UNIVERSITY OF CAPE COAST

HATCHERY WASTE MEAL AS PROTEIN SOURCE IN DIETS FOR GROWER-FINISHER PIGS (*SUS DOMESTICUS*)

BY

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DECLARATON

Candidate's Declaration

I hereby declare that this submission is my own work towards the PhD and that, to the best of my knowledge it contains no material published by another person, nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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Supervisors' Declaration

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

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ABSTRACT

The series of experiments reported in this work considered the possibility of utilising hatchery waste as replacement for fish meal in grower-finisher diet. An initial survey in the Greater Accra region estimated that as high as 15 (fifteen) tons of waste was generated per annum from just 5 (five) hatcheries. Analysis of the waste showed however, that it had some levels of microbial load, although the presence of *Escherichia Coli* and *Salmonella* were not detected. Methods of processing waste using temperature and time combinations showed that simple steaming for 5 minutes at 80°C (5M80T) gave a product that retained high CP as well as had low microbial load suitable for inclusion in feed formulated for pigs. A 16-week study using sixty (60) Large White grower intact male pigs (average liveweight of 17.55 ± 0.1 kg) randomly allotted to 5 dietary treatments [designated 0% Hatchery Waste Meal, 2.5% Hatchery Waste Meal, 5.0% Hatchery Waste Meal, 7.5% Hatchery Waste Meal and 10.0 %] in which HWM replaced Fish Meal directly in the diet. The study again shows that HWM could be processed into a form that can be used after simple processing (steaming) without much loss in nutrient content, particularly protein. The inclusion of HWM up to 5.0% had no significant ($p > 0.05$) effect on weight gain, feed conversion ratio as well as economy of gain. In the course of the feeding trial, some biochemical and haematological indices assessed also indicated levels within normal ranges for good health in pigs. At the end of the feeding trial the effects of HWM replacement of FM on carcass characteristics (primal cuts, organs weights and measurement of fats) indicated no significant ($p > 0.05$) dietary treatment effects on all the parameters assessed, except for weight of the empty stomach, GIT (Gastro Intestinal Tract) and thymus gland. Finally, a more comprehensive survey to determine volumes of HWM generated across hatcheries in Ghana should be done to indicate more accurately the cost-saving potential of this feed ingredient for pig farmers in Ghana.

KEY WORDS

Animal Protein

Aveage Daily Gain

Carcass Characteristics

Feed Intake

Fishmeal

Hatchery waste meal

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DEDICATION

This work is dedicated to my Mum, Mrs Christiana Asiedu

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LIST OF ACRONYMS

AA	Amino Acid
ADFI	Average Daily Feed Intake
ADG	Average Daily Gain
ADWG	Average Daily Weight Gain
AEA	Agricultural Extention Officer
AIBPs	Agro-Industrial By-Products
ALBP	African Locust Bean Fruit Pulp
ALT	Alanine Aminotransferase
AME	Apparent Metabolisable Energy
ANOVA	Analysis of Variance
ARI	Animal Research Institute
AST	Aspartate Aminotransferase
BDG	Brewers' Dried Grain
BFT	Backfat Thickness
BMD	Bone Mineral Density
CBC	Complete Blood Count
CF	Crude Fiber
CP	Crude Protein
CRD	Completely Randomized Design
CSIR	Council for Scientific and Industrial Research
DCP	Dried Cashew Pulp
DE	Digestible Energy
DM	Dry Matter

DUIE	Dried Un-Hatched Incubator Egg-Based
EE	Ether Extract
EEAL	Ethanol Extract of *Amaranthus Spinosis* Leaf
FBC	Full Blood Count
FCR	Feed Conversion Ratios
FFA	Free Fatty Acids
FLW	Final Live Weight
FM	Fish Meal
GAF	*Gmelina Arborea* Fruit
GE	Gross Energy
GIT	Gastro-Intestinal Tract
GLM	Gliricidia Leaf Meal
GLPC	Glyricidia leaf protein concentrate
GNC	Groundnut Cake
Hb	Haemoglobin
HBP	Hatchery By-Products
HCT	Haematocrit
HDL	High Density Lipoprotein
HP	Hatchery Operatives
HW	Hatchery Waste
HWE	Hatchery Waste Eggs
HWM	Hatchery Waste Meal

ICMSF	International Commission on the Microbiological Specification for Food
ILW	Initial Live Weight
LDL	Low-Density Lipoproteins
LEA	Loin Eye Area
MCH	Mean Cell Haemoglobin
MCHC	Mean Cell Haemoglobin Concentration
MCV	Mean Cell Volume
ME	Metabolizable Energy
MIU	Motility Indole Urea
MLGA	Membrane Lactose Glucuronide Agar
MoFA	Ministry of Food and Agriculture
NCFR	Non-Conventional Feed Resources
NE	Net Energy
NFE	Nitrogen free extract
NPU	Net Protein Utilization
PCT	Procalcitonin
PCV	Packed Cell Volume
PKM	Palm Kernel Meal
PW	Post-Weaning
RBC's	Red Blood Cells
SBM	Soybean Meal
SPCA	Standard Plate Count Agar
TAMB	Total Aerobic Mesophilic Bacteria

TBA	Thiobarbituric Acid
TFI	Total Feed Intake
TP	Total Protein
TSI	Triple Sugar Iron
TWG	Total Weight Gain
UCCIRB	University of Cape Coast, Institutional Review Board
UIE	Un-Hatched Incubator Eggs
WBCs	White Blood Cells
WCDC	White Cell Differential Count
WHWM	Whole Hatchery Waste Meal
WSV	Water-Soluble Vitamins
XLD	Xylose Lysine Desoxycholate

CHAPTER ONE

INTRODUCTION

Background to the Study

Controlling feed costs in pig production is critical for profitability in the industry given that it represents approximately 70 percent of total cost of production. This is due to the high cost and scarcity of traditional protein and energy feed ingredients such as fish meal, maize and supplements such as lysine, methionine, et cetera. Low-cost by-product substitutes used for some of these traditional ingredients include palm kernel cake, groundnut cake and tuna waste (especially as replacement for fish). It is still economically expedient to explore the use of other non-conventional feed resources (NCFR) particularly agro-industrial by-products (AIBPs) as animal feed ingredients, as presently these are abundant, less utilised and cheap. An added advantage is the fact that such novel ingredients are not used directly for human consumption and therefore, would not create competition between humans and pigs (Rhule *et al.*, 2007).

It is clear from the abundance of research published about the usefulness of by-product feed ingredients in non-ruminant diets, that most of these are generally acceptable to pigs. One such non-conventional feedstuff which could be of value for pig feeding is hatchery waste meal (HWM). Hatchery waste is composed of egg shells, infertile eggs, dead-in-shells and dead chicks. These occur in varying proportions, and can potentially be made into supplemental energy, protein and mineral sources, if health issues likely to be associated with their use can be adequately addressed. Some published work indicates that its safety as feed may be achieved through cooking, drying

and grinding into a meal termed Hatchery Waste Meal (Glatz *et al.*, 2011). The development of such a potentially cheap source of energy and protein to replace conventionally more expensive feed ingredients such as fish meal will be of utmost economic importance for efficiency and profitability of the pig industry.

According to Urlings *et al.*, (1993), the crude protein content of hatchery waste meal (HWM), was estimated to be from 16.83% to 18.17 %. Hatchery waste meal in general can be quite variable, depending on the substrate that is being processed (Watson, 2006). On the average, hatchery waste in its raw state contains about 44.3% crude protein, 30.0% ether extract, 1.90% crude fiber, 14.0% ash, 4572 Kcal/Kg gross energy and 3600 Kcal/Kg metabolizable energy (Young *et al.*, 2002). It is rich in calcium but low in phosphorus, although the calcium level depends on the level of shell moiety and hatch percentage (Young *et al.*, 2002). Hatchery waste meal is generally a palatable and high-quality feed ingredient due to its high content of essential amino acids, fatty acids, vitamins and minerals (Shelton *et al.*, 2001).

Hatchery waste meal has been evaluated as a possible replacement in nursery pig diets for high-priced protein sources such as spray-dried animal plasma (Veum *et al.*, 1995). A couple of studies using HWM in pig diets have however, shown a decrease in average daily liveweight gain (Hamm and Whitehead, 1982; Orozco-Hernandez *et al.*, 2003). Also, Orozco-Hernandez *et al.*, (2003) reported that pigs fed increasing levels of HWM, up to 7.5% of the diet (on DM basis), from weaning until market, had decreased growth performance compared with control pigs not fed HWM.

Justification

Chicken production, particularly the layer and broiler enterprise, has played a key role in meeting Ghana's national protein supply needs (Rondon and Ashitey, 2011) through the supply of eggs, in addition to poultry meat. Since the hatchery operation is the main lifeline to the poultry industry, an increase in the number and capacity of hatcheries are essential for the growth of the local poultry industry. Consequent to this will be the generation of large quantities of hatchery waste made up of hatched egg shells, infertile eggs, dead-in-shells and dead chicks. It is necessary to find a safe but economic disposal outlet for these wastes. This would invariably increase opportunities for wealth creation along the value chain in the poultry industry whilst addressing the critical problems of environmental pollution and waste disposal.

Inadequate feeding has been identified as a major constraint in pig production in Ghana. High protein feedstuffs such as fishmeal and soya bean meal as well as synthetic amino acids are often used in preparing pig diets. Fish meal, mostly imported, is expensive and tends to be scarce at certain times of the year in Ghana. It is estimated that 0.8 to 3.3 billion tons of hatchery wastes are generated every year, worldwide, using a hatchability value of 50 - 80% (FAO, 2005). Fishmeal, locally made from anchovy i.e. "Keta school boys" is also a major source of protein in human diets in Ghana (Okai *et al.*, 2006). The resulting competition between humans, poultry and pigs has been responsible for the high price of fishmeal as a feed ingredient and for that matter, compounded feeds. Fishmeal is more expensive than soyabean meal per unit weight according to Sullivan *et al.*, (1989).

The wastes from the hatchery business is usually composed of hatched egg shells, infertile eggs, dead-in-shells and dead chicks. It has been estimated that almost 992 tonnes of hatchery waste eggs (HWE), including infertile eggs, dead embryos and dead chicks that failed to break out of eggs are discarded by the poultry industry each year in Ghana (Djang-Fordjour, 2016).

A reduction in feed cost should be of utmost concern to both nutritionists and animal producers since it would ultimately ensure the availability of low price meat and meat products. Hatchery waste with its high level of CP and favourable amino acid profile could fill an important gap in attaining profitable pig nutrition. The availability and utilization of hatchery by - products (HBP) therefore, should be of economic significance and attraction to pig and poultry producers. The disposal of HBP as garbage is not only a waste of valuable protein, mineral and energy sources but also potentially dangerous pollutants to the environment. Its use in pig diets could reduce the need for more expensive fishmeal and other protein supplements in the animal feeding regimen. This will save on feed cost, in addition to improving the state of the environment.

Hypotheses

i. HA: Replacing fish meal with processed hatchery wastes will increase the cost of feeding pigs.

ii. H0: Replacing fish meal with processed hatchery wastes will not increase the cost of feeding pigs.

iii. HA: Use of processed hatchery wastes as an alternative animal protein source to fish meal will make feeds safer for the pig industry.

iv. H_0: Use of processed hatchery wastes as an alternative animal protein source to fish meal will not make feeds safer for the pig industry.

v. H_A: Use of processed hatchery waste in well-balanced diets for grower-finisher pigs, in place of fish meal, will adversely affect pig performance (growth and carcass characteristics) and farm profitability.

vi. H_0: Use of processed hatchery waste in well-balanced diets for grower-finisher pigs, in place of fish meal, will not adversely affect pig performance (growth and carcass characteristics) and farm profitability.

Significance and Benefits of the Study

Potential benefits of the study will be:

a. Promoting use of hatchery by-products as feedstuff for pigs.

b. Increasing the production of pigs by overcoming a major feeding constraint in terms of supply of useful protein, minerals and energy ingredients.

c. Creating a range of useful products that add on to the economic value of hatchery wastes for the poultry industry.

d. Improving the state of the environment by reducing pollution caused by poor disposal of hatchery wastes.

Objectives of Study

Main Objective

The overall goal of this work was to investigate the feasibility of using HWM in place of FM in rations for grower-finisher pigs.

Specific Objectives

The research specifically sought to:

1. Determine the quantities of hatchery wastes generated by selected hatcheries in the Greater Accra region and establish how these hatcheries manage, handle and dispose of their wastes.
2. Develop a simple, cheap and effective technology for handling and processing hatchery wastes into a form that can be incorporated into formulated rations and at the same time render them safe for pig consumption.
3. Compare growth and cost-benefit analysis of HWM in formulating diets for grower-finisher pigs.
4. Determine the possible adverse effect on pig fed HWM-based diets through the assessment of some haematological and biochemical studies.
5. Carcass evaluation of pigs fed diets in which HWM replaced fishmeal at varying levels

Delimitation

The study did not consider slaughtering all the experimental animals at the same time and taking their weights for carcass evaluation because of the absence of cold storage facilities for storing the carcasses. Again, Sensory analysis of meat could not be carried out as the pigs were slaughtered based on the number of days to slaughter

Limitation

Physiological age groups of pigs ie. Reproductive phase, weaner phase etc. was not considered due to financial constraints.

Organization of the Study

The work has been planned into five main studies based on five specific objectives. Study one: survey to determine quantities of hatchery wastes generated by selected hatcheries in the Greater Accra region. Study two: to develop a simple, cheap and effective technology for handling and processing hatchery wastes into a form that can be incorporated into formulated rations of pigs. Study three: to compare growth and cost-benefit analysis of HWM in formulating diets for grower-finisher pigs. Study four: to determine the possible adverse effect on pig fed HWM-based diets through the assessment of some haematological and biochemical studies. Study five: to determine the carcass evaluation of pigs fed diets in which HWM replaced fishmeal at varying levels

CHAPTER TWO

LITERATURE REVIEW

In this chapter, literature relevant to the subject areas of this study, have been reviewed and discussed.

Origin and Nature of Pigs

Pig production is one of the oldest forms of livestock farming dating as far back as 5000 BC in Europe and Asia. The domestic pig (*Sus scrofa domesticus*) is usually given the scientific name *Sus scrofa*, although some taxonomists refer to it as *S. domesticus*, reserving *S. scrofa* for the wild boar (Giuffra *et al.,* 2000*)*. It has been shown that the upper canines of the pig are sharp, with distinctive tusks that curve outward and upward. Compared to other artiodactyles, the head is relatively long, pointed, and free of warts. The head and body length ranges from 0.9 to 1.8 m (35 to 71 in), and pigs can weigh between 50 and 350 kg (Pennisi, 2015). Pigs are mostly used for food but their hides were also used for shields and shoes, their bones for tools and weapons, and their bristles for brushes. With around one billion individuals alive at any time, the domestic pig is among the most populous large mammals in the world (Angier, 2016).

Pigs are omnivores and can consume a wide range of foods *(*Harper, 2015*)*. Biologically, pigs are very similar to humans in many anatomical and physiological functions, and thus are frequently used for medical research related to humans (Grush, 2016). Their feeding behaviour in searching for roots churns up the ground and makes it easier to plough, their sensitive noses lead them to truffle, an underground fungus highly valued by humans. In effect, their omnivorous nature enables them to eat human waste and thus keep

settlements clean (MoARD, 2007). Pig production in developing countries is characterised by traditional, small-scale, subsistence-driven production systems in which they provide much more than meat, unlike in the western countries where pig production is based on human edible foods. Pigs in such low-input systems provide value-added services for farmers by consuming feed that would otherwise be wasted. Hence, while pigs might contribute to food security and provide protein, they also constitute a financial safety net, fulfil a role in cultural traditions, or provide additional cash for school fees, medical treatment or small investments (Angier, 2016).

Until recently, pigs were reared by most Ghanaian farmers extensively or semi-intensively, with modest supplementation based on household, school, institutional (e.g. hotels and restaurants) 'leftovers'. Pigs were thus commonly seen scavenging for food on refuse dumps, eating human excreta, and wallowing in gutters and swamps (Okai and Boateng, 2011). Currently, pig farming has become the most commercialised form of livestock farming, after poultry in Ghana, and this change has had its attendant challenges (Osei, 2013).

Table 1: Production of pigs and pork in Ghana (2001 to 2015)

Year	Pigs	Pork (tons)
2001	312,000	1,050.00
2002	310,000	1,041.6
2003	303,000	1,016.40
2004	300,000	1,008.00
2005	290,000	1,024.80
2006	477,000	1,545.60
2007	491,000	1,650.60
2008	506,000	1,696.80
2009	521,000	1,751.00
2010	536,000	1,800.00
2011	552,750	2,507.00
2012	578,850	1,785.80
2013	637,320	2,064.60
2014	685,110	905.00
2015	730,000	1,167.53

Source: (FAOSTAT, 2017)

Ghana is divided into six ecological zones namely; Sudan Savannah, Guinea Savannah, Forest- Savannah Transition, Semi-Deciduous Rainforest, High Rainforest and Coastal Savannah. The Guinea Savannah zone covers the whole of the Upper West, North East, Savannah and Northern regions. It also occupies parts of the Upper-East region as well as the northern parts of the Bono and Ahafo as well as Volta regions. In all the agro-ecological zones of Ghana, the average growth rate (from 2009 to 2015) for pigs was 5.54 percent.

The Transition and Coastal Savannah zones had the highest (61.68 percent) and lowest proportions (1.22 percent) respectively (SRID, 2017).

Pig Population and Distribution in Ghana

Pig population in Ghana was estimated at 355,000 in 1996; 347,000 in 1997; 339,000 in 1998; 332,000 in 1999, 324,000 in 2000; and 310,000 in 2002. Table 1 gives figures on production of live pigs and pork meat in Ghana from 2001 to 2015, indicating a growth rate of negative 3.7% (Veterinary Services Directorate, 2001; FAO, 2005). In 2002, 23.55% of consumed pork and 3,257 live pigs were imported into Ghana to make up for the deficit in pork and pig supply to the market (FAO, 2005). For religious reasons, a good number of Ghanaians do not eat pork. Furthermore, due to the recent increasing health-consciousness among Ghanaians, a sizeable number of people avoid pork. However, the vast majority of Ghanaians have always loved their pork (Okai *et al.,* 2006). For these reasons, the production level of pigs in Ghana has increased from 536,000 in 2010 to 730,000 in 2016 representing 36.4% increase (FAOSTAT, 2017). Despite the increase in production, large quantities of pork products are still imported each year to partially meet the growing domestic demand. Pork products imported into the country includes, but not limited to pig meat, pig fat, pig sausage and pig offal. A total of 1,259 MT (worth $1.27miillion), 1,408 MT ($1.63million), 986 MT ($0.93million) and 5,005.00 MT ($3.36million) of pig meat were imported into the country for 2013, 2014, 2015 and 2016 respectively (FAOSTAT, 2017).

