at the ventral side of the body of the pigs. It is usually processed into bacon before being sold. The observed trend in the values obtained for the belly revealed a corresponding increase in yield as live weight increased, with exception of pigs in groups one and two. The possible reason for the observed trend in this study is that, the pigs in groups one and two were all females totalling thirty-three, and groups three and four contained the males totalling fourty-seven. Male animals of the same age lay down more muscles which is heavier than fats which the female animals mostly lay down. The implication of the increasing trend observed among the yield of pigs in groups 3 and 4 is that, more profit will be accrued by meat processors since, the belly after it is processed into bacon becomes highly valued than spareribs and loin chops, and ranked the third highly valued cut after ham. The recorded percentage yield of the belly in this study ranges from 3.1 to 3.7% which is lower, compared to 12.97 to 13.9% recorded by (Unruh et al., 1996). The lower values in this study could be due to stuntedness of the pigs used in this study, emanating from poor feeding and the breed of pig used which is large white, noted for reproductive functions. Therefore, the implication of the

lower age and weights of the animals in this study could mean that a more tender and leaner meat would be obtained relatively from the pigs used in this study since, fat deposition and development of connective tissues increases with age. The insignificant differences in the belly weights observed among the pigs also mean that, irrespective of the variation in slaughter weight, the yield of the belly will not vary significantly among the pigs.

Fillet

The recorded values for the fillets in this study also showed a trend in which, as the slaughter weight increased, the weight of the fillets also increased even though, the increase was insignificant among the pigs in the various groups. The recorded average values in this study for the fillets ranged from 0.5 to 0.8%, which is lower compared to 0.89 to 0.99% recorded by Boler et al., (2014). The lower values recorded for the fillet could be attributed to the comparatively lower weight and age of pigs used in this study. In addition, the insignificance of the variation in the yield of the fillets among the pigs in this study could mean that, the yield of fillet from may not differ significantly despite changes in the slaughter weights. The location of the tenderloin commonly called fillet is within the ribcage. The loin cut is composed of the fillet which is a slender long muscle. Among the primal cuts, the leanest is the fillet, which makes it the choicest and healthiest cut to consumers and therefore has the highest price tag. Also, the fillet is the highest priced primal cut according to the price list obtained from the meat processing unit and a study by Bertol et al. (2015). A higher slaughter weight which translates into a higher fillet weight will lead to a higher profit to meat processors (Lutaaya, Misztal, Mabry, Short, Timm, & Holzbauer, 2001).

Trotters

When it comes to the trotters in this study the observed trend is that, as the live weight increased the yield of the trotters, in proportion to the body, decreased. In other words, the higher the live weight, the lower the proportion of the trotters although, the differences in the yield values among the pigs are insignificant. The recorded values for the trotters in this study ranged from 4.1 to 4.4% which is lower, compared to 5.02 to 6.33% recorded by Álvarez-Rodríguez & Teixeira (2019). The lower values recorded in this study could possibly be due to improper husbandry practices like inadequate feeding, inadequate parasite control for the animals. Antibiotics and dewormers were being given to the pigs. Formulated feed were also being used to feed the pigs. The piglets were being treated with iron dextran injection to prevent anaemia. Consequently, meat processors, butchers and pig patronisers should know that heavier pigs may have lower yield in terms of the trotters and vice versa when making purchasing decisions and estimating of profit margins.

Head

A trend observed when it comes to the head was that, as the live weight increased among the pigs, the weight of the head in proportion to the body, decreased. Therefore, when purchasing pigs, one should know that smaller ones may have relatively heavier proportion of the heads to their bodies and vice versa. The recorded percentage values ranged from 5.8 to 7.4% for pigs used in this study compared to 7.2 to 10.5% recorded by Álvarez-Rodríguez & Teixeira (2019). These lower values recorded in this study may be due to the comparatively lower ages of the pigs used. The observed trend in this study agreed with the trend observed by Álvarez-

Rodríguez & Teixeira (2019) in that, as slaughter weight increased among the pigs, the weight of the head in proportion to the body, decreased. The head as well as the trotters are the least priced parts due to lower demands. Such less parts must be of lower proportions in a carcass to avoid low income to meat vendors. In contrast, highly valued parts such as ham, fillet, loin chop ought to be high in carcasses to boost profit of meat vendors.

Table 3: Weekly patronage of the various primal cuts in all months except festive (April, September, December) months

Primal cuts	Means	Price (GHS)/kg
Ham(kg)	41.57±20.58	44
Shoulder(kg)	41.52±21.82	35
Loin chops(kg)	20.30±13.43	38
Spareribs(kg)	5.06±4.02	35
Trotters(kg)	5.00±3.96	30
Head(kg)	4.36±6.69	30
Fillet(kg)	1.96±2.22	50

Field Data, 2022

Pork Consumption

Ham

From Table 3, the most patronised primal cut of pork is the ham with a mean patronage of 41.57 kilograms per week. This finding agrees to finding of Byrd & Almanza (2021) where ham patronage ranked highest in the United States. Possibly, the reason behind the high patronage of the ham may be due to its meatiness. According to the price list of the Meat Processing Unit, ham ranked the second highest priced primal cut after fillet, with a kilogram of it being sold at GH¢ 44.00 as at April, 2022. The high patronage of the ham and it being the second highest priced primal cut could translate to a higher profit margin to the meat enterprise. The implication of this finding is that if a primal cut needs to be selected for further processing, ham should be exempted, since

it is the most patronised. In order of preference of the primal cuts, ham was the first probably, because of its meatiness. Secondly, the shoulder was the second preferred cut and followed by loin chop as the third preferred primal cut. The spareribwas the fourth preferred cut. The fillet is also highly preferred, but its yield is very limited in pigs. The belly is also not sold on fresh basis but processed into bacon which is highly preferred. The trotters and the head are the least preferred cuts possibly, because of the bony nature of these parts.

Shoulder

The shoulder ranked the second highest patronised primal cut at the Meat Processing Unit. Although, shoulders were the second highest patronised primal cut, it is lowly priced just a little higher than that of the head and trotters which are the least priced primal cuts. A kilogram of shoulder was sold at GH¢ 35.00, which is second to last in terms of the least priced primal cut. Therefore, when a primal cut is to be used for further processing and value addition, the shoulder is recommended for such purposes in order to raise returns from its sales. This finding regarding the patronage of the shoulder is in contrast to the findings of Choi et al. (2015) who reported that belly is the most patronised due to its high fat content compared to all the other primal cuts among South Koreans, and it is a unique preference among them over all the other primal cuts.

Loin chop

The loin chop is the third most patronised primal cut from Table 3. A kilogram of loin chop was sold at GH¢ 38.00 at the time of this research. This could inure to the benefit of meat firms and processors as large volume of sales could be made from the loin chop. This finding with regard to the

demand of the loin chop is in contrast with that of Luke (2021), who reported that patronage of loin chop is the lowest in the United States. The probable reason for this disparity may be due to differences in geographical location and differences in consumer's taste and preference.

Spareribs

The spareribs ranked fourth among the most patronised primal cut at the meat processing unit. Although it ranked fourth in terms of patronage, the price tag for it is among the lowest, similar to the price of the shoulder. A kilogram of spareribs is sold at GH¢ 35.00, which means that lower returns could be realised from its sale of spareribs compared to ham or fillet. However, Oh & See (2012) reported loin chop to be among the highest patronised primal cuts in China and the United States. Healthwise, available literature indicated that loin chop have lower amount of fat deposits compared to belly, which is reported to be the highest in terms of fat deposit among all the primal cuts (Daniel, Cross, Koebnick, & Sinha, 2011). Therefore, the consumption of the loin chop will be advantageous to consumers regardless of the less profit margin meat firms stand to accrue from its sales.