Results from economic and market analysis of pig rearing and pork production in Ghana shows that from 2008 to 2013, pork prices rose rapidly between 115

and 120%. i.e. the price of a kilogram of pork ranged between GHC 9.33 to GHC 16.00 depending on its quality (SRID, 2017). Table 2 shows the six agro-ecological zones and population of pigs.

Table 2: Population of pigs in the various Agro-Ecological Zones in Ghana

Agro - ecological zone	Rainforest/ Deciduous	Transition	Guinea Savannah	Sudan Savannah	Coastal Savannah	Total
Pigs	343	753	83	27	15	1221

Source: MoFA. (2007*); Value expressed in 1,000 animals*

The Pig Industry in Ghana and its Constraints

The move towards intensive commercial pig production in Ghana is increasing at an unprecedented pace despite financial, feeding and health challenges. Pork production and consumption have risen rapidly in Ghana over the past decade, driven by population growth, urbanisation, increasing incomes, and changing tastes of consumers (Okai *et al.*, 2006) Pigs are highly prolific and can be used to increase meat production in a very short time. Growth rate is high and pork meat can be lean and account for 69-72% dressing percentage; relatively higher than in other meat-producing animals. These have combined to remarkably change the economics of pig production in recent years.

The pig industry is considered as an important avenue that provides employment opportunities and more importantly, becomes a poverty alleviation mechanism. Pig production offers one of the fastest means of reducing or completely curtailing meat imports. Pigs can be processed into more products than any other animal thereby expanding its market and

generating employment in several sectors of the economy (Okai and Boateng, 2011). However, the stench associated with the environment in which pigs are kept led to their being proscribed in many communities. The numerous benefits enjoyed by famers for adopting intensive pig farming has been found to far outweigh the challenges they face. Provision of cheap but good quality feed still remains a major constraint in pig production. The availability of highly prolific breeds, limited know-how in feed formulation and feeding regimen, and poor management practices are among other major challenges facing the pig industry. In addition, very little endeavour in terms of processing and marketing of pork and its products is made locally, contributing to increased importation of pork products to meet market demands.

Nutrition in Pigs

Pigs require a number of essential nutrients to meet their needs for maintenance, growth, reproduction, lactation and other functions. Pigs require six general classes of nutrients namely water, carbohydrates, fat, protein minerals and vitamins (Peader *et al.*, 2005). Nutrient requirement is that amount of each essential nutrient that will result in maximum production with a minimum of feeding. Hence, high quality feeds containing the essential nutrients in the amounts necessary to meet the animal's requirements, must be provided in order to attain an optimal rate and efficiency of growth from birth to market (Adesehinwa, 2008).

Amino Acid and Protein Requirements of Pigs

Traditionally, pig diets are formulated on the basis of crude protein. This refers to the nitrogen content of the feedstuff x 6.25 (NRC, 1988). A

good quality protein is one that provides the ten essential amino acids required for normal body function, in the amounts and proportions necessary for the particular needs of the pig (Adesehinwa and Ogunmodede, 1995). Regular amounts of protein are required to accommodate weight gains based on biological relationships that exist in utilizing dietary nutrients for tissue growth (NRC, 1988). To gain one gram of protein, 0.12 grams of digestible lysine is needed. The requirements for other amino acids can be calculated in a similar way (Batterham, 1992). However, in practice, the requirements for other amino acids are expressed as a percentage relative to lysine.

Lysine is typically the first and most limiting amino acid in pig diets, which means that it is the first amino acid that needs to be supplemented to meet the requirements of the pig (Peader, 2005). Expressing requirement for the other amino acids relative to lysine (ie. lysine is set at 100%) makes it easy to calculate these requirements at any stage of growth. For example, if a high lean gain pig at 60 kg of body weight requires 1.07% lysine, then its threonine requirement is 0.63 x 1.07 = 0.67%.

Amino acids are reported to be the chemical components of protein and are generally supplied to the pig from the crude protein in the diet (NRC, 1988). Failure to supplement a low protein diet or feedstuff with sufficient amounts of high-quality protein source was reported by Adesehinwa and Ogunmodede (1995) to result in fatness, general unthriftiness and or reduce reproductive performance. The capacity of the diet or feedstuff to provide sufficient indispensable (essential) amino acids and nitrogen for the synthesis of dispensable (non-essential) amino acids determines the adequacy of the dietary protein level (NRC, 1988). Hence, the need for a nutritionally balanced

ration in an economically viable pig production system (Adesehinwa, 1992). Lower levels of dietary protein are required to maximize growth and efficiency of gain for a protein source with well-balanced amino acid profile (Bender, 1975), in contrast to a protein source with poor amino acid pattern where more is required, to be efficiently utilized (Adesehinwa, 1992). Protein quality therefore becomes synonymous with amino acid balance. The amino acid requirements expressed as a percentage of the diet decrease as the pig becomes heavier; that is, the requirements are greatest during the rapidly growing stages of the young animal (Conrad, 1984).

It has been shown that increasing the level of protein in a maize/soya bean meal diet from 16 to 32% crude protein, compared to feeding only soya bean meal of 48% protein, resulted in decreased appetite and a lowered daily weight gain, but had no effect on feed conversion (Peader, 2005). In addition, there was an increase in the percentage of lean cuts which was in direct relation to the amount of soya bean meal in the diet. Perhaps, the most important conclusion is that pig performance does not necessarily improve by increasing protein in the diet. Table 3 indicates effects of varying levels of protein in diet on some performance characteristics assessed in growing pigs,

Table 3: Effect of High Levels of Protein in diet on Performance of Growing Pigs

Parameter assessed	Protein level in the diet, %		
	14	16	22
Feed intake, kg/d	2.41	2.22	1.92
Average daily gain, g	700	640	550
Feed conversion ratio	3.45	3.48	3.50

Peader, 2005

Fetuga (1984) reported the protein and amino acid requirements for the tropics to be higher than those recommended by NRC (1979) for the temperate zones. This view was also expressed in an earlier work by Babatunde *et al.* (1972).

Literature indicates that the reduction of dietary crude protein (CP) level from an optimal level (i.e. control diet supplying all essential amino acid (AA) at or above requirements), depresses performance of both growing pigs or lactating sows when no free AA are supplemented (Castell *et al.*, 1994). Supplementation with free AA however, improves performance (daily body weight gain) and becomes equivalent to that obtained with the control diet (Figueroa *et al.*, 2002).

Energy Requirement of Pigs

Feed is the single most expensive input in commercial pig production, representing more than 50% of the total cost of production. The greatest proportion of this cost is associated with the energy component, thus making energy the most important dietary input in terms of cost. For efficient pork production, it is imperative that diets are formulated to accurately match dietary energy supply to requirements for maintenance and productive

functions (Mavromichalis, 2006). It is critical that the energy value of feeds is precisely determined and that the energy system that best meets the energy needs of a pig used (Velayudhan *et al.*, 2014).

Burrin (2001) reported that energy is what an animal derives from its food, through the process of cellular respiration. This involves a set of metabolic reactions and processes that take place in the cells to convert biochemical energy from nutrients into energy units. It has been shown that energy enclosed in the feed as chemical energy is released by partial or complete oxidation following digestive and absorptive mechanisms in the gastrointestinal tract (Pond *et al.*, 1995) and can only be measured in its transformation from one form to another (Kleiber, 1975). Pigs tend to eat to meet their requirement for energy. Mavromichalis (2006) reported that energy can be defined as the ability to do work and it occurs in various inter-convertible forms such as thermal, radiant or chemical energy.

Diets high in energy result in a typically decreased feed intake (NRC, 1998). Pigs will consume more feed when the energy content of a diet is diluted with fibrous feedstuffs (Ellis and Augspurger, 2001). Understanding this relationship is important when calculating nutrient recommendations because nutrient concentrations required in the diet are energy dependent (Noblet *et al.*, 2001). A high energy diet will cause intake to decrease and, therefore, concentrations of other nutrients should be increased to maintain a constant daily intake. A diet, low in energy would contain a lower concentration of nutrients because feed intake will be increased (Ellis and Augspurger, 2001).

The rule of thumb indicates that the addition of fat to the diet will improve Feed: Gain ratio by approximately 0.04 points for every 1% fat added (Johnson *et al.,* 2004). The pig is only able to meet its lean gain potential if sufficient energy is available. In support of this, if the energy intake is limited, lean gain is compromised and consequently, amino acid requirements would be lower (Noblet *et al.*, 1994). The first and second laws of thermodynamics, state that all forms of energy are quantitatively convertible to heat (Baldwin and Bywater, 1984) and therefore, all measurements of energy are made and conveyed in terms of heat energy or calories.

The International System of Units (S.I units) measures energy in joules (J) while calorie is the metric system unit of energy. Pond *et al.,* (1995) defined calorie as the amount of heat required at a pressure of one atmosphere to raise the temperature of one gram of water by one degree Celsius. Furthermore, for diets and feed ingredients, energy content can be expressed as calories (cal), kilocalories (kcal), or megacalories (Mcal) of gross energy (GE), digestible energy (DE), metabolisable energy (ME), or net energy (NE) [NRC, 1998]. Gross energy is rarely used in feed formulation except for computational purposes. Gross energy or heat of combustion is the quantity of energy released by burning a sample of feed in excess oxygen. It has been observed that GE content of feed depends upon the amount of carbohydrates, fat and protein it contains (Velayudhan *et al.,* 2014). For carbohydrates, the GE value varies since monosaccharides (such as glucose) yield 3.75 kcal/g and polysaccharides (such as starch) yield 4.16 kcal/g (Wenk *et al.*, 2000). On the other hand, the GE content of protein and fat depends on the amino and fatty acid composition, with an average of 5.64 kcal/g for protein (Wenk *et al.*,

2000); for fat the widely acknowledged GE value is 9.51 kcal/g (Velayudhan *et al.*, 2014). If the nutrient composition of feed ingredients is known, the GE content can be estimated using existing prediction equations (Noblet and Perez, 1993). However, the GE is totally independent of the animal and provides no indication of available energy to pigs.

Digestible energy (DE) on the other hand, is the energy in feed after subtracting the energy lost in faeces. Digestible energy is not a true measure of the energy values of the nutrients absorbed from the digestive tract and so, it is often referred to as apparent digestible energy (Just, 1982). Boisen and Verstegen (2000) reported that digestible energy is usually determined from the GE in the feed consumed and the GE of faecal matter excreted. Metabolizable energy could be defined as the DE minus urinary energy and gaseous energy (GE_{gas}; mostly methane). In pigs, the GE_{gas} is generally overlooked because it represents only a small fraction of DE and usually pegged between 0.1% and 3% (Wenk *et al.*, 2000). It has been shown that metabolisable energy is further used to meet different energy requirements of the pig namely, maintenance, growth, protein or lipid gain, milk production among others. There is a marked variation observed in the average efficiency of utilisation of ME for these different purposes: approximately 80% for fat gain (k_f) or maintenance (km), 60% for protein deposition (k_p), 75% for weight gain (k_g) during growth, and 70% for milk production (k_l) (Noblet *et al.*, 1994).

When pigs consume feed, dietary energy is either absorbed or excreted in faeces, urine, or as heat. Dietary energy absorbed by pigs is then utilised for maintenance or retention of protein or lipids (Lizardo *et al.*, 2002). It has been

assumed that energy in pigs is first prioritised for maintenance and additional energy intake in excess of the energy requirement for maintenance is retained as protein or lipids in the body (Lizardo *et al.*, 2002). The energy requirement for maintenance accounts for approximately one third of total dietary energy utilisation and the remaining two thirds of dietary energy is stored as proteins or lipids in growing pigs (Black and de Lange, 1995; NRC, 1998).

Requirements for Vitamins

Vitamins are regularly added to pig diets because the natural ingredients commonly used (cereal grain, soybean meal, etc.) are deficient in them (Darroch, 2001). Neil *et al.*, (2000) reiterated that vitamins are organic nutrients that are important for standard growth and development but are needed in much smaller amounts than the essential amino acids. Vitamins can be divided into two groups namely fat-soluble (vitamins A, D, E and K) and water-soluble (riboflavin, niacin, pantothenic acid, choline, biotin, vitamin B12, vitamin C and folic acid). Most vitamins serve as coenzymes or part of coenzymes; they are required in only little amounts and have catalytic purposes and are used for metabolic reactions (NRC, 1998).

Darroch (2001) reported that some vitamins do not occur in plant products, but only in the plant pigment. β-carotene can be converted to vitamin A in the intestine of the pig. Good and natural sources of β-carotene include green pastures, leafy alfalfa hay or meal. Deficiency symptoms of vitamin A in growing pigs include weakness of the back, paralysis, night blindness and total blindness. Sows may fail to come into oestrus, have poor conception rates, resorb their foetuses, and have weak, dead pigs at birth or those with various deformities. Sterility may occur in boars.

Pigs that have daily access to adequate sunlight produce their own vitamin D. However, pig diet fortified with vitamin D is necessary when pigs are fed indoors as most feedstuffs are practically devoid of vitamin D (Crenshaw, 2001). Vitamin D is needed for the efficient absorption and metabolism of calcium and phosphorus, and is, therefore, required for normal calcification of bones. A deficiency in young pigs results in rickets, stiffness, lameness, enlargement of the joints and general unthriftiness. In mature and market animals, bone fractures are common if vitamin D is deficient. Excessive amounts of vitamin D in the feed or as an injectable are harmful due to deposits of calcium in soft tissues. Excessive intake can occur if diets are not properly formulated and mixed (NRC, 1998).

A decline in the use of pasture for pigs and an increase in artificial drying of grains have resulted in the reduction of vitamin E intake and an increase in occurrence of deficiency symptoms. Grains low in selenium increase the need for vitamin E as the dietary concentration of any one of these nutrients affects the metabolism of the other (Dove and Cook, 2001). Vitamin E functions as an antioxidant in intracellular membranes. Deficiency signs in growing pigs are indistinguishable from those of selenium deficiency which include, sudden death, mulberry heart, jaundice, edema, white muscles and liver necrosis. Nursing sows deficient in vitamin E may experience muscular incoordination and sudden death. Vitamin E is primarily transferred to newborn pigs via colostrum (Lindemann *et al.*, 2008).

Vitamin K was the last of the fat-soluble group of vitamins to be discovered (Binkley *et al.*, 2002). The role of vitamin K in the blood clotting cascade has been well documented. Vitamin K has recently been implicated in

improving bone health. Vitamin K is available in multiple natural and synthetic forms. The predominant function of vitamin K in the body is to induce gamma-carboxylate peptide bound glutamine and glutamate residues. Gamma-carboxylation confers calcium (Ca) binding capacities to the glutamyl residue containing proteins, facilitating the formation of Ca bridges essential for proper function. Known vitamin K dependent proteins include clotting factors, coagulation inhibiting protein, and osteocalcin in the bone (Monegue, 2013).

There is considerable debate among nutritionists and veterinarians as to what health, management and nutritional measures are available to maintain pig performance in relation to water-soluble vitamins (WSV). Among the WSV commonly encountered are riboflavin, niacin, pantothenic acid, choline, biotin, vitamin B12, folic acid and vitamin C.

Riboflavin is mostly found in cereal grains and plant by-products such as soybean meal. It functions in the body as a constituent of several enzyme systems. Therefore, a deficiency of riboflavin results in a wide variety of symptoms. In growing pigs, a deficiency may cause loss of appetite, stiffness, dermatitis and lowered growth rate. Poor conception and reproduction have been noted in sows fed riboflavin-deficient diets. Pigs may be born prematurely, dead or too weak to survive (FASS, 2010).

Niacin is present in adequate amounts in cereal grains. It however, exists in a bound form that is largely unavailable to the pig. The protein source and content of the diet can also affect the dietary need for niacin because the amino acid tryptophan, if in excess, can be converted into niacin. This can develop into tryptophan deficiency in a diet low in both niacin and tryptophan.

Slow growth, diarrhoea, dermatitis, loss of hair and occasional vomiting are deficiency symptoms. Alfalfa meal and good pasture are natural sources of riboflavin, pantothenic acid and niacin (NRC, 1998; Dove and Cook, 2001).

It has been shown that corn-soybean meal diets are usually deficient in pantothenic acid. A deficiency may result in lower fertility, reduced growth rate, diarrhoea and an uncoordinated, wobbly or high-stepping gait called goose-stepping. Many of these symptoms are similar to those observed from other deficiencies and indicate that, in practical feeding situations, it is difficult to determine exactly which vitamin may be lacking. In fact, in many cases, it is a combination of observable vitamin deficiencies (NRC, 1998; Dove and Cook, 2001).

Supplemental choline results in an increased litter size in gestating sows fed corn-soybean meal diets. Choline deficiency also has been implicated by some as the cause of straddle legs in newborn pigs. However, there is limited data to support this hypothesis. The choline requirement of growing and finishing pigs is met by natural feedstuffs. However, the need for supplemental choline is increased in diets low in the amino acid, methionine. Choline should be part of the vitamin mixture provided in sow diets (Patience and Zijlstra, 2004). Common feedstuffs contain enough biotin to meet the requirement of the growing pig but the bioavailability is poor in small grains. Biotin supplementation of corn-soybean meal-based diets appears to improve litter size at weaning for first parity sows. While it has been promoted by some that pigs will have fewer cracks in their hooves, this has not been validated (NRC, 1998; Dove and Cook, 2001).

Cereal grains and other plant products do not contain vitamin B12 but animal products are good sources. The requirement for this vitamin is approximately one-thousandth the amount of the other B vitamins discussed. Signs of a deficiency include reduced growth rate and anaemia. Vitamin B12 is also known as cyanocobalamin. It is required with folic acid, iron, and copper to make red blood cells (Dove and Cook, 2001).

It has been shown that folic acid supplementation in gestation and a lactation diet has increased the number of pigs born alive and weaned per litter; therefore, it is recommended to supplement breeding herd diets with folic acid. Weakness, poor growth and anaemia are symptoms of folic acid deficiency. Green, leafy plants are excellent sources of this vitamin (Dove and Cook, 2001). The pig's requirement for folic acid for growth and maintenance is met from feedstuffs and bacterial synthesis in the hind-gut (NRC, 1998).

Dove and Cook (2001) reported that pigs do not necessarily have a vitamin C requirement, due to adequate biosynthesis from glucose. However, research has shown improvements in boar fertility when diets were supplemented with the vitamin, and several nursery trials have shown benefits from early addition of vitamin C. Vitamin C is made by the pig; again some research suggests that nursery pigs may benefit by its supplementation to reduce the effect of stress at weaning. Deficiency signs associated with these vitamins may be produced when diets contain an antagonist or high levels of sulpher drugs. However, the amounts of these vitamins present in practical diets plus that synthesised by microbes (thiamine and B6) are considered to be sufficient to meet the requirements of the pig. In the finishing phase, vitamin C supplementation has largely been thought to be unnecessary. Yet, disease

can cause a negative impact on liver function and other factors necessary for vitamin C biosynthesis. Vitamin C, in the form of pure ascorbic acid, is not heat stable and should only be used in mash feeds. A heat-stabilized form of vitamin C (Stay-C from DSM) should be used when feeding pelleted diets.

Requirements for Minerals

Minerals serve many important functions in pig nutrition. These range from structural functions in bone to a wide variety of chemical reactions essential for maintenance, growth, reproduction and lactation. Minerals are component and activators of several metalloenzymes, and have a major function in production and secretion of hormones. They also play roles in skin and wound healing, and in maintaining the integrity of the immune system (Pearce *et al.*, 2015). Minerals needed in quantities greater than 100 mg/kg of feed are called macro minerals whereas minerals required in smaller quantities (< 100 mg/kg) are called micro minerals or trace minerals. Examples of micro minerals are Copper (Cu) and Zinc (Zn). However, unlike most other minerals, Cu and Zn have antimicrobial properties and they are therefore often added to diets in quantities greater than what is needed to fulfill the nutritional requirements.

The biological mechanism of Zn in enhancing growth performance may be related to its function in the intestinal integrity and morphology in weanling pigs (Hill *et al.,* 2000; Pearce *et al.*, 2015). High Zn intake improves the intestinal morphology of weaning pigs, increasing the villous height as well as the villous height to crypt depth ratio (Li *et al.*, 2001; Li *et al.*, 2006; Hu *et al.*, 2013a; Xia *et al.*, 2017; Zhu *et al.*, 2017). It also decreases crypt depth in the small intestine of weaned pigs (Li *et al.*, 2001, Zhu *et al.*, 2017).

Dietary Zn also assists in the regeneration of injured intestinal epithelial tissue (Alam *et al.*, 1994), stability of the microflora and diversity of the coliform microbes (Katouli *et al.*, 1999), reduction of intestinal permeability of weanling pigs (Zhang and Guo, 2009) and lymphocyte proliferation (van Heugten *et al.*, 2003). Nursery pigs usually require 80 to 100 mg/kg of Zn (NRC, 2012) and deficiency of Zn in weanling pig diets leads to growth retardation, loss of appetite, skeletal abnormalities and hyperkeratinisation of the skin called parakeratosis (van Heugten *et al.*, 2003). However, use of pharmacological levels (2,000 to 4,000 mg/kg) of inorganic Zn in the form of zinc oxide (ZnO) is a common recommendation to reduce post-weaning diarrhoea and improve growth performance (Hill *et al.*, 2000; Hu *et al.*, 2012).

On the other hand, copper is an essential component of several metalloenzymes including cytochrome oxidase and lysis oxidase, and is involved in oxidation–reduction reactions, transport of oxygen and electrons, and protection against oxidative stress (Hill, 2013). Pigs deprived of copper develop critical dysfunctions and hypocuprosis (Hill *et al.*, 2000). Microcytic anaemia is a sign of copper deficiency due to its role in haemoglobin formation and development (Ma *et al.*, 2015). Pigs may also suffer from bone abnormalities and unusual leg condition with various degrees of crookedness due to a lack of copper in the diet (Baxter *et al.*, 1953). Addition of pharmacological levels of Cu in pig diets has been a common practice to improve growth performance (Ma *et al.*, 2015). Supplementing Cu to diets fed to weanling pigs at 100 to 250 mg/kg may reduce post-weaning scouring, improve average daily gain (ADG) as well as average daily feed intake (ADFI) (Poulsen, 1995, Rutkowska-Pejsak *et al.*, 1998, Perez *et al.*, 2011).

Sodium and chloride assist in maintaining the osmotic pressure of body fluids and acid/base balance. Sodium is also involved in nerve function while chloride is essential for hydrochloric acid production in the stomach. A deficiency of sodium and chloride depresses appetite and impairs growth. Grains and plant protein supplements are low in sodium and chloride, so these minerals must be added to the diet. They are generally added as common salt in the form of 40% sodium and 60% chloride (NRC 1998; Darroch, 2001).

Water Requirements of Pigs

One resource which has been largely neglected by pig producers is water. This has occurred mainly because water has been accepted as a relatively cheap material, representing only a small percentage of the overhead costs on most agricultural holdings. Water is one of the most important of all nutrients and is often ignored when the nutrition of pigs is being considered. The reasons for this seem to be two-fold. Firstly, until recently, water has not been considered an economically significant input into pig production.

Secondly, nutritionists have proceeded on the assessment that the provision of water was not limited and as a result would not be limiting to pig performance (Barber, 1992). Animals can survive without feed for longer periods than they can survive without water. A starving animal may lose nearly all of its fat, half of its body protein and forty percent of its body weight, and still live. However, if it loses ten percent of its water, serious disorders will occur; and if it loses twenty percent of its body water, it will die (Maynard *et al.*, 1979).

Water is the single nutrient that is required in the greatest quantity by pigs; it is the most essential nutrient required for life and should be closely

monitored (Rosenlund, 2002). Pigs require water for most metabolic functions namely control body temperature, transport food and waste products throughout the body, the production of milk, and growth and reproduction. Water usage is also a very good predictor of health issues. Pigs consume majority of water by drinking but some water is ingested through the feed or is generated through metabolism. Pigs excrete water via the urine, faeces, respiration and evaporation (Gondret and Lebret, 2002). Feed ingredients that are most commonly used in pig diets typically contain about 10 to 12% water (NRC, 1998).

Metabolic water originates from the breakdown of carbohydrates, fat and protein. However, drinking water is by far the major and most important source of water for pigs, even though metabolic water and water contained in feed reduce the amount of water that the pig must drink to meet its daily requirements. It has been observed that there are many different factors that can influence the amount of water required by pigs on a daily basis and these include feed intake, ingredients in the diet, temperature, state of health and stress level. Water needs may vary by as much as 50% due to some of these factors. In turn, only estimates of water requirements are reported. As a general rule, pigs will consume 1.5 to 2 times more water than feed (Gondret and Lebret, 2002).

Water fulfils the following important functions in all animals:

a. It affords a medium for the transportation of various substances such as nutrients and waste products.
b. It is necessary to the life and shape of every cell and is a constituent of every body fluid.

c. It is necessary for many of the chemical reactions of digestion and metabolism.

d. It plays a major role in temperature regulation in the body i.e cooling the animal by evaporation from the skin and upper respiratory tract (insensible heat loss).

e. It aids gaseous exchange in respiration by keeping the lung alveoli moist.

f. As a constituent of the synovial fluid, it lubricates the joints; in the cerebrospinal fluid, it acts as a water cushion for the nervous system; in the perilymph in the ear, it transports sound; and in the eye it is concerned with sight and provides a lubricant for the eye.

g. Due to the high specific heat capacity of water, large changes in heat production can take place within the animal with very little alteration in body temperature.

h. It acts as a solvent for a number of chemicals which can be detected by taste buds (Gondret and Lebret, 2002).

Rosenlund, (2002) reported that the restriction of water supply to the grower and finisher pigs.has been shown to negatively impact feed intake, average daily gain and feed conversion

Role of Some Local Agro-Industrial By-Products in Pig Nutrition

According to Pond *et al.*, (1995) as sited by Asiedu, (2009).The major constraint on pig production in Ghana has been the provision of adequate nutrition. Attention has been focused on agro-industrial by-products (AIBPs) as potential solution to the problem with feeding pigs. Agro-industrial by-products such as cassava peels, palm kernel cake, copra cake, soybean meal, dried cocoa pod husk, brewers spent grains, wheat bran and rice bran

have been found to overcome the difficulty of feeding expensive items to pigs as well as reducing the competition between human and farm animals for cereals.

Cassava Peels

Cassava peel is a by-product of cassava tuber processing. The peel represents about 20 per cent of the whole tuber and contains about 3.93% CP, 11.16% CF and 1.29% EE (Ifut, 1992). In Ghana, the peel is readily and cheaply obtained in almost all the agro-ecological zones. Cassava peels, usually discarded when the tubers are processed, can be collected and dried for use as an energy source. The peel contains two cyanogenic glycosides; linamarin and lotaustralin, which on hydrolysis yields hydrocyanic acid (HCN), glucose and a ketone or an aldehyde. It is generally considered that the HCN content of cassava is about 1.3 to 6.3 mg HCN/100g fresh weight which limits its utilization (Ifut, 1992; Okai *et al.*, 1994). Levels as high as 30 and 37.5 % has been fed to grower-finisher pigs without any adverse effect on growth rate, and for weaner pigs the range is about 20-29% (Sonaiya and Omole, 1997) Cassava peels have been fed at levels up to 55-65% to grower-finisher pigs (Dodoo, 1981; Barnes and Oddoye, 1985). Cassava and its by-products have been shown to be good sources of vitamins and minerals for monogastrics animals (Phuc and Linberg, 2000). The threshold of 40% for cassava peel inclusion may cause some decline in performance. In the light of this, cassava peels should not exceed 40% due to the high cyanide content of some cassava varieties (Iyayi and Tewe, 1992). Certain treatments have been applied to detoxify cassava peels before feeding, these treatments include sun drying and ensiling (Wyllie and Lekule, 1980).

Palm Kernel Cake (PKC)

Palm kernel cake is produced in large quantities in a number of tropical countries and is available at competitive prices. It has been estimated that four million metric tons of PKC was produced in the world in the year 2002 with an average annual growth of 15% over the last two decades. Palm kernel cake has been widely used in pig's diets (Agunbianade *et al.,* 1999; Kim *et al.*, 2001).

Palm kernel cake contains about 14-21% CP and 10-20%CF. The first limiting amino acid in PKC is methionine with the content of lysine, histidine and threonine being low. Live weight gain in pigs decreased linearly with increasing levels of PKC from 21 to 62 % (Jegede *et al.*, 1994; McDonald *et al.,* 1998). However, they found no significant effect of PKC inclusion on the performance of pigs fed diets with graded levels of 20, 30, 40 and 50% PKC.

Twenty per cent PKC inclusion in the diet of pigs have been found to be satisfactory (Thorne *et al.*, 1989). In Nigeria, PKC used for feeding pigs was ranked lowest in terms of protein quality compared to other local protein sources and it produced a loss in weight (Ocampo, 1994). In Columbia, good results have been reported when almost 40% of PKC was used in the diet of grower-finisher pigs (Jegede *et al*, 1994). Grower-finisher pigs have also been fed diets containing PKC at inclusion levels between 20 - 35 % respectively without any adverse effects on performance (Jegede *et al.*, 1994; Rhule, 1996; Rhule *et al.*, 2005; Okai, 2008)

The use of PKC in the diets of pigs should be limited due to the following reasons:

- Physically, PKC is gritty and unpalatable (Ocampo, 1994).

- Nutritionally, it may contain anti-nutritional substances such as mannan or galactomannan and xylan or arabinoxylans which have been proven to decrease nutrient uptake in pigs (Balasubramaniam, 1976, Duesterhoft *et al.*, 1993).
- It has been observed that the local PKC may undergo the Maillard reaction due to the heat applied during oil extraction (Babatunde *et al.*, 1975; Sundu and Dingle, 2003).

Copra Cake (CC)

Copra cake (CC) is a by-product from the manufacture of coconut oil and it is used as protein source in non-ruminant diets (Woodroof, 1979). Copra cake is produced in large quantities in a number of tropical countries. It has been estimated that two million metric tons of CC were produced in the world in 2002 with annual growth of 1.4% of CC over the last two decades. Copra cake has been widely used in pigs diets (Kim *et al.*, 2001; FAO, 2002).

Copra cake contains about 19.09% CP, 16.25% CF, 5.48% EE and 89.70% on dry matter basis (Okai *et al.*, 1991). Copra cake has low levels of lysine and histidine. It has been reported that feed intake of pigs decreased linearly with increasing level of CC from 20 to 30% (Paniraghi, 1992; McDonald *et al.*, 1995). Grower - finisher pigs have been fed diets containing CC at inclusion levels of 5 and 10% respectively without any adverse effect on performance (Lekule *et al.*, 1986). On the contrary, Lachance and Molina, (1974) stated that various graded levels (10, 20, and 40 %) of CC improved feed conversion ratio during the finisher and grower finisher periods.

Data from Kim *et al.*, (2001) suggested that 10% CC in the diet of pigs had been found to be satisfactory. The incorporation of CC above 10% and

possibly poor lysine availability have been found to be the main contributing factors for the decreased rate and efficiency of gain of pigs (Luis, 2002). In view of this, the maximum inclusion level of CC in the grower-finisher diet of pigs should not exceed 20%. The use of CC in the diet of pigs should be limited due to it susceptibility to rancidity (Mc Donald *et al.*, 1988).

Dried Cocoa Pod Husk (DCPH)

Cocoa pod husk is what remains after the beans have been removed from the cocoa fruit. The DCPH contains about 8.1% CP, 34.8% CF, 3.3% EE, 7.6% ash and 33.6% NFE (Okai *et al.*, 1994). The DCPH can present a serious disposal problem. In addition to this, it can become a serious source of disease innoculum when used as mulch in cocoa plantations (Kimura, 1979).

Grower and finisher pigs have been fed diets containing DCPH at inclusion levels of 30 to 50% without any adverse effect on performance (Arueya, 1991). In another study, the DCPH was fed without toxic effects in quantities of 2kg per day to grower-finisher pigs (Adeyanju *et al.*, 1975). The incorporation of 25% of DCPH in the diet of pigs did not significantly affect performance (Barnes *et al,* 1984 and Okai *et al.*, 1984). The content of theobromine as well as the low content of cystine and methionine appears to be the most important limiting factors to the use of this by-product. Theobromine inactivates digestive enzyme by the formation of enzymes complexes in the digestive tract (Owusu-Domfeh, 1972). Due to the presence of theobromine in cocoa cake, cocoa-cake-with-shell should not exceed 0.21% in the diets of pigs (Rhule, 2001).

Brewers' Spent Grains (BSG)

Brewers spent grains (BSG) is a by product from beer production. The material can be fed in the wet or dried form. It is bulky, especially when wet, low in energy but quiet high in crude protein (21 %) and crude fibre (20 %) on DM basis (Chenost and Mayer, 1977). Wet brewers spent grains (WBSG) has been used in feeding both ruminants and non - ruminants. The palatability of WBSG declines, with increasing storage time. However, brewer's dried grains usage is limited in monogastrics because of its high fiber (24 % ADF) content, so it is not normally used in intensive feeding systems. Brewers spent grains is a potential source of protein, especially where soybean and fishmeal are not available (Yaakugh and Tegbe, 1990).

High BSG levels in diets depressed feed intake and growth rate. It has also been shown that the bulky nature of BSG diets may adversely affect the digestibility as well as the availability of amino acids and other nutrients for pigs (Tebge 1985; Yaakugh and Tebge, 1990). The inclusion of brewers spent grains at up to 15% in the diets of pigs from weaning until slaughter at 92 kg had no significant effect on performance. In sows, inclusion rates up to 20% of BSG did not depress average daily gain or feed conversion efficiency. The BSG has been found to be satisfactory source of protein in most finishing pig rations (Amaefule *et al.*, 2006).

Soybean Meal (SBM)

Soybean meal (SBM) contains about 44.0% CP, 7.30% CF, 7.84% EE, 3.3% cellulose and 3.48% hemicellulose on DM basis (O' Doherty, 2001). Soybean meal has very high protein and energy digestibility and is considered good source of supplemental protein in diets for swine. It is often referred to

as the "gold standard" in that all other protein sources are generally compared to SBM. It has an excellent profile of highly digestible amino acids being a rich source of lysine, tryptophan, threonine, isoleucine and valine but low in methionine (Dunsford *et al.*, 1989; Li *et al.*, 1991; Makinde *et al.*, 1996).

Soybean meal can be used at levels of 10% in grower (30 to 65 kg) pig diets without affecting pig performance while they can be used at levels of 20% in finisher pig (65 kg) diets without affecting pig performance. A typical starter diet for nursery pigs may contain SBM at levels ranging from15 to 25% (O' Doherty and Keady, 2000; McKeon and O' Doherty, 2001). Soybean meal may contain anti-nutritional factors, which have been implicated with decreased growth performance of newly weaned pigs when fed directly (Li *et al.*, 1991). The inhibitors such as tannins, saponins and trypsin inhibitors are however, destroyed by heat, during the normal processing steps in preparing SBM. Due to the anti-nutritional factors and crude fibre content of soyabean meal, SBM should not exceed 40% in the diet of pigs (O' Doherty and Keady, 2000).

Rice Bran (RB)

Rice bran, a by-product in the processing of paddy rice, contains about 14.00% CP, 2-3% EE and 12.90% CF (Sikka, 1990). Rice bran actually is a mixture of the pericarp, seed coat and some of the aleurone layer. Rice bran is a good source of B-vitamins and is fairly palatable to pigs (Sikka and Chawla, 1984). Steyaert *et al.*, (1989) suggested that rice bran could be used up to 300 g/kg diet for broilers. Tiemoko (1992) reported that 300 g/kg rice bran diet for broilers, replacing maize, significantly ($P < 0.01$) improved liveweight gain while feed conversion efficiency was unaffected. The use of rice bran has also

been shown to reduce feed cost per kg weight gain. Rice bran has been found to contain a high level of dietary fibres (beta-glucan, pectin and gum), in addition, it also contains 4-hydroxy-3-methoxycinnamic acid (ferulic acid) which affects growth rate and digestibility in growing pigs and sows. Rice bran can be used as a replacement for WB and as a partial replacement for maize or the cereal component of the diet (Okai, 1998). The substitution of 20 or 30% RB for maize in a maize-soybean meal diet reduced weight gain and significantly reduced feed efficiency and carcass firmness (Steyaert *et al.*, 1989).