Head and trotters

From Table 3, the trotters and the head ranked fifth and sixth with regard to the patronage with mean values of 5.00 and 4.36 kilograms respectively. The price tag for both parts was GH¢ 30.00 at the time of this research. The head and the trotters are not economic parts as it is not eaten in some jurisdictions (Ngapo, 2017; Choi et al., 2015). Products derived from pork are but not limited to meats such as sausage, prosciutto, bacon, ham, hot dogs, ham hocks, pork chops, trotters and brawn. Meat

processors are therefore entreated not to waste resources in the storage of these parts in order to avoid losses since their patronage and pricing are low. These parts should be channelled to the pet feed and bone meal industry to be used in animal feed preparation. The findings regarding the purchase and pricing of the trotters and the head agreed to the finding of Nguyen-Viet, Dang-Xuan, Pham-Duc, Roesel, Huong, Luu-Quoc & Grace (2019) that, trotters and head demand in Vietman is the lowest among the primal cuts of pork. The probable reason may be the inadequate flesh associated with these, and makes them undesirable among consumers. In agri-food markets, it is important to analyze consumer perceptions of product value. This is especially true for those products which are still considered as commodities, such as unbranded fresh pork in many cases. In that sense, chain orientation towards the end-consumer is fundamental for the organization of all agents, since a food supply chain will only be competitive if it is in tune with consumers' needs, wants and demands (Vieira et al., 2009).

Consumers are also very concerned about health issues and body form, and consequently they are increasingly looking for products with lower fat and caloric content, but higher quality and food safety characteristics. The image of pigs as fatty animals, raised under precarious hygiene conditions and inadequately fed is beginning to change. Small and unspecialized producers who engage in pig production as a secondary activity has been confronted with the development of industrial and professional pig production (Vieira et al., 2009). The development of innovative pork products (tasty, healthy, convenient and with more affordable prices) could lead to a significant

increase in consumption, or at least prevent a further loss of market share for pork relative to beef and poultry.

Fillet

The fillet is the highest priced primal cut among all the others. The possible reason for such a low patronage may be associated with its limited quantities obtained per slaughter. A kilogram of the fillet sells at GH¢ 50.00 and the income level of consumers may not be adequate to guarantee the continual purchase of the fillet, thus, may also has accounted for its low patronage. This finding agrees to the findings of Verbeke, De Smet, Vackier, Van Oeckel, Warnants, & Van Kenhove (2005), that, the fillet is the leanest primal cut of pork and is very expensive than all the other parts. A pork fillet is tender, lean, boneless cut of pork. Among the many factors that globally affect consumption of meat are consumer prices, the living standard, animal husbandry and meat production conditions, and food consumption patterns (Dai, Yabe, Nomura & Takahashi, 2022). Therefore, meat firms and processors should be informed that although the fillet has the highest price tag, its yield is always limited when animals are slaughtered. So, in the planning and estimation of volume of sales and expected profit margin, this should guide them to make realistic planning and extrapolations.

Table 4: Weekly patronage of the various primal cuts in festive (April, September, December) months

Primal cuts	Means	Price (GHS)/kg
Ham(kg)	63.28±10.86	44
Shoulder(kg)	34.44±16.79	35
Loin chop(kg)	30.35±13.64	38
Spareribs(kg)	6.17±4.86	35
Trotters(kg)	5.87±4.03	30
Head(kg)	3.35±7.49	30
Fillet(kg)	2.96±2.55	50

Field Data, 2022

Seasonal consumption

The seasonality of consumption considered in this study centred around Easter, Christmas and the festival celebrations among the people of Cape Coast. Just like any other festive season, expenditure, demand and patronage of food items increase and the demand for pork was of no exception (Popescu, 2016). From Table 4, the demand for ham saw an increase in the festive seasons with a mean value of 63.28 kilograms compared with the non - seasonal patronage mean value of 41.57 kilograms. This increase in the consumption of ham is advantageous to meat firms in order to make available this primal cut so as to increase their profit margins. Also, it is an indication to meat processors to consider other primal cuts for further processing due to their low patronage other than the ham. This finding agreed to the finding of Soare, Balan & David (2015), who reported an increase in ham and other primal cuts patronage during festive seasons in Romania. In the case of the loin chop, there was an increase from 20.30 kilograms during non-festive to 30.35 kilograms in the festive seasons. This increase in demand for the loin chop could inure to the benefit of meat industries, because increase in patronage will translate to increase in income.