Rice bran can be used at levels up to 40% in grower-finisher pig diets without reducing performance. Good results have been reported when 30-40% RB was included in the diets of grower-finisher pigs (Campadadal *et al.*, 1976). It has also been observed that levels as high as 50% could be satisfactory for pigs (Tuah and Boateng, 1982). However, Tuah *et al* (1974) had earlier indicated that RB levels between 40 and 60%, when fed to finishing pigs reduced growth rate.

Wheat Bran (WB)

Wheat bran (WB) is a commonly used by-product. It serves as an energy source in the diets of non-ruminants. Wheat bran contains about 16% CP and 1322 Kcal ME/kg (NRC, 1998). Wheat bran is produced in large quantities as a by-product of the flour milling industry in Ghana. Wheat bran is not very digestible, however, its water holding capacity and the consequent slight laxative effect makes it particularly well adapted for use in pig rations. Its amino acid balance is superior to that of whole wheat but inferior to that of most protein supplements. Wheat bran is quiet high in phosphorus, but low in

calcium, so that a nutritional imbalance of calcium and phosphorus occurs, if WB is a major component of the diet (Pond and Maner, 1974; Okai *et al.*, 1995). It has been shown that WB is palatable and a good source of iron, manganese and Vitamin B complex (Ranjhan, 2001).

Wheat bran is regarded as a good feed ingredient and it is quite common to have diets containing at least 25%. Finishing pigs can be fed diets containing as much as 40% WB and even though there could be a significant decline in growth rate, carcass traits would be better and such diets are found to be cheaper and lead to reduction in feed cost per kg gain (Okai *et al.,* 2000). Wheat bran can be safely used for all classes of pigs and levels up to 30% can be included satisfactorily in diets for finishing pigs. Studies with finishing pigs indicated that growth performance and some carcass characteristics could be depressed significantly when WB level exceeded 40 per cent of the diet (McDonald *et al.*, 1988).

Okai *et al.,* 2000 fed wheat bran (WB) at WB20 (control), WB30 + Optizyme and WB40 + Optizyme inclusion level to grower-finisher pigs without any adverse effect on performance. The inclusion rate for the Optizyme was 50g/100 kg diet. The ADG were 0.60, 0.68, 0.63 kg/day respectively. The feed/gain recorded when growing-finisher pigs were fed WB20 (control), WB30 + Optizyme and WB40 + Optizyme were 3.19, 3.07, and 3.12 respectively. There were no significant differences ($P > 0.05$) between the observed means.

Changing Nature of Feeding Regimes for Pigs

Pig diets are composed mainly of grains, agro-industrial by-products (AIBPs), protein supplements, and mineral and vitamin supplements. The diet of pigs is normally formulated by computer programmes which match the composition of feed ingredients with diet specification to achieve the lowest cost of feed. The most frequently used grain in Ghana is maize; soya bean meal and fish meal as typical protein sources (Asiedu *et al.,* 2014).

Protein from leaves may also be compounded and fed to pigs in the form of leaf protein concentrate (Nguyen *et al.,* 2004). Several leaf meals made from shrubs have been used in pig diets and found useful (Ly *et al.,* 2001; Reddy *et al.,* 2004); and gliricidia leaf meal could be a potential source of protein in pig diets.

More recently, the growth of the animal feed industry has allowed considerable use to be made of agricultural by-products and wastes, some of which although containing potentially toxic components, can be safely included in compounded feeds in relatively low proportions. Various agro-industrial by-products (AIBPs) and other non-conventional feedstuffs have been evaluated in Ghana as potential feed ingredients for non-ruminant farm animals. Studies have been conducted on brewers' spent grain, cocoa pod husk, dried coffee pulp, mango kernel meal, oil palm slurry among others (Rhule *et al.*, 2007).

Feed and Growth Performance in Weaner Pigs

Feed is defined as the material which after eating by an animal is capable of being digested, absorbed and utilized; whilst growth may be explained as an increase in weight and size, associated with changes in shape,

until the pig reaches maturity (Mavromichalis, 2006). Commercialized production of feed involves use of ingredients that have high costs due to their competitive use between humans and animals. In Ghana, the cost of animal feed ingredients rises significantly from time to time (Rhule *et al.*, 2007). Furthermore, improvement in pig production through the use of non-conventional feed ingredients, especially protein sources have long been advocated (Nnadi *et al.*, 2007).

The term weaning is used for the moment piglets are separated from their mother; simultaneously, there is need to change their diet from milk to solid feed. In addition, weaning often involves a new environment and mixing of litters. In Ghana, it is observed that weaning of piglets may not occur before 28 days of age (Rhule *et al.*, 2007). The average age of weaning in Ghana is 42 days of age (Ingris, 2015). In nature, the weaning process occurs more gradually over a period, and finishes at about 14-16 weeks of age (Jensen, 1980). Piglets at weaning, are vulnerable to disease as they go through major changes in diet and environment, causing increased level of stress. Weight gain during first week post-weaning (PW) has major impact on subsequent growth performance (Kats *et al.*, 1992), and is therefore of particular importance in pig production.

High feed intake during the early post-weaning period is very important. It has been shown that low feed intake during the early post-weaning period severely limits growth potential, intensifies morbidity and mortality and reduce turnover of capital (Nnadi *et al.*, 2007). Weaner feed is designed to be fed during the suckling period through to approximately two weeks after weaning

(http://www.riverina.com.au/products/piglet-supastarter-crumbles-medicated/). In general, for every 100 g of extra feed per day consumed during the first week post-weaning, body weight increases by 1 to 2 kg at the end of the fourth week post-weaning. This has a dramatic effect on overall performance during the growing-finishing period as pigs that barely maintain their weaning weight during the first week post-weaning may require an extra 10 to 20 days to reach market weight compared to pigs that grow at their pre-weaning gain rates during the same period (Mavromichalis, 2013).

Early weaned pigs require about 300 g of dry feed per day, during the critical first week post-weaning to maintain their pre-weaning growth rate. Actual feed intake, however, rarely exceeds 200 g per day during this period, and this is barely enough to maintain body weight under thermo-neutral conditions. It has been shown that feed intake generally increases by enhancing the digestibility of the diet through the use of cooked cereals, milk proteins, fish meal, and simple sugars such as lactose and sucrose (Mavromichalis *et al.,* 2001); although such diets are more expensive than simpler diets (based on corn and soybean with a bit of whey), the benefits are tremendous in terms of improved performance and health during the whole growth period.

The inclusion of hatchery waste meal (HWM) in weaner diets was shown to have no significant effects on the feed-gain ratio of piglets fed different dietary inclusion levels (Adeniji and Adesiyan, 2007). In another experiment there was a decrease in feed intake as the levels of HWM in the diets increased (Belewu and Ologunleko, 1996). Piglets fed 7.5% HWM had similar ($p > 0.05$) final weight of 9.79 kg compared to those fed on 15%

HWM diet (7.77Kg). The piglets fed 22.5 and 30% HWM diets also had comparable (P>0.05) final body weight values of 6.09 and 4.97kg respectively. Piglets fed the control diets had a significantly higher (P<0.05) body weight gain (0.26 Kg) relative than those fed the HWM diets (Adeniji and Adesiyan, 2007). The body weight gain of the pigs fed HWM diets decreased as the levels of HWM in the diets increased (Adeniji and Adesiyan, 2007). Dhaliwal (1998) also reported that boths the body weight gains and feed conversion ratio revealed no statistically significant differences among different treatment groups when HWM replaced fishmeal at 0, 33.3, 66.6 and 100% levels in broiler rations.

Feed and Growth Performance of grower-finisher Pigs

The type of feed and method of feeding greatly influence the feed efficiency, growth rate, breeding efficiency, carcass quality and the general health of pigs. The choice of feeding periods for pigs is based entirely on nutritional and economic considerations (English *et al.*, 1988).

Feeding restriction is commonly practised with market pigs to improve carcass quality and feed efficiency, while decreasing production costs. *Ad-libitum* feeding, particularly if it involves feeds of high energy density, tends to promote synthesis of body fat which is inefficient in terms of feed conversion. Compared to *ad libitum* access to feed, a restricted feed allowance simultaneously reduces back fat thickness and intramuscular fat content (Wood *et al.*, 1996), whereas free access to a low-protein diet has the opposite effects (Karlsson *et al.*, 1993).

Feed-restricted pigs show decreased back fat thickness, low adipocyte volume and lipogenic capacity (Mersmann *et al.*, 1981; Leymaster and Mersmann

1991; Gondret and Lebret, 2002). The meat industry requires animals to be as lean as possible since pork meat with low fat content reduces human caloric intake and intramuscular fat is related to lower sensory quality traits (Fernandez *et al.*, 1999).

The elements which influence the capability of a pig to grow and the ultimate attainment of maximum size are fixed by heredity. However, other factors which may affect growth and performance of pigs are as follows; feed, sex, environmental temperature, management and stockmanship (Candek-Potokar *et al.*, 1998). Nutrition is an important factor determining whether optimum growth will be reached, and an optimum nutritional management is one which allows the organism to take full advantage of its heredity (English *et al.*, 1988). English *et al.*, (1988) reported that pigs within a liveweight range of 20 to 50 kg are able to grow at a rate of 900 g/day. According to Serres (1992), improved breeds of pigs can grow at a rate of 400 g/day following weaning, 500 g/day at 30 kg and over 600 g/day up to 40kg.

High level of carcass fat is, therefore, unacceptable because of the associated health problems. It is also convenient that breeding animals, particularly in the tropics, should not gain excessive weight because of the heat. Thus, Sudduth (2002) suggested increasing the feeding frequency as a management practice to alleviate the effects of heat on the animals. Under tropical conditions, it is therefore logical to adopt a restricted system of feeding. Restricted feeding involves a fixed amount of feed distributed to each pen or to each animal, in two or three meals daily (Serres, 1992). When feed intake is reduced below the maintenance level, pigs tend to become more efficient in digesting feed and in utilizing the nutrients (INRA, 1984).

Performance (weight gain, feed DM: gain, and protein efficiency ratio) was improved by twice compared with once daily feeding, but there was no difference between twice and thrice daily feeding (INRA, 1984). Table 4 show effects of once, twice and three times daily feeding on some performance traits in pigs.

Table 4: Mean values (with SE) for performance traits of the pigs given the same daily feed allowance once, twice or thrice daily

Feeding frequency	Once	Twice	Thrice
Number of pigs	16	16	16
Live weight (kg)			
Initial	16.30±0.03	16.25±0.04	16.38±0.02
Final	30.06±0.23^{b}	37.22±0.16^{a}	38.76±0.20^{a}
Daily gain	0.225±0.11^{b}	0.328±0.11^{a}	0.348±0.12^{a}
Feed DM intake (kg/day)	1.2±0.00	1.2±0.00	1.2±0.00
Protein intake (g/day)	204.0±0.00	204.0±0.00	204.0±0.00
Feed: gain	5.33±0.68^{b}	3.66±0.68^{a}	3.45±0.76^{a}
Protein efficiency ratio (PER)	1.10±0.14^{b}	1.61±0.11^{a}	1.71±0.21^{a}

Source: INRA (1984).

^{ab} Means on the same row having different superscripts are different at $p < 0.05$; PER is weight gain/ protein intake

Tengan *et al.*, (2012) fed varying levels of African Locust Bean fruit pulp (ALBP) to grower-finisher pigs and observed that the average daily

weight gain (ADWG) on the diet without ALBP (control diet) was significantly ($p < 0.05$) lower compared to pigs fed diets with ALBP. Olatidoye (2003) made a similar observation where feed intake decreased in grower pigs fed HWM.

Feed and Carcass Characteristics

The state of nutrition and the type of ingredients used in feeding pig have influences on their carcass characteristics. Pigs that are fully fed a concentrate diet, yield much fat in carcass and eventually, are less able to convert feed to meat that is lean than pigs fed slightly lower than *ad libitum* energy intake (Aberle *et al.*, 2001). Attoh-Kotoku *et al.*, (2007) fed maize bran to grower-finisher pigs and observed that, the chilled and warm dressing percentages, as well as the loin eye area, back fat thickness and carcass length were similar ($p > 0.05$) among pigs fed the 4 dietary treatments.

Carcass characteristics were not significantly affected ($p>0.05$) by the inclusion levels of gliricidia leaf meal (GLM) up to 7.5 % indicating that pigs can tolerate up to 7.5% dietary inclusion of GLM in their diets. However, the pigs fed 7.5 % GLM diet had slightly higher loin eye area, thigh and thymus gland as well as slightly lower warm, and chilled dressed weights, and backfat thickness compared to those fed 0 % GLM, 2.5% GLM and 5.0% GLM diet (Asiedu *et al.*, 2014).

Results obtained for carcass traits generally decreased with increase in the levels of whole hatchery waste meal (WHWM) included in the diet. Broilers fed with control diet (no WHWM) had highest mean values for eviscerated weight (2.20 kg) and dressing percentage (77.86%). There were no significant effects on eviscerated weights when cockerels were fed hatchery

waste meal diets (Abiola, 2001). Values recorded for abdominal fat and internal organs (liver, lungs, heart and gizzard) did not show any particular trend.

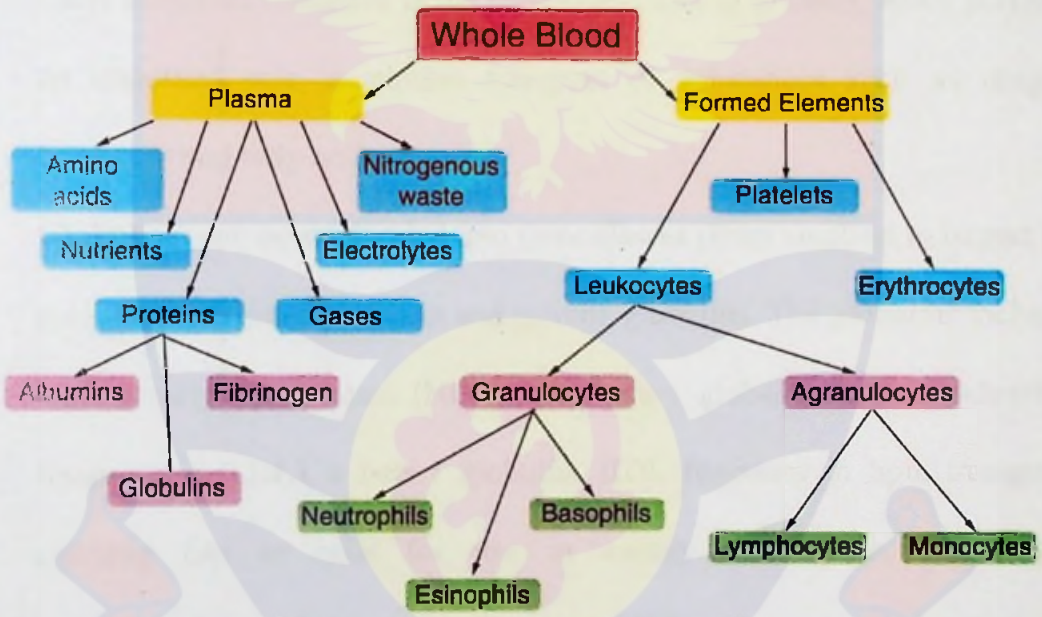
Armah *et al.*, (2008) reported that carcass parameters were similar ($p > 0.05$) among growing pigs fed dried cashew pulp (DCP) at varying levels. It has been established that maize bran has no negative influence on performance (growth and carcass trait characteristics) of growing pigs (Attoh-Kotoku *et al.*, 2007).

Blood and its Composition

Blood is a fluid that transports oxygen and nutrients to the cells and carries away carbon_dioxide and other waste products. According to Isaac *et al.*, (2013), blood is a vital and special circulatory tissue which is composed of cells suspended in a fluid intercellular substance (plasma) with the main purpose of maintaining homeostasis. Lewis *et al.*, (2002) defined blood as a complex mixture that has several functions in the body. It is composed of 17-18% protein and 75-82% moisture; whereas haemoglobin, a protein found in red blood cells, makes up approximately 70% of total blood proteins (Leoci, 2014).

The blood in pigs varies with age, sex, weight, body type, and other factors; but a rough average figure for a mature pig is about 60 millilitres per kilogram of body weight (Lewis *et al.*, 2002). An average young animal has a plasma volume of about 35 millilitres and a red blood cell volume of about 30 millilitres per kilogram of body weight. There is little variation in the blood volume of a healthy pig over long periods, although each component of the blood is in a continuous state of flux. The normal volume of blood provides

such an adequate reserve that appreciable blood loss is well tolerated. Withdrawal of 500 millilitres (about a pint) of blood from normal blood donors is a harmless procedure. Blood volume is rapidly replaced after blood loss and within hours, plasma volume is restored by movement of extravascular fluid into the circulation system. Replacement of red cells is completed within several weeks (Lewis *et al.,* 2002). Figure 1, is a schematic drawing indicating various components of blood.



Source: *Isaac et al., (2013)*

Figure 1: Composition of normal blood.

The medium of blood is liquid plasma that has several suspended or dissolved biochemical substances. Blood plasma comprises more than half of the volume of blood, which is 90-92% water and 1% dissolved molecules comprising of nutrients, salt, hormones, gases and metabolic waste (Lewis *et al.*, 2002). Blood plasma also contains 7 - 8% dissolved proteins of about 70 different types. Protein concentration in the plasma at a given time is a function of hormonal balance, state of health, water balance and nutritional

status (Lewis *et al.*, 2002). There are three major categories of plasma proteins and each type of protein has its own specific properties and functions in addition to their overall collective roles:

i. **Albumins:** are the smallest and most abundant plasma proteins. Reductions in plasma albumin content can result in a loss of fluid from the blood and a gain of fluid in the interstitial space (space within the tissue); this may occur in nutritional, liver and kidney disease. Albumin also helps many substances dissolve in the plasma by binding to them, hence playing an important role in plasma transport of substances such as drugs, hormones and fatty acids.

ii. **Globulins:** can be subdivided into three classes (from smallest to largest in molecular weight) alpha, beta and gamma globulins. The globulins include high density lipoproteins (HDL), an alpha-1 globulin, and low-density lipoproteins (LDL), a beta-1 globulin. HDL functions in lipid transport carrying fats to cells for use in energy metabolism, membrane reconstruction and hormone function. HDLs also appear to prevent cholesterol from invading and settling in the walls of arteries. LDL carries cholesterol and fats to tissues for use in manufacturing steroid hormones and building cell membranes. It also favours the deposition of cholesterol in arterial walls and thus appears to play a role in disease of the blood vessels and heart. High density lipoproteins and LDL therefore play important roles in the regulation of cholesterol and hence, have a mark impact on cardiovascular disease (Hoffman and Monroe, 2001).

iii. **Fibrinogen:** is a soluble precursor of a sticky protein called fibrin, which forms the framework of a blood clot. Fibrin plays a key role in coagulation of blood (Lewis *et al.*, 2002).

iv. **Red blood cells (RBC):** also known as erythrocyte, it ensures appropriate pH and cation concentration differentials between the RBC and the plasma (low potassium, high sodium and calcium), an adequate area to volume ratio, fluidity and osmolarity (Mohandas and Chasis, 1993). Lewis *et al.*, (2002) and Frandson and Spurgeon (1992) reported that their precursor forms are found and produced within red bone marrow at a rate of 2 - 3 million per second. A mature red blood cell has no nucleus and therefore cannot carry out metabolism. Red blood cells that are mature are biconcave, disc-shaped and filled with heamaglobin. Red blood cell carries carbon dioxide away from the tissues and oxygen to the tissues because of the presence of heamoglobin. Normal body pHs of fluid is also maintained by red blood cell, and help sustain the specific gravity and viscosity of blood (Bone, 1988). The lack of a nucleus means that RBCs are unable to repair themselves. However, the resulting biconcave shape means that the cell has a greater ratio of surface area to volume, enabling oxygen (O_2) and carbon dioxide (CO_2) to diffuse quickly to and from haemoglobin (Hb).

v. **White blood cells (WBCs):** are also known as leukocytes. They can be divided into granulocytes and agranulocytes. The cytoplasms of the WBC contain organelles that appear as coloured granules by way of light microscopy, hence their name. Granulocytes consist of neutrophils, eosinophils and basophils. In contrast, agranulocytes do not contain granules. They consist of lymphocytes and monocytes. Leukocytes (WBC)

are not as many as the red blood cell in circulating blood (Swenson, 1970). The types of white blood cells that exist in order of abundance in normal organisms are five. They are lymphocytes, neutrophils (T cells and B cells), basophils, monocytes and eosinophils (Lewis *et al.*, 2002).

vi. **Thrombocytes or Platelets:** Platelets are small and colourless cell fragments in mammals that live for about 1 week and initiate the clotting process of blood. Platelets originate as part of a huge bone marrow cell called a megakaeryocyte (Lewis *et al.*, 2002). They secrete factors that increase local platelet aggregation, enhance vasoconstriction and promote blood coagulation. Platelets are small fragments of bone marrow cells and are therefore not really classified as cells themselves. Platelets have the following functions:

a. Secrete vasoconstrictors which constrict blood vessels, causing vascular spasms in broken blood vessels
b. Form temporary platelet plugs to stop bleeding
c. Secrete procoagulants (clotting factors) to promote blood clotting
d. Dissolve blood clots when they are no longer needed
e. Digest and destroy bacteria
f. Secrete chemicals that attract neutrophils and monocytes to sites of inflammation
g. Secrete growth factors to maintain the linings of blood vessels

The first three functions listed above refer to important haemostatic mechanisms in which platelets play a role during bleeding namely, vascular spasms, platelet plug formation and blood clotting (coagulation).

According to Swenson (1970), parameters that are often measured under haematological profile are red blood cell (RBC) and white blood cell (WBC) counts which deal with the number of RBC and WBC in a given sample of blood. Others are packed cell volume (Haematocrit) referring to the volume of packed red blood cells in the sample, mean cell volume (MCV), mean cell haemoglobin concentration (MCHC) and mean cell haemoglobin (MCH). These parameters give the average proportion of the mean cell size (MCV) occupied by the haemoglobin (Hb).

Relationship between Nutrition and Blood Parameters

The function of the haematological constituents is to enable the animal to respond physiologically to its external and internal environments. In other words, haematological profile reveals the manner and way the animal reacts to its environment externally and internally, which include feeding and feed (Esonu *et al.*, 2001). Haematological analysis involves the determination of different blood parameters which can be done using either electronic quantification or manual version (Etim *et al.*, 2013). Haematological studies have been found useful for disease prognosis and for therapeutic and feed stress monitoring (Togun and Oseni, 2005). As reported by Togun *et al.*, (2009), haematological studies represent a useful process in the diagnosis of many diseases as well as investigation of the extent of damage to blood.

Ovuru and Ekweozor (2004) and Isaac *et al.*, (2013) stated that haematological studies are of ecological and physiological interest in helping to understand the relationship of blood characteristics and the environment. Haematological parameters are those parameters that are related to the blood and blood forming organs (Waugh and Grant, 2001; Bamishaiye *et al.*, 2009).

Haematological parameters are good indicators of the physiological status of animals (Khan and Zafar, 2005). As reported by Isaac *et al.*, (2013), animals with good blood composition are likely to show good performance. Madubuike and Ekenyem (2006) reported that serum biochemical and haematological assay of livestock show the physiological status of the animal to their nutrients.

It is therefore, always possible to take blood samples from animals and analyze these to find out if a feedstuff has had any undesirable influence on the animal's physiology or blood profile (Iheukwumere and Herbert, 2002). Nutritional status of an individual is independent of dietary intake and effectiveness of metabolic processes; and it can be determined by combinations of clinical, anthropometric, biochemical or dietary methods (Bamishaiye *et al.*, 2009). Dietary contents affect the blood profile of healthy animals (Odunsi *et al.*, 1999; Yeong, 1999; Kurtoglu *et al.*, 2005; Iheukwumere and Herbert, 2002).

According to Oyawoye and Ogunkunle (2004), haematological components, which consist of red blood cells, white blood cells or leukocytes, mean corpuscular haemoglobin and mean corpuscular haemoglobin concentration, among others, are valuable in measuring toxicity as well as the physiological and health status of farm animals. Afolabi *et al.*, (2010) posited that changes in haematological parameters are often used to determine stresses due to nutrition and other factors. Pig farmers feed their animals with various feed products without recourse to the health and physiological implications on the animals (Etim *et al.*, 2014). It thus, becomes imperative to pay attention to the quality of feed fed to livestock (Okunnade *et al.*, 2000). Haematology

remains the commonest parameter for measuring these implications (Aro *et al.*, 2012; Etim *et al.*, 2014a).

Functional Relationship between Nutrition and Haematology

Blood of animals might be influenced by certain factors such as nutrition, among others (Odunsi *et al.*, 1999). Addass *et al.*, (2012) reported that nutrition affects the blood of animals. Dietary contents affect the blood profile of healthy pigs (Kurtoglu *et al.*, 2005; Iheukwumere and Herbert, 2002). Diets have been established to have measurable effects on blood components and the latter in turn are widely used in nutritional evaluation and survey of animals (Church *et al.*, 1984; Olajide *et al.*, 2009).

A readily available and fast means of assessing clinical and nutritional health status of animals on feeding trials may be the use of blood analysis, because ingestion of dietary components have measurable effects on blood composition (Church *et al.*, 1984; Maxwell *et al.*, 1990) and may be considered as an appropriate measure of long term nutritional status (Olabanji *et al.*, 2007). The blood transports or conveys nutrients and materials to different parts of the body. Therefore, whatever affects the blood, such as nutrition, will certainly affect the entire body adversely or moderately in terms of growth, maintenance and reproduction (Oke *et al.*, 2007; Ajao, 2013).

Haematological investigations have been explored extensively to distinguish normal state from stress (Olajide *et al.*, 2009), which could be nutritional stress. Isaac *et al.*, (2013) stated that haematological components which consist of red blood cells, white blood cells or leucocytes, mean corpuscular haemoglobin and mean corpuscular haemoglobin concentration

are valuable in monitoring feed toxicity, especially with feed constituents that affect the blood as well as the health status of farm animals.

Etim *et al.,* (2014) documented that haematological traits, especially Packed Cell Volume (PCV) and haemoglobin, were correlated with the nutritional status of the animal. Isaac *et al.,* (2013) reported that PCV is involved in transport of oxygen and absorbed nutrients. Haematological changes are routinely used to determine the various influences of nutritional factors (Garacyk *et al.,* 2003). The comparison of blood profile with nutrient intake might indicate the need for adjustment of certain nutrients upward or downward for different animal groups (Rafiu *et al.,* 2013; Etim *et al.,* 2014a).

Haematological Standards for Pigs and their Implications

Haematological values could serve as baseline information for comparison in conditions of nutrient deficiency, physiology and health status of farm animals (Daramola *et al.,* 2005). Furthermore, it has been shown that haematological values of farm animals are influenced by nutritional status and other factors (Church *et al.,* 1984; Aro, and Akinmoegun (2012). As pigs are consumed and also used more frequently as medical models for human diseases, having reference intervals for commonly measured haematological parameters will be useful as it will aid in diagnosis and monitoring of nutritional status of animals on feeding trials (Maxwell *et al.,* 1990; Olayeni *et al.,* 2006; Etim *et al.,* 2014a). According to Togun and Oseni (2005), it would also be useful for feed stress monitoring. The normal ranges of values for pigs are shown in Table 5.

Table 5: Reference Haematological Values for Pigs

Parameters	Range of Values
WBC (10^3/µl)	11.0 – 22.0
Neutrophils (10^3/µl)	28.0 – 51.0
Lymphocytes (10^3/µl)	39.0 – 62.0
Monocytes (10^3/µl)	2.0 – 10.0
Eosinophils (10^3/µl)	0.5 – 11.0
Basophils (10^3/µl)	0.0 – 2.0
RBC (10^6/ µl)	5.0 – 8.0
Hgb (g/dl)	10.0 – 16.0
PCV (%)	32.0 – 50.0
MCV (fl)	50.0 – 68.0
MCH (pg)	17.0 – 21.0
MCHC (g/dl)	30.0 – 34.0
Platelets (x1000)	325 – 715
MPV (fl)	5.0 – 20.0

Adapted from: Coronado (2014)

Research Animal Resources (2009) documented values that they were subjectively averaged from a variety of sources. There appears to be a great range of values reported which may be accounted for by variations in age, sex, breed or strain, sampling techniques and testing methodology. As such, the range limits are not firm boundaries and should be used only as guidelines (RAR, 2009; Etim *et al.*, 2014b). Table presents a range of values that can be used as reference guide for pigs (RAR, 2009; Etim *et al.*, 2013)

Table 6: Reference Haematological Values for Pigs

Parameters	Range of Values
PCV (%)	32 – 50
Hgb (g/dl)	10.0 – 16.0
MCV (fl)	50 – 68
MCH (pg)	17 – 23
MCHC (g/dl)	30 – 36
WBC (x1000)	7 – 20
Differential Count (%)	
Lymphocytes (10^3/µl)	40 – 60
Monocytes (10^3/µl)	2 – 10
Eosinophils (10^3/µl)	0 – 10
Basophils (10^3/µl)	0 – 2

Adapted from: Research Animal Resources (2009)

Togun *et al.*, (2007) observed that an increase in PCV, coupled with marginal increase in RBC, is indicative of more efficient erythropoiesis. Nwanbe and Elechi (2009) reported that lower values of PCV and Hb imply high level of blood dilution and low efficiency of cellular oxygen transportation. According to Togun *et al.*, (2007), when haematological values fall within the normal range reported for the animal, it is an indication that diets did not show any adverse effect on haematological parameters during the experimental period. On the other hand, when the values fall below the normal range, it is an indication of anaemia. As reported by Bawala *et al.*, (2007), low values for haematological parameters could be due to the harmful effects of

high levels of dietary contents. Copland (1976) stated that the usual cause of lower values in pigs is thought to be due to malnutrition.

Immune status is reported to be a function of leucocytes, neutrophils and lymphocytes (Nwanbe and Elechi, 2009). Lymphocytes are known to play key roles in immune defense system of both humans and animals (Ameen *et al.,* 2007). According to Copland (1976), significantly higher leucocyte count of pigs is thought to be due to chronic pneumonia and parasitism. According to Ameen *et al.,* (2007), when WBC, neutrophils and lymphocytes fall within the normal range, it indicates that the feeding pattern do not affect the immune system.

Eheba *et al.,* (2008) posited that a decrease in WBC count, however, reflected a fall in the production of defensive mechanism to combat infection. Togun *et al.,* (2007) reported that a significantly lower lymphocyte count was an indication of a reduction in the ability of the experimental animals to produce and release antibodies when infections occur.

Some Blood Biochemical Indices of Pigs

The study of biochemical profile of blood has received great significance as it serves as valuable guidelines in evaluating the nutritional adequacy of the diet and health status of the animal (Kurtoglu *et al.,* 2005). It was also reported that the dietary contents affect the blood profile of healthy animals (Iheukwumere and Herbert, 2002; Ogbuewu *et al.,* 2008). The ranges quoted for biochemical values in cattle, sheep, goats and pigs are shown in Table 7.

Table 7: Ranges in Serum constituents (conventional units) for Cattle, Sheep, Goats and Pigs.

	Cattle	Sheep	Pigs	Goats
Electrolytes				
Sodium (mEq/L)	132-152	145-152	140-150	135-156
Potassium(mEq/L)	3.9-5.8	3.9-5.4	4.7-7.1	3.4-156
Chloride (mEq/L)	95-110	95-103	95-103	98-110
Osmolality(mOsmol/kg)	270-306	-	-	-
Minerals				
Calcium, total (mg/dL)	9.7-12.4	11.5-13.0	7.1-11.6	9.2-11.6
Calcium, ionised (mg/dL)	4.8-6.2	5.7-6.5	3.5-5.8	-
Phosphorus (mg/dL)	5.6-6.5	5.0-7.3	5.3-9.6	4.0-11.2
Magnesium (mg/dL)	1.8-2.3	2.2-2.8	1.1-1.5	3.5-5.2
Iron (µg/dL)	57-162	166-222	73-140	-
Renal function				
Urea nitrogen (mg/dL)	6-27	10-35	10-30	12-26
Creatinine (mg/dL)	1-2	1.2-1.9	1.0-2.7	0.6-1.6
Liver function				
Total bilirubin (mg/dL)	0.01-0.5	-	-	-
Direct (conjugated) bilirubin (mg/dL)	0.04-0.44	-	-	-
Metabolites				
Cholesterol (mg/dL)	65-220	43-103	28-48	-
Free fatty acids (mg/dL)	>30	30-100		-
Glucose (mg/dL)	45-75	50-80	85-150	-
Ketones				
Lactate (mg/dL)	5.0-20.0	9.0-12.0	-	-
Triglyceride (mg/dL)	0-14.0		-	-
Enzymes				
Alanine aminotransferase (ALT)	11-40	22-38	31-58	-

(units/L)				
Alkaline phosphatase (units/L)	0-500	70.0-390	120-400	0-300
Aspartate aminotransferase (AST) (units/L)	78-132	60-280	32-84	0-300
Creatine kinase(units/L)	35-280	-	-	0-100
Protein				
Total protein (g/dL)	5.7-8.1	6-7.9	3.5-6	6.2-7.9
Albumin (g/dL)	2.1-3.6	2.4-3	1.9-2.4	2.9-4.3

Source: Merck Manual, 2017

Need for Alternative/Non-Conventional Feed Stuffs for Pigs

The increasing cost of feedstuffs mainly protein and energy sources has been a serious limitation to the survival of the livestock industries in Ghana and other developing countries (Okai *et al.*, 2000). There is the need to therefore shift attention towards the use of other feedstuffs or non-conventional feed ingredients that may be available but not widely used locally. Most of these non-conventional feed ingredients may be considered currently as waste, and are therefore comparatively cheaper, as compared to conventional feedstuffs.

The free range pig is observed feeding on a wide range of items, from herbage to rejected agro-by-products. Agro-industrial by-products (AIBPs) and other palatable waste materials can be used to replace important feed ingredients either totally or partially. They are seen as a way of resolving the high cost of conventional feedstuffs which are scarce, thereby supporting the livestock industry. Their usage must however be done with care. According to Myer and Hall (2004), the following must be considered when using edible

waste or by-products as an alternative feed source: it must not have bad influence on the end products of the animals; it should be free from possible health hazards like aflatoxins; it must be palatable to the animal; it must be available and easy to obtain; information on the content of nutrient must be well-known; and processing, handling, and storage should not involve additional costs.

There are a lot of edible wastes and agro-industrial by-products that are yet to be evaluated and used as possible feed for livestock. Hatchery waste is one of such untapped by-products available in Ghana. The waste is usually rejected after the hatch. Disposing of the waste has become a problem in some communities. Nutritional information on the hatchery waste meal is scanty, particularly on its value for pigs. Also, it is foreseen that if the nutritive potentials of hatchery waste meal and other by-products are established, another Non-Conventional Feed Resource will be made available and at a relatively cheap cost. It will also eradicate the problems of disposal of most of these by-products. Because of the relatively low cost of these by-products, farmers will be encouraged to use them and therefore, decrease the cost involved in pig production in Ghana.

Hatchery Waste as a Potential Feed Ingredient in Pig Rations in Ghana

Animal protein sources are known to be superior to those of plant origin because of their higher biological value (Khan *et al.*, 2005). The potential of recycling waste of animal origin such as hatchery by-products have been well documented (Abiola, 2000). A number of studies have revealed that hatchery waste meal can be utilized as feedstuff in poultry diets because of high nutritional value. The proximate composition and nutritive

value of unhatched incubator eggs were evaluated by Abiola and Onunkwor (2004). The chemical composition of sun-dried un-hatched incubator eggs (UIE) is presented in Table 8.

Table 8: Chemical composition (g/kg) of dried un-hatched incubator eggs

Parameters	Composition (g/kg)
Crude protein	560
Crude fibre	18.5
Ether Extract	180.5
Nitrogen free extract	240
Calcium	10.4
Phosphorus	0.1
Metabolizable Energy (kcal/g)	3.95

Source: Abiola and Onunkwor (2004)

Raw hatchery waste can be cooked with water at a 2:1 ratio for 15 minutes and then oven-dried at 65 ^{0}C. Hatchery waste meal prepared contains about 32% crude protein, 16% ether extract, 0.9% crude fibre, 40% total ash, 11.1% nitrogen free extract, 20% calcium and 0.6% available phosphorus with no *Escherichia coli* and Salmonella (Tymoczko *et al.*, 2002; Khan *et al.*, 2005).

Challenges Associated with Disposal of Hatchery Waste

The cost for an average hatchery to dispose of their waste in Australia is high (Aus$127/tonne and 10.4 tonnes per week) (Khan *et al.*, 2005). In other countries, the cost is greater due to reduced areas available for landfill. The current world population of chickens is approximately 8 billion birds; 90% of these chickens are hatched in commercial hatcheries (Myer and Hall,

2004). The volume of hatchery waste that needs to be disposed of yearly is in the millions of tonnes. Disposing of hatchery waste in land fill sites causes environmental problems such as releasing methane into the air and possibly microbial contamination. It is likely that hatcheries in the future will not be permitted to dispose hatchery waste into landfill. Sustainability of these hatcheries is threatened and the challenge is to design a system that converts waste on site to valuable products which can be used on site or sold (Khan *et al.*, 2005).

The real challenge for the poultry industry in general is to turn all the waste into economically-valuable products, using low-cost treatment systems. The huge volume of waste generated by the industry needs to be treated, using bioprocesses, to produce feed ingredients, fertiliser and fuel. These processes need to be applied to the organic waste streams (e.g. poultry manure, hatchery waste) and turn the cost of waste disposal into a source of income, recycled nutrients and reduce pollution. This can be achieved by characterising and separating waste, developing products, designing systems, and providing risk assessment and quality control. These approaches enable maximum conversion of carbon, nitrogen, phosphorus, and water in waste streams into biofuels and agri-products, while at the same time achieving pathogen and odour control (Khan *et al.*, 2005).

Management of Hatchery Waste

The majority of hatcheries use a vacuum extraction system to transfer the waste into bins. Some hatcheries store the waste in a cool room and then place the waste into a Bio-Bin. Other hatcheries will crush the waste first, then use a vacuum or auger system to transfer waste into the bin (Glatz and Mioa,

2009). In the USA, one disposal option is to transport the hatchery waste to a facility that separates the liquids from the solids by using a centrifuge (Cawthon, 1998). The liquid is refrigerated and transported to a pet food manufacturing plant; the solids are sent to land fill.

Separation of Waste at the Hatchery

Hatchery waste can be separated into solid and liquid components and then treated separately. For example, the liquid in hatchery waste can be separated from the solid hatchery waste by spinning (Philips, 1996; Schilling and Mintz (1998). In addition, inclined screens, followed by the use of belt or filter presses can be used for separation of solid and liquid portions of the waste. These methods produce about 45% of solid materials (Van Slyke *et al.*, 2011). In other industries, a flexible multi-layer filter can be used to separate liquid wastes from sludge wastes. The principle of this process relies on liquid waste passing through the liner into the container by gravity (Philips, 1996). Another system for separating liquid and solid waste is to use a conveyor with an upper and lower conveyor roller and an endless conveyor belt extending around the conveyor rollers. A waste deflector extends above and along the lowest portion of the upper run. Liquid and solid wastes are separated and placed in collectors which are located near the upper and lower rollers (Van Slyke *et al.*, 2005).

Processes of Improving Hatchery Waste Utilization

One approach to improve utilization of hatchery waste by pigs is through the use of simple processing techniques. This may be achieved in several ways; for example, through enhanced processing. Hatchery waste can

be processed into useful feed ingredients by dehydration, boiling, toasting, drying, autoclaving, grinding and irradiation (Abiola *et al.*, 2004).

i. Boiling/ Cooking and Drying

Hatchery waste could be treated in the same way as poultry waste (feathers, heads, intestine, lung, spleen) by boiling at 100 °C with a pressure of 2.2 kg/ cm^2 for 15 min; then boiled again at 100 °C for 5 hours; followed by boiling at 130 °C for 1 hour; thereafter it is cooled to ambient temperature (Kirkpinar *et al.*, 2004). Likewise, dead embryos could be boiled at 100 °C for 30 min, soaked in cold water for 20 min to remove shells, sun-dried for 4days, and used in poultry feed (Abiola and Onunkwor, 2004). Cooking hatchery waste with water (at 2:1 ratio), then dehydrating to a dried product to be used as livestock feed (Rasool *et al.*, 1999; Sohail & Bashir, 2002). Nutritive value of the dried dead embryos so treated was 36% CP, 27% ether extract, 17% ash, 10% calcium and 0.6% phosphorus (Kirkpinar *et al.*, 2004).

ii. Ensiling

Kompiang (1994) reported a method of ensiling rejected hatchery eggs. The eggs were mixed in a 1:1 ratio with formic and propionic acids for 8 weeks, at room temperature. Formic acid is suitable for the ensiling of materials such as wet and protein-rich resources. Propionic acid and formic acid have been used to preserve and ensile non-fertile eggs as well as dead embryos. These acids act by intervening specifically in the metabolism of the microorganisms involved in spoilage. In addition, the reduction in pH creates an environment which is unfavorable for growth of microorganism. The rapid reduction in the pH diminishes the growth of bacteria which produce butyric acid and ammonia, and promotes the growth of lactic acid-producing bacteria.

The lactic acid is responsible for the low pH necessary for storage of the by-product before being used in animal feed.

iii. **Enzyme or Sodium Hydroxide Treatments**

Kim and Patterson (2000) treated culled birds for 12 h at 21 °C with 25.6 mg of INSTAPRO enzyme; or for 2h at 21 °C in 0.4 N NaOH. The resulting product was fermented (with added sugar) for 21 days. After fermentation, the products were autoclaved at 124 kPa and 127 °C for 90 min, then dried in a forced-air oven at 60 °C, and the final product was used as poultry feed. The advantage of the enzyme or NaOH treatment is that nutrients in poultry meal are more readily digestible by birds and improve the availability of essential amino acids in the treated meal.

iv. **Composting**

Composting is a common method for solid organic waste disposal (Imbeah, 1998; Cambardella *et al.*, 2003). In this process, mesophilic and thermophilic micro-organisms convert biodegradable organic waste into a value-added product (Lau *et al.*, 1992; Liao *et al.*, 1993; Imbeah, 1998). The decomposition of organic waste is performed by aerobic bacteria, yeasts and fungi. The composting process kills pathogens, converts ammonia nitrogen to organic nitrogen and reduces the waste volume (Imbeah, 1998; Volterra and Conti, 2000); the product can be used as a fertiliser. Disadvantages of composting are loss of some nutrients, including nitrogen, the large land area required for the composting, and odour problems. Das *et al.*, (2002) reported that composting hatchery waste with sawdust and yard trimming (in a ratio of 3:2:1) or composting it with sawdust, yard trimmings and poultry litter (in a ratio of 2:1:1:2) eliminated 99.99% of E. coli. Composting with litter also

eliminated Salmonella; but Salmonella was present if temperature was too low. When hatchery waste is composted with poultry litter it will produce a safe and rich organic product which is a good organic fertiliser.

It is important to control the moisture content and keep raising the temperature of the compost to eliminate the pathogens. Composting hatchery waste with poultry litter produces a product that contains 1% nitrogen, 2.5% phosphorus and 0.25% potassium, on a dry weight basis. The product also contains high calcium and other micro-nutrients (MAF, 1996). A potential method for treating hatchery waste on a hatchery site is to use an 'in-vessel' composting technique to decompose and stabilize the un-separated hatchery waste obtained directly from the hatchery. The hatchery waste can be mixed with wood shavings to reduce the moisture before it is composted (Cawthon, 1998).

Hatchery waste was successfully amended with sawdust and yard trimmings, and in one treatment, with poultry litter (broiler), to determine the feasibility of composting hatchery waste. Hatchery waste co-composted with poultry litter maintained higher temperatures during the experiment, resulting in higher dry matter and volatile solids and greater losses of nitrogen, by the end of the composting process. The composted product containing poultry litter had higher levels of plant nutrients such as P, K, and many of the other micro nutrients than the product without poultry litter. Both treatments were effective in eliminating 99.99% of *Escherichia coli*; however, more Salmonella reduction was observed in the treatment containing poultry litter than the treatment without poultry litter (Das *et al.*, 2002; Veerabadran, *et al.*, 2012).

v. **Toasting**

Rasool *et al.* (1999) toasted hatchery waste without any addition of water. The toasting of waste was carried out in an open vessel at temperature of 100 ^{0}C, with regular stirring. The resultant meal revealed that it contained 44.25 % crude protein, 30.01 % ether extract, 1.90 % crude fibre, 14.04 % ash, 9.80 % nitrogen free extract, 4572 kcal/kg (gross energy) and 3600 kcal/ kg (metabolizable energy).

All the previously mentioned processing techniques clearly indicated that the application of appropriate methods not only destroys the pathogens but also enhances the keeping quality as well as palatability of the waste material. Properly processed hatchery wastes have no undesirable effects on birds' health because processing techniques not only minimize the harmful pathogens but also improve the nutritional quality of the waste material. Biological evaluation of processed Hatchery Waste Meal (HWM) is determined by their protein and energy qualities. Protein quality is perhaps the most important single factor, demanding serious consideration when formulating poultry rations (Khalique and Rasool, 1998).

Utilization of Hatchery By-Products

Hatchery by-product meal is hatchery waste consisting of a mixture of egg shells, infertile and un-hatched eggs, and culled chicks (Freeman, 2008; Al-Harthi *et al.*, 2010). Hatchery by-product meal from layer type has a higher protein level than that from broiler chick hatcheries because males are culled from layer type chicks and go into the by-product. As a result of the high calcium content, hatchery by-product meal should be limited to no more than 3% of the diet of growing-finishing pigs and sows (Thaler and Holden, 2010).

At this level, it will replace the lysine in 2% of soybean meal and supplemental calcium.

Waste products from the poultry processing and egg production industries must be efficiently dealt with, as the further growth of these industries depends largely on waste management (Jayathilahan *et al.,* 2012). The intensive and large-scale production of food animals and animal products has generated an enormous disposal problem for the animal industry (Freeman, 2008). These wastes, including animal excreta, hair, feathers and processing wastes are convertible to useful resources (Thaler and Holden, 2010).

An efficient, thermophilic and anaerobic digester system that converts animal manure to methane has been reported by Shih (1993). A feather-degrading bacterium, *Bacillus licheniformis*, which can ferment and convert feathers to feather lysate, a digestible protein source, for feed use. An enzyme, keratinase, secreted by this bacterium, was purified and characterized. The keratinase is a potent proteinase that hydrolyses collagen, elastin and feather keratin. Urlings *et al.,* (1993) studied the proteolysis and amino acid breakdown of heated and irradiated poultry by-products of muscle tissue and concluded that during processing of poultry meat and poultry wastes, enzymic activity has to be reduced or eliminated to ensure safe and high quality products. The main by-products from the poultry industry are un-hatched incubator eggs, egg shells, dead-in-shell, culled chicks, infertile eggs, feather meal and blood meal (Thaler and Holden, 2010).

Composition of Hatchery Waste and its Use as Feed

Composition of HW as reported in the literature shows quite a wide variation in content of nutrients. This is understandable, as different authors had inputs that varied widely, i.e. shells, infertile eggs, dead-in-shell, dead chicks etc. Some reported values nutrient content of hatchery waste meal (HWM) with shell are: CP of 16.83 % to 18.17 % (Urlings *et al.,* 1993); a high protein waste with 43–71% moisture (Hamm *et al.,* 1992). Dried hatchery waste contains 33.1% crude protein (CP), 29.0% ether extract, 12.1% crude fibre, 21.5% ash and 28.8 MJ/kg of gross energy (Sharara *et al.* 1993a). Apparent metabolisable energy (AME) of hatchery waste by-product meal was quoted at 23.9 MJ/kg, and its apparent amino acid availability of the by-product meal was 73.5% (Sharara *et al.,* 1992b). On the other hand, Rasool *et al.,* (1999) reported 44. 25% CP for hatchery waste meal fed to broilers.

Additionally, Abiola *et al.,* (2004) reported 58% - 59.3% crude protein, 5.1% - 4.4% ash content for different batches of hatchery wastes. Hatchery by products (candled out eggs, egg shell and dead in embryo) have high protein content and can be processed into useful energy and protein feed stuff (Reddy, 1985). According to Cox & Braden, (1999). it is a useful and economical source of nutrients, especially during feedstuff shortages which will also reduce pollution and its attendant consequences on the climate. Shelton *et al.,* (2001) reported that hatchery waste meal has been found to be a good source of protein, energy and minerals, especially phosphorus and calcium. Its calcium-phosphorus ratio is 2:1 which favours the bio-availability of the minerals (Reddy, 1988).

Some of the authors observed that rations containing hatchery waste meal elicited better performance in terms of weight gain and feed efficiency in broilers fed 12 % HWM than those fed similar amount of fish meal.

However, a couple of studies using HWM in pig diets have shown a decrease in average daily live weight gain (Orozco-Hernandez *et al.,* 2003). Kim and Easter (2001) also reported that the apparent digestibility of poultry meal and growth response in young pigs could vary depending on the temperature used in drying the meal.

Utilization of Un-hatched Incubator Eggs

Discarded eggs from candling stations, culled eggs and chicks from hatcheries, are by-products of the egg industry. Bloodspot eggs from egg candling stations are often available at little or no cost. Eggs including the shell contain 60% moisture, 10% protein, 9% fat, 6% calcium, 0.2% phosphorus, and 0.7% lysine. Thaler and Holden, (2010) reported that, finishing pig in which one-third of the dietary energy was from eggs demonstrated satisfactory performance.

Abiola (1999) also indicated that body weight gain of cockerels decreased with increased levels of dried un-hatched eggs included in the diets. This could be indicative of poor utilization of nutrients in the whole hatchery waste meal (WHWM) diets. However, there were no significant effects on eviscerated weights when cockerels were fed hatchery waste meal diets (Abiola, 2001). Raw eggs in the shell are best utilized by growing-finishing pigs and are not recommended for young weanling pigs or sows.

The Chemical composition of sun-dried un-hatched incubator eggs is presented in Table 9.

Table: 9: Chemical composition (g/kg) of dried un-hatched incubator eggs

Parameters	Composition (g/kg)
Crude protein	56.0
Crude fibre	18.5
Ether Extract	18.0
NFE	24.0
Calcium	10.4
Phosphorus	0.1
ME (kcal/g)	3.95

Source: Abiola and Onunkwor (2004)

Utilization of Egg Shell as Feed Ingredients for Pigs

Egg shells are waste materials from hatcheries, homes and fast food industries (Amu *et al.*, 2005; Phil and Zhi hong, 2009) and can be readily collected in abundance. Egg shell waste disposal contributes to environmental pollution. Egg shell and shell membranes are non-edible by-products with little saleable value but they may contain biologically active compounds (Nakano *et al.*, 2003). The composition of the egg shell is approximately 98.2 %, 0.9 %, 0.9 % of Calcium carbonate, Magnesium and Phosphorus (phosphate) respectively (Romanoff *et al.*, 1949). Table 10 shows the nutrient composition of some poultry by-products, on as-fed basis. Shell membrane comprises 69.2% protein, 2.7% fat, 1.5% moisture and 27.2% ash (MacNeil, 1997). Shell membrane protein comprises approximately 10% collagen (Froning, 1998). Schaafsma *et al.*, (2002) reported a positive effect of egg shell calcium supplementation (with added magnesium and vitamin D) on bone mineral density (BMD). One the whole, medium sized egg shells yields about 750-800 mg of elemental calcium (Bee, 2011).

Egg shells contain calcium and trace amounts of other micro elements i.e. magnesium, boron, copper, iron, manganese, molybdenum, sulphur, silicon and zinc (Bee, 2011). Egg shell calcium is probably the best natural source of calcium and it is about 90% absorbable (Bee, 2011). It is a much better source of calcium than limestone and can be incorporated up to 3-5% into feeds for animals (Mishra *et al.*, 2015). Abiola *et al.*, (2010) observed that, the higher ash content of hatchery waste could be due to the high content of egg shell at the time of processing which could also cause the reduction of the CP content in the diet of broiler chicken. AFRIS (2007) indicated that approximately 84% of the egg shell is ash, of which most is calcium carbonate. Carcass quality depends on the level of calcium and phosphorus fed to animals (Driver *et al.*, 2006).

Table: 10: Nutrient Composition of Hatchery by-products, on as-fed Basis

By-product	ME (kcal/ lb)	Dry Matter (%)	Crude Fiber (%)	Crude Protein (%)	Lys (%)	Trp (%)	Ca (%)	P (%)
Hydrolyzed feather meal	1000	94.6	1.0	85.0	1.94	0.50	0.20	0.80
Poultry by-product meal	1300	93.0	1.0	55.0	3.70	0.45	4.40	2.50
Bloodspot eggs	500	40.0	0.0	10.0	0.50	0.10	6.00	0.20
Hatchery by-product meal-broiler chick	800	90.0	0.0	22.2	1.16	0.22	24.60	0.35
Hatchery by-product meal-egg chick	1000	90.0	0.0	32.3	1.83	0.30	17.20	0.60

Source: (Thaler and Holden, 2010)

Utilization of HWM in Broiler Diets

The nutritionally rich hatchery by-product meal can be incorporated in poultry and pig diets because it has greater potential as feed for animals (Rahman *et a.l,* 2003). Shahriar *et al.,* (2008) investigated the effects of different levels of hatchery wastes (HW) in broiler chicken diets. Birds were fed HW in diets at levels of 0, 2, 4, 6 and 8%. The HW was controlled after processing (drying). The results obtained showed the use of waste up to the level of 4%, as being non-significantly different among treatments in weight gain, feed intake and feed conversion ratio (FCR). Average carcass composition was significantly different in breast weight % ($p<0.05$) and abdominal fat ($p < 0.01$) in between groups; organoleptic quality of the grilled breast meat was also significantly different between treatment groups, both in males and females ($p<0.05$). The glucose value of the serum was significantly different at 5 and 8 weeks ($p<0.05$).

Broiler chicks were fed diets incorporating hatchery waste for 42 days, as a substitute for fish meal. The diets were D1 (8 % FM + 0 % HW), D2 (4 % FM + 4 % HW), and D3 (0 % FM + 8 HW). Performance and meat yield were studied. The growth rate, feed conversion, performance index and profitability increased with the inclusion of dietary HW in increased amounts. Feed consumption showed no significant difference with replacement of fish meal (FM) by HW. It was further suggested that 8% HW be used in the diets to completely replace fish meal to formulate of a well-balanced and economical diet, for maximum growth and meat yield (Rahman *et al.,* 2003).

The addition of cooked HWM at 4% level had no effect on body weight compared with the control diet. Feed intake was found to be similar at

all levels of HWM inclusion; intake was found to be significantly less in the control diet during the starter phase although generally similar to birds fed 2% and 4% cooked HWM (Saima *et al.*, 2001). A study was conducted on hatchery waste as a protein source based on its nutritional value. The HWM was subjected to different processing techniques to establish the most appropriate level for usage in broiler rations in the commercial poultry production sector. Hatchery waste was subjected to processing techniques like cooking, toasting and formalin treatment. The dried raw and processed hatchery waste meals were then micro-biologically analyzed. The chemical composition of raw and processed HWM showed non-significant differences in various proximate fractions.

Gross energy contents analyzed in cooked hatchery waste meal were 4462.72 kcal/kg of dried material, whereas toasted meal was found to contain 4477.11 kcal/kg gross energy. Feed consumption was significantly ($P < 0.05$) low in birds fed on the control diet while the differences among the diets containing various levels of cooked and toasted HWM were non-significant.

Birds fed on the control diet had best value for FCR (2.01) while birds consuming diet containing 6% showed HWM had the worst value. Maximum liver weight per 100g body weight was recorded in birds kept on diets with 6% cooked HWM (Saima, 2001). In a feeding trial, significantly higher weight gain was observed on the diet containing 12% HWM compared to that containing a similar amount of fish meal. A performance trial on broiler chickens also revealed better weight gain and feed efficiency on the diet containing 12% HWM than that containing a similar level of fish meal (Rasool *et al.*, 1999).

Abiola and Onunkwor (2004) replaced fish meal with hatchery waste meal in layer diets at 0%, 33%, 66% and 100% levels; both feed and protein intakes were higher on HWM diets. The highest hen-day production of 73.97% was obtained on Diet 2 in which 33% of fish meal was replaced with HWM. Diets with HWM produced thicker egg shells (0.33 mm) than those fed on the control diet (0.32 mm). Results obtained for yolk weight were also significantly different ($P < 0.05$); highest values for yolk weight (16.91g) and albumen weights (40.93g) were recorded for birds fed with Diet 4 in which 100% fish meal was replaced with HWM. HWM can therefore replace fish meal completely in layer diets without adverse effect on egg quality characteristics.

Dried and powdered egg shells as waste from a hatchery was fed as a source of calcium to white Leghorn laying birds at 52 weeks. It was observed that egg shell thickness differed significantly due to Ca and P sources. The use of egg shells instead of limestone or oyster shell could maintain the egg production and egg quality traits in laying birds (Toppo *et al.*, 2003).

Utilization of HWM in Cockerel Diets

Abiola (2000) investigated the effect of feeding HWM diets on haematological indices and serum metabolites in cockerels. Haematological values were generally higher in birds fed HWM diets than those fed control diet. PCV and Hb concentrations tended to decrease with an increase in the level of HWM included in the diets, with values that ranged between 23.50 – 27.50 % for PCV and 7.85 g/100ml – 9.20 g/100ml for Hb. Lowest WBC count of 5.40 ($x10/mm^3$) was recorded for birds fed the control diet.

Cholesterol concentration appeared to increase with increase in level of HWM in the diets. A highest value of 144.50mg/100ml cholesterol was recorded on 15% HWM diet. Dietary treatments had significant effects ($P<0.05$) on total protein, creatinine and urea concentrations. There were no abnormal blood characteristics however in the birds fed HWM diets. Cockerels will tolerate 15% HWM diet in the starter phase without adverse effect on performance.

. The feeding trial revealed that cockerels fed dried un-hatched incubator egg-based (DUIE) diets were superior in body weight gain and feed intake than those fed soybean-based diets. Results of feed conversion ratio were statistically significant ($P<0.05$). The best FCR of 2.92 was recorded for birds fed the diet containing 5% (DUIE). Efficiency of protein utilization was also superior on the diets containing DUIE where the best ratio of 1.68 was recorded at the 10% inclusion level. The author also indicated that this will help minimize the disposal problem with hatchery waste and provide another protein source for the poultry industry (Abiola, 1999).

Abiola (2001) substituted groundnut cake with hatchery waste meal in the finisher diets of cockerels. Cockerels were fed four experimental diets in which groundnut cake (GNC) was replaced with hatchery waste meal (HWM) at 0, 10, 15, 20% levels. Dietary treatments had significant effects ($P<0.05$) on growth rate of cockerels and increased with rise in the level of HWM in the diet. Daily weight gain was highest on 20% HWM diet with a value of 22.10g/bird/day. The high energy content of HWM diets depressed feed intake, improved feed utilization and increased abdominal fat deposition.

Replacement of Fish Meal with other Protein Sources

Many attempts have been made over the years to replace fish meal with other protein resources with the view to reduce feed costs. Efforts at this, has aimed to include relatively inexpensive feed ingredients. For example, fish meal was replaced with maggots in diets with no significant effect on the performance of broilers (Awoniyi *et al.*, 2003; Ravindra-Reddy and Rajasekhar-Reddy, 1985). Agbede and Aletor (2003) indicated that fish meal protein in the diet of broilers could be replaced by 25% Glyricidia leaf protein concentrate (GLPC) without adverse effect on performance, carcass characteristics, muscle development, or haematological variables.

The effect of supplementation of palm kernel oil in fresh periwinkle and palm kernel cake-based diets on carcass characteristics and meat quality of broilers was evaluated. Birds were assigned to five dietary treatments in a completely randomized design. Carcass measures and cuts were significantly influenced ($p < 0.05$) by dietary treatments. Also, carcass cuts were significantly increased ($p < 0.05$) in birds on periwinkle and palm kernel oil diets, with abdominal fat being highest in Diet 5, having 40mg kg^{-1} palm kernel oil. However, proximate composition, physical and sensory properties were not significantly ($P>0.05$) influenced by dietary treatment. Results showed that carcass characteristics improved as compared to the control group (Okon and Ayuk, 2003; Odunsi *et al.*, 2013; Yıldırım, *et al.*, 2014).

Qualitative Research Approach

The philosophical underpinnings of qualitative research is constructivism (Creswell, 2014). Qualitative research therefore deals with people's understanding of the lives they choose to live, the meanings they

attach to their experiences and the feelings they hold about their conditions (Newby, 2014). Qualitative research usually uses interviews and observations as collection methods (Newby, 2014 and Yin, 2016), and does not involve large samples or participants (Henn *et. al.,* 2006; Connaway and Powell, 2010). According to Leavy (2017) the qualitative research approach is adopted when the primary purpose of the research is to explore, describe, or to explain a phenomenon.

Summary of the Literature Reviewed

The literature reviewed suggests that it is clear from the abundance of research published about the usefulness of by-product feed ingredients in non-ruminant diets that most of these are generally acceptable to pigs. One such non-conventional feedstuff, which could be of value for pig feeding, is hatchery waste meal (HWM). Hatchery waste is composed of egg shells, infertile eggs, dead-in-shells and dead chicks. These occur in varying proportions, and can potentially be made into supplemental energy, protein and mineral sources, if health issues likely to be associated with their use can be adequately addressed. Some published work indicates that its safety as feed may be achieved through cooking, drying and grinding into a meal termed Hatchery Waste Meal (Glatz *et al.*, 2011).

It may be inferred from the literature that the crude protein content of hatchery waste meal (HWM), was estimated to be from 16.83% to 18.17 % (Urlings *et al.,* 1993). Hatchery waste meal in general can be quite variable, depending on the substrate that is being processed (Watson, 2006). On average, hatchery waste in its raw state contains about 44.3% crude protein, 30.0% ether extract, 1.90% crude fiber, 14.0% ash, 4572 Kcal/Kg gross

energy and 3600 Kcal/Kg metabolizable energy (Young *et al.*, 2002). It is rich in calcium but low in phosphorus, although the calcium level depends on the level of shell moiety and hatch percentage (Young *et al.*, 2002). Hatchery waste meal is generally a palatable and high-quality feed ingredient due to its high content of essential amino acids, fatty acids, vitamins and minerals (Shelton *et al.*, 2001).

CHAPTER THREE

Objective 1: Determining the quantities of hatchery wastes generated by selected hatcheries in the Greater Accra Region and establishing how these hatcheries manage, handle and dispose of wastes

Introduction

The rapid growth of the poultry industry has been accompanied by the production of large quantities of by-products, particularly hatchery wastes (Das *et. al.*, 2002). It has been estimated that about 140,000 tons of waste is produced by hatcheries annually in the United States alone (Das *et. al.*, 2002). In Pakistan, the eggs set for incubation between 2008 and 2009 was estimated to generate 9,974 tons of hatchery waste (GOP, 2008). Even though data is not readily available for Ghana, it is believed that, the industry generates over 1,000 tons of waste annually (Djang-Fourdour, 2016)

The disposal of hatchery waste is of great concern to the poultry industry, as well as to the general public in many countries, including Ghana (Cai *et. al.*, 1994; Das *et. al.*, 2002; Djang-Fourdour, 2016). Cai *et. al.*, (1994) and Das *et. al.*, (2002) reported that fresh hatchery waste (HW) has high moisture content (67%) making it highly perishable; and requiring frequent hauling to dump sites due to poor storage facilities usually at the hatcheries. Worldwide, the common ways of disposal are incineration, rendering method as well as land fill (Miller, 1984). This makes the disposal of HW a very expensive venture to producers and, also unsafe for the environment in general (Deshmukh and Patterson, 1997; Shao *et. al.*, 2008; Mahmud *et al.*, 2015).

At land fill sites, HW breaks down and produces methane gas, which escapes into the atmosphere. If large amounts of these wastes are directly applied into the soil, it pollutes the environment, including ground water

(Mahmud *et. al.*, 2015). William (1999) reported that this high protein waste leads to high nitrogen losses, with 50% of the total nitrogen lost in just a few months. This results in enrichment of ground water, lakes or streams, as well as increases in pathogen distribution, production of phytotoxic substances, air pollution and greenhouse gas emissions. Bitzer and Sims (1988) also reported that high levels of organic waste in soils can result in nitrate (NO_3) contamination of ground water. Stevenson (1986) and Kelleher *et al.* (2002) also indicated that high levels of NO_3 in drinking water can result in cancer and respiratory illness in humans as well as foetal abortion in livestock.

Research has further shown that the practice of disposing of hatchery waste as garbage at far flung areas is not only a contributory factor to environmental pollution but rather an immense wastage of valuable protein and energy sources (Freeman, 2007). As the poultry industry continues to expand, the increases in on-farm waste material and hatchery residue call for more efficient ways of conversion of such materials into more useful products or disposal (Blake and Donald, 1992).

It has been amply demonstrated that, a more efficient and cost-effective method for the disposal of HW might be to recycle it to produce a hatchery waste meal (HWM) for inclusion in rations, provided this feed component does not negatively affect the productive performance of livestock (Kim and Easter, 2001; Shelton *et al.,* 2001). Interestingly, hatchery wastes, if processed and managed well, has been reported to have great potential as a non-conventional feedstuff for non-ruminant production including pigs through proper processing (Babiker *et al.,* 1991; Jatoi *et al.,* 2014).

Hatchery waste is reportedly a potentially high protein waste material, which can be developed into high protein feedstuffs and other valuable products, or utilized as organic fertilizer after appropriate treatment (Shelton *et al.*, 2001; Young *et al.*, 2002). Researchers have explored various methods for processing HW including cooking, autoclaving and extrusion (Abiola and Onunkwor, 2004). Given the large volumes of hatchery waste that needs disposal in Ghana, it is important to conduct and identify potential methods of processing, handling and managing this waste that will retain quality and value.

Purpose of the Study

The purpose of this study was to explore and describe how Ghanaian hatcheries handle HW. It was also to determine quantities of HW generated per year. Since this study is exploratory in nature, the process of allowing the data to speak for itself supports a qualitative method of inquiry (Creswell, 2014). Given that qualitative methodology uses context, individual experience, and subjective interpretation, generalizability is not possible, nor is it a goal (Creswell, 2007). This study also aimed at finding a way to come up with novel strategies for managing, using or properly disposing of hatchery waste, in Ghana; more specifically, to determine the value of HWM in Ghana.

Research Methodology

This section presents the methodology adopted for the study. It focuses on the research design, research approach, data collection methods and sampling.

Study Area

The selected sites for the study were hatchery operations in some districts and communities in the Greater Accra Region. The region is the smallest in Ghana in terms of land mass, covering a total surface area of 4,450 km^2 (GAPS, 2013). Figure 2 shows a map of the Greater Accra Region. It is centrally located within the coastal belt of Ghana and shares boundaries with the Eastern Region to the north, Central Region to the west and Volta Region to the east. To the south of the region lies the Gulf of Guinea which spans a distance of 220 km coastline stretching from Langma near Kasoa in the west to Ada in the east. In terms of population, however, it is the second most populated region, after the Ashanti Region, with a population of 2,905,726, accounting for 15.4 per cent of Ghana's total population (GAPS, 2013).

The rainfall pattern in the region is bi-modal (i.e. with major and minor seasons). The major season occurs from April to July and the minor season from August to October. Rainfall is usually characterized by thick cloudy conditions and high intensive storms. This situation usually causes flooding of valley bottoms. The coastal wetlands also get flooded as a result of the occasional spillage of the Weija Dam in the Ga South Municipal Assembly, which affects crop and animal production. The annual temperatures range between 25.1°C in August and 28.4°C in February-March, which are the hottest months of the year. Soils are sandy and clayey loams. Alluvial soils are found at the valley bottom, likewise the estuary (GAPS, 2013).

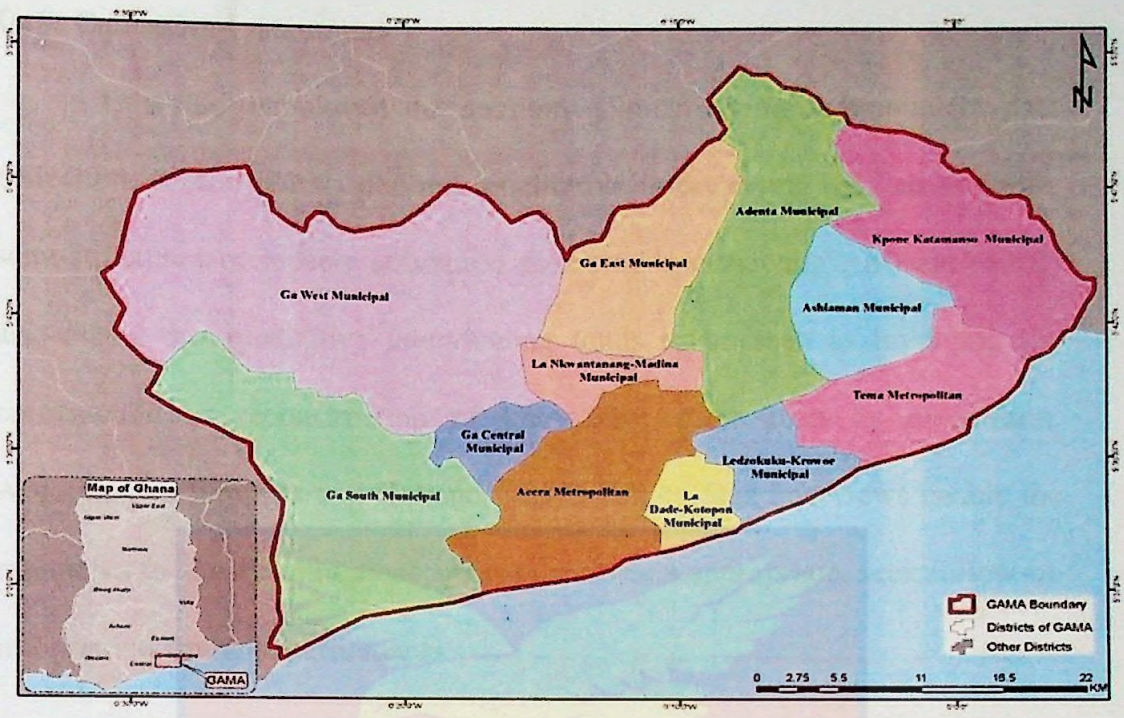


Figure 2: Map of the Greater Accra Region.

The Research Approach

The qualitative research approach was adopted for this study. The qualitative research approach is concerned with subjective assessment of attitudes, opinions and behaviours. Research in such a situation gives the researcher insights and impressions about the subject under study. Such an approach generates results either in non-qualitative form or in the form which is not subjected to rigorous quantitative analysis. According to Rajasekar *et. al.* (2013) qualitative research/method is:

i. Non-numerical, descriptive, applies reasoning and uses words

ii. Aims at getting the meaning, feeling and describes the situation

iii. The data cannot be graphed

iv. Exploratory

v. Investigates the why and how of decision-making

Data Collection Instrument

This study employed the qualitative interviewing technique for data collection. Mason (2002) defined 'qualitative interviewing' as "an in-depth, semi-structured or loosely structured forms of interviewing". Mason (2002) also stated that qualitative interviewing tends to be seen as involving the construction or reconstruction of knowledge more than its excavation. According to Edwards and Holland (2013) face-to-face interviews enable the researcher to clarify ambiguous answers and when appropriate, seek follow-up information from the participants.

Five semi-structured interviews were conducted with Hatchery Operatives (HPs). The interview schedules included 'a set of prepared, mostly open-ended questions' built upon themes initially identified through telephone conversations with the HPs (Appendix 7). This allowed flexibility on the part of the interviewer and respondent enabling relevant areas to be discussed, in addition to other themes that spontaneously arose during the interaction. Rubin (2012) suggested that using a responsive interviewing approach with a flexible and relaxed style helps to establish 'a relationship of trust between the interviewer and interviewee that leads to more give-and-take in the conversation'. This strategy proved vital for this particular research.

Estimation of Quantities of Hatchery Waste Generated

Since the HPs did not quantify the volume of hatchery waste generated the Researcher specifically undertook to collect weekly data for 3 months (i.e. September to November 2017) at three out of the five hatchery sites with the view to estimating the quantities of HW generated in the Greater Accra Region. Also investigated during the data collection period at the hatcheries

was the hatching performance of the various hatcheries investigated. The estimated quantities of HW was determined as total number of eggs rejected prior to setting in the incu bator and the volume of waste that was produced after every hatch. Table 11 shows the format adopted to estimate quantities of hatchery waste generated.

Table 11: Format to estimate quantities of hatchery wastes generated in selected hatcheries as a basis for estimating volumes produced across the region

Objective	Questions	Major themes	Minor themes
The quantity of hatchery wastes generated to estimate volumes of waste produced	Do you estimate quantity of eggs rejected before setting in the incubator? (compute into percentage)	Rejected eggs before setting	Low or None (rejected eggs)
	Do you measure the actual volume or quantity of waste generated after each hatch?	Waste generated after hatching	Waste cannot be determined

Source: Field Survey, Asiedu (2020)

The results obtained were to ascertain data that fitted the major themes (which involved eggs rejected before hatching and HW after hatching). The minor themes established that there was either a lower quantity of HW generated by hatcheries or in some cases none were recorded (or could not be estimated).

Interview Process

Hatchery operatives (HP) in the Greater Accra Region were initially contacted by telephone, or in person, by an Agricultural Extension Agent (AEA) of the Ministry of Food and Agriculture (MoFA). The purpose of the research study was explained to them. The HPs who were willing to participate in the study provided a convenient time and location for the interviews. An individual, face-to-face interview was carried out with each HP in 2017 by the researcher and an AEA from MoFA. The HPs spoke either in Twi or English depending on which language they felt more comfortable to express themselves in. The interviews followed an already prepared guide. Interviews were audio recorded and fully transcribed by the researcher.

Five HPs participated in the interview sessions. To afford them privacy their names and locations were coded as HP 1 to HP 5. The HPs were thus assured of confidentiality regarding any information given. The HPs were interviewed either in their offices or homes. All HPs contacted volunteered to be part of the interview sessions, and gave approximately 1 hour of their time to the interview session.

Data Analysis

Data collected was analysed using the thematic content approach. Major and minor themes identified in the study are expressed accordingly in relevant aspects of the study. This is supported by quotations obtained from the responses of the participants.

Results

This section addresses the findings from the interview sessions as well as the data analysis of the data collected on the HW and hatchery performance. The findings primarily cover the demographic profile of the HPs, the quantities of HW generated in the selected hatcheries as a basis for estimating the volumes produced across the region, how selected hatcheries handle their waste, the hatching performance and also novel strategies for managing or properly disposing of HW generated.

Socio-demographic characteristics of HPs

This section of the study focuses on the demographic profile of the participants used in this study. This covers the location of the hatchery, period of operation and previous training of the HPs. The length of time for which the hatcheries have been in operation ranged between 6 and 15 years. Out of the 5 participants, 3 participants had been in the hatchery operation business for over 10 years (fig.3)

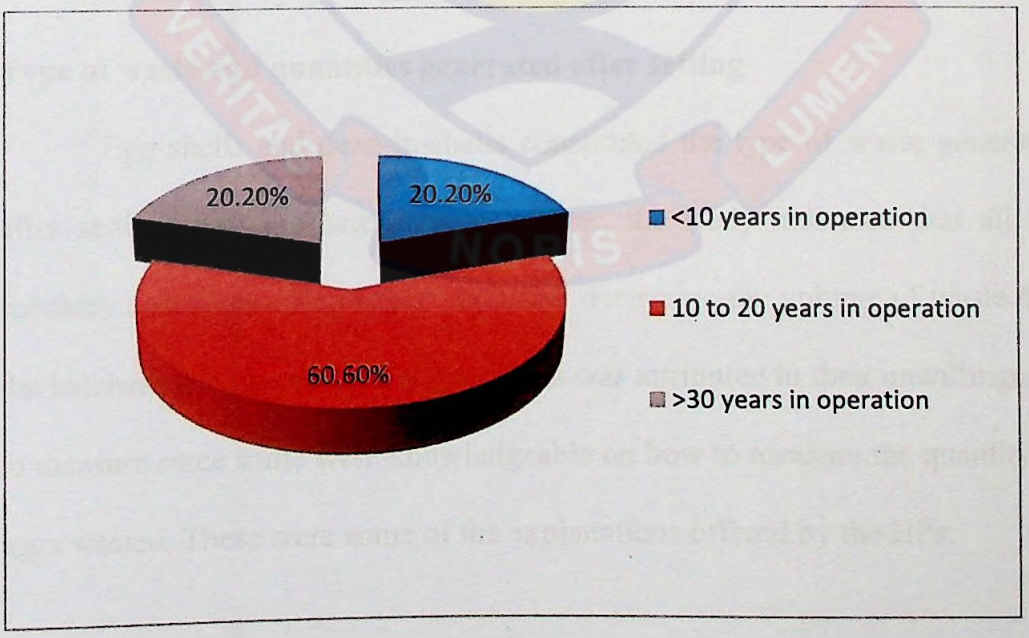


Figure 3: The period of training of HPs in the Greater Accra Region

Quantities of HW generated

The quantities of waste generated varied in relation to the number of eggs set, and number of eggs hatched. The minor themes established that there were low to no waste generated by the hatcheries.

Eggs rejected before and after setting

The recorded levels of rejected eggs before hatching were low, ranging between 5 and 10% of all eggs set. HP 1 and HP 2 had this to say:

> *I haven't really taken proper count of that. But maybe if I set 1002 eggs in the incubator, about 100 (10%) would be rejected* [HP 1].
>
> *About 500 (5%) eggs will certainly be rejected* [HP 2]

However 2 out of 5 HPs indicated that they did not have issues with rejection of eggs before setting. In this regards HP 3 gave this reason:

> *No, here I don't reject any set of them because they are already selected and I set all of them. But again, on the eighteenth day, I do my counting and the eggs that do not pass are rejected, but before that, I do not* [HP 3].

Type of waste and quantities generated after setting

Egg shells and dead-in-shells constituted the type of waste generated after setting from the hatcheries. However, the study indicated that all the hatchery operatives interviewed could not determine the volume of waste that the hatcheries produced after setting. This was attributed to their unwillingness to measure since some were knowledgeable on how to measure the quantity of eggs wasted. These were some of the explanations offered by the HPs:

No we do not, but one can calculate if you know the weight and number of eggs you set. We were taught all these but I have forgotten [HP 3]

A second HP also stated that:

No, we do not really measure but we can estimate the quantity using the weight of the egg and the number of eggs that are set at a time [HP 4]

However, the results of the measurement by the Researcher indicated that the hatcheries produced about 25,079.6 kg of hatchery waste, that is 25 tons per annum from an average of 5,000 eggs set per week (Table 12).

Table 12: Hatching performance and hatchery waste generated during September to November 2017

Months	Number of Eggs set	Dead in shell (kg)	Egg shells (kg)	Rejected chicks (kg)	Infertile eggs	Chicks hatched	% hatch	% waste generated
1	5000	90.2	43.1	0.9	200	3600	72.0	28.0
2	5323	98.8	42.0	1.1	212	3577	67.0	33.0
3	4700	100.4	40.6	2.1	188	3384	72.0	28.0
Total	**15,023**	**289.4**	**125.7**	**4.1**	**600**	**10,561**	**70.3**	**29.7**

Source: Field Survey, Asiedu (2020)

Handling of hatchery waste

The responses from the HPs indicated that each used a different method to handle hatchery waste. This included discarding the waste in dustbins or recycling the waste generated. Under these major themes, the minor themes that were observed from the responses involved the use of the services of waste collectors and their personal delivery of waste to dumping sites. Table 13 shows details of how some hatcheries handled and disposed their HW.

Table 13: Handling and disposal methods of hatchery waste in the Greater Accra Region

Objective	Major themes	Minor themes
How selected hatcheries handled and dispose off hatchery waste	Separating waste	o Solid waste o Liquid waste
	Re-use	o Feed for pigs
	Discarded in bins	o Services of waste collectors o Personally disposing off waste at the dumping site

Source: Field Survey, Asiedu (2020)

Disposing of hatchery waste in bins and, employing the services of waste collectors

The study established that generated HW are disposed in their raw state, thus waste generated from the hatcheries were primarily placed into sacks and discarded in the bins.

The HPs however recognized the importance of employing the services of waste collectors for proper disposal of the hatchery waste so as to prevent pollution of the environment and compromise the safety of both humans and animals in that vicinity. HP 3 had this to say in that regard:

> *Yes, at the end of the month we pay a little money to the waste collectors. When the waste collectors delay coming, we contract some of these boys who use the motor-king tricycle to collect it and we pay like GHC 5 or 10.* [HP 3]

Another HP also explained thus:

> *I just pick them [the HW] and put them into the dustbin, and it is taken every day and we pay every month.* [HP 5]

Personally disposing off waste at the dumping site

Dumping sites are not available in every community. Nonetheless, people and businesses that are situated near such locations have an easier option to discard their waste due to proximity. Thus, some operators of hatcheries were observed to have chosen this method of discarding their waste after placing them in their bins following operations. This is explained by one HP who says:

> *We have a dumping site down there where we dispose our waste* [HP 4]

Re-use of hatchery waste

The HW generated from the hatcheries was often utilized as feed for pigs. Wastes piled up daily or weekly were supplied to persons who used them in other farm operations. This is reflected in a response provided by HP 2:

There is a young man who normally comes here to pick up the waste to feed to his pigs. When he doesn't come, it is disposed of [HP 2]

Also, another HP stated that:

I wouldn't say we treat them because they are waste, and after putting them in the sack we just send them to the piggery and if they do not need them, then we send it to the dump site [HP 4]

Separation of wastes

The hatcheries produce both liquid and solid waste that must be segregated in order to adequately manage them. Both liquid and solid wastes were handled separately prioir to being disposed.

Liquid waste

The liquid waste was primarily from washing the hatching machines. Its disposal was explained by HP 3 in these words as being more tedious compared to the solid waste:

For the liquid aspect of the waste, at times you have to mop and clean, but for the solid waste it is far easier to handle [HP 3]

Solid waste

HP 1 explained how solid waste which constituted the bulk of the HW generated was disposed. The solid wastes were generated before and after the hatching of eggs.

The solid wastes are not processed, because it is waste. What I do is that I throw them into the dustbin [HP 1]

This was corroborated by HP 2:

No we do not process, we just dump them" [HP 2].

Developing novel strategies for managing or properly disposing of hatchery waste

The study observed that disposing of waste HW in bins by the HPs was the most commonly used disposal method in hatcheries in the Greater Accra Region. Table 14 shows the strategies suggested for managing and properly disposing of hatchery waste when the HPs were asked to propose other novel strategies they had heard of or planned to institute in future in the disposal of their wastes.

Table 14: Novel strategies for managing, using or properly disposing of hatchery wastes in the Greater Accra Region.

Objective	Major theme	Minor theme
Novel strategies for managing, using or properly disposing of hatchery waste	Waste treatment	Composting
	Disinfecting the waste	Boiling

Source: Field Survey, Asiedu (2020)

Treatment of hatchery waste

The following treatment methods were employed in situations where the waste was not disposed of in its raw state.

Composting

Composting was employed by some hatcheries to minimize or eliminate the discomfort to employees of the hatchery and individuals or organizations located around their surroundings during the natural decomposition of the waste. The resultant product – manure, was used as a soil amendment as explained by HP 4.

The waste is being used as compost (manure) [HP 4].

HP 3 also had this to say:

I was taught that some of them autoclave it, others too boil and give it to their animals, some use it as compost and fertilizer for their crops whilst others give it to their animals raw without any treatment [HP 3].

Boiling

Boiling was also indicated as one of the treatment methods of solid waste in the hatcheries in the Greater Accra Region. This was to minimize the microbial load when the material was to be used as livestock feed ingredient, specifically pigs. This helps to reduce the incidence of harmful bacteria that could be transferred to the pigs when the product is consumed in its raw state. This was explained by HP 2 thus:

Some farmers too boil it and give it to their pigs [HP 2]

Discussion

The quantities of hatchery wastes generated in some selected hatcheries as a basis for estimating volumes produced across the region

The low waste generation prior to eggs being hatched has been attributed to the fact that most of our local hatcheries are producing below 60% capacity (Ghana Business News, 2013) partly due to the fact that our hatchery machines are very old and have seen no replacement for a long time. The hatcheries may therefore not be meeting modern incubation standards anymore due to the fact that the incubators used were mostly out-moded. According to information found at the Poultry Site (2014) and cited by Djang-Fourjour (2016), Ghana's poultry sector is having challenges which include hatcheries operating below expectation. The under-performance of the local hatcheries was attributed to the unrestricted trade liberalization that permits avian products to be freely imported. While Ghana's poultry industry was producing close to 90% of the National requirements as of 1993 (MoFA, 2013), it now produces only 10%, with more forex being channeled into the importation of poultry products from year to year.

However, the findings of the hatching performance in this study is close to the results of Nwanta *et. al.,* (2006) and Djang-Fourjour, (2016) which show that hatching rates for eggs set in incubators are usually within the range of 70-75%. Thus, the current study shows that the local hatcheries are performing within international standards in terms of their hatching performance.

The inability of HPs to quantify the volume of HW generated after setting was attributed to lack of interest to measure mainly due to either the

lack of or the low economic benefits of hatchery waste in Ghana. It is however believed that this trend will change when some economic benefit is placed on the product. It was however impossible to compare the estimated value of 25 tons per annum HW in the current study to figures in other jurisdictions as they reported on national values instead of values from particular regions. Besides, in Ghana most of the hatcheries are found in the Bono, Ahafo and Ashanti regions (Djang-Fourjour, 2016).

How hatcheries handle and dispose of hatchery waste

The methods of handling and disposal of HW in the current study are however not environmentally healthy, neither are they economically prudent. It is suggested therefore that HPs be educated on the proper handling and or economic prudent way of utilizing HW in Ghana. For example, HW could be incorporated in animal feed as reported by Kim and Easter (2001), Shelton *et al.*, (2001) and Djan-Fordour *et al.*, (2016) however, the practice of feeding the product in its raw state may not be prudent due to the high microbial load Osei-Somuah (2003).

However, the findings of this study indicating that hatchery operators generally managed waste by discarding them in waste bins and is consistent with results by Glatz and Miao (2009) in Australia.

Novel strategies for managing, using or properly disposing of hatchery waste

The knowledge of the HPs of novel strategies for managing, using or properly disposing of hatchery waste such as composting is laudable and must be exploited by policy makers in the education of the HPs with regards to managing, utilization and disposal of HW, as stated by Imbeah (1998),

composting altered ammonia nitrogen to organic nitrogen ratio which could be utilized as fertilizer and so decrease the volume of waste. This implies that HW could have more to offer than its primary intended use.

Again, the results of this study revealed that boiling was a suitable and feasible approach to handling and managing hatchery waste locally. This finding is supported by Khan *et al.* (2005), which revealed that HW can be cooked at a 2:1 ratio with water for a period of 15 minutes and subsequently dried in an oven at a temperature of 65^0C for the elimination of possible bacteria such as *Escherichia coli* and *Salmonella spp.* Following this, treated HW can provide suitable minerals, protein and energy for livestock feed (Shelton *et. al.*, 2001). The results obtained from this study generally indicate that the management of HW should be a significant aspect of managing the operations of a hatchery. Moreover, when adequately managed, waste generated could serve multiple uses to the hatchery and other interested farmers.

Conclusions

The population of the study involved hatchery operatives that were engaged in hatchery operations in the Greater Accra Region. The study utilised semi-structured interviews to collect data from the participants for the study. Subsequently, an analysis was conducted using the thematic analysis approach, which identified major and minor themes that were relevant to the study.

It can be concluded from the studies that waste produced in the hatchery was mostly disposed of using garbage collectors. Such waste was directly applied into the soil (at dumping sites), which subsequently pollutes the environment, including the ground water.

The study indicated that large quantities of HW were available from operations of hatcheries in the Greater Accra Region. Estimates from 5 hatcheries alone gave quantities of about 25 tons per annum. This when dumped inappropriately constitute a major source of air, land and water pollutant. However, if separated and well processed, this could constitute a significant amount of potential animal protein sources for pig farmers.

CHAPTER FOUR

Objective 2: Developing a Simple, Cheap but Effective and Safe Technology for Handling and Processing Hatchery Wastes for incorporation into Rations for Pigs

Introduction

As human population increases, the poultry industry also continues to grow to meet the demand for poultry products (FAO, 2013). The importance of poultry lies in the quality of products that are generated from the enterprise. Layer farms provide eggs rich in proteins and vitamins, especially the fat-soluble vitamins (A, D, E, and K). Poultry farms are reportedly fast-paced operations that can fulfill the demand for meat and eggs, and can be expanded easily to meet the ever-growing human food needs (Farran, 2009).

Rondon and Ashitey (2011) revealed that commercial poultry production in Ghana had high peaks between the 1980s and 1990s when the industry was so vibrant that it supplied about 80% of poultry meat and egg consumed in the country. The poultry industry however produces large amounts of hatchery waste which includes both solid and liquid waste. The solid hatchery waste comprises empty shells, infertile eggs, dead embryos, late hatchings, dead chickens as well as a viscous liquid from eggs and decaying tissue and waste water coming from water used to wash down incubators, hatchers and chick handling areas (Glatz *et al.*, 2011). Land fill, composting, rendering and incineration are some of the methods currently used worldwide in waste disposal (Das *et al.*, 2002).

Das *et al.*, (2002) reported that when most of the hatchery waste is sent to land fill site or subjected to composting, it costs the chicken meat industry millions of dollars each year in disposal costs; and even then, only small amounts of hatchery waste are rendered. Other potential methods for treating hatchery waste on site include use of a furnace to heat the waste (incineration) to produce steam to run a turbine generator or the use of an in-line composter to stabilize the waste (Das *et al.*, 2002). There is also the potential to use anaerobic digestion at hatcheries to produce methane and organic fertilizers (Glatz *et al.*, 2011).

On the other hand, waste disposal methods in Ghana include sending it to land fill sites, disposing off it directly into the sewer or into water bodies. Land fill hatchery waste will break down naturally