Moreover, since the price tag for the loin chop ranked the third highest, efforts should be made by meat firms to make this primal cut available to maximize gains from its sales during festive seasons. This finding relating to increase in the loin chop agreed to reports by Hayes, Schulz, Hart & Jacobs (2021), that patronage of loin chop and other cuts in the United States increased during festive seasons, with particular emphasis on Christmas and Easter celebrations. The patronage of the spareribs is not different from the trend of the ham and loin chop in that, there was an increment in patronage from 5.06 kilograms to 6.17 kilograms of the spareribs during festive seasons. The importance of this increased patronage of the loin chops will inure to the benefit of the meat dealers in the sense that, more patronage will generate more income to meat producers and meat firms. Also, the storage cost of preserving the meat will be avoided due to increase in the patronage (Haley & Gale, 2020). This finding with regard to the spareribs agreed to the finding of McEwan, Marchand, Shang, & Bucknell (2020), who reported an increase in the loin chop and pork products in Canada during festive seasons. In the case of trotters, the patronage increased from 5.00 kilograms a week during normal patronage in Table 3 to 5.87 kilograms during seasonal patronage in Table 4. Though, this increase is advantageous to meat industries because of increased volume of sales, the price tag and demand of the trotters from Table 3 were both low. Nonetheless, a little more profit could be realised compared to if there was no increase in sales of trotters. The cost of storage which would have reduced the profit margin of the meat firm could possibly be catered for by the increased patronage during the festive seasons.

This finding with regard to an increase in the patronage of the trotters in this study is in contrast to the result of Tonsor, Lusk & Tonsor (2021), who reported a decline in patronage of trotters, which in most cases are used as pet feed in China, and a similar report by McEwan, Marchand & Shang (2021) in the United States. The patronage of the fillet also increased from 1.96 kilograms in Table 3 to 2.96 kilograms a week in Table 4 during the festive seasons. This could benefit the meat dealers as the fillet is the highest priced primal cut. Whereas the other primal cuts such as ham, fillet, loin chops, spareribs and trotters saw an increase in their patronage during the festive seasons, there were decreases in patronage of shoulder, belly and head due to changes in consumers taste and preference. This decrease should inform meat processors to consider using these primal cuts for further processing to convert them into other pork products instead of attempting selling them on fresh basis. The decrease in their patronage will translate to profit decline as cost of storing them until their purchase will increase the cost of meat firms and meat producers. This result agrees to the finding of Vitek, Pulkrabek, Valis, David, & Wolf (2008) who reported that, patronage of shoulder and belly in Czech Republic declined as these primal cuts were less valued, compared to other primal cuts such as fillet, ham and loin chop.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary and Conclusions

In Ghana and Africa, there is inadequate data to empirically show yield of slaughtered pigs for processors and marketers to effectively trade and market pork on primal cut basis. A total of eighty large white breed of pigs were slaughtered after their live weights were taken. Their primal cuts were also weighed and recorded to discover the relationship of the live weights and the yield. A secondary data on patronage of the primal cuts was obtained from the meat processing unit and analysed.

The following conclusions have been drawn:

- There is a positive relationship between live weight and yield of pork, in that, an increase in the live weight among the group of pigs led to an increase in the yield of the primal cuts.
- The shoulder and ham took the highest proportion of the yield of the pork with 36 % and 29% respectively, whiles the fillet took the lowest proportion with a percentage value of 1.3.
- The most patronised primal cuts on fresh basis were ham and shoulder respectively, and the belly after it was processed into bacon, was highly patronised.

Recommendations

From this study, the following recommendations are made:

- Meat processors are advised to always purchase heavier pigs for slaughter, as this may translate into higher proportions of valuable parts.
- Meat firms and meat processors should consider using other primal cuts such as spareribs, loin chop and belly for further processing into pork chops, sausages and bacon respectively, other than the ham and the shoulder because, these two are highly demanded on fresh basis.

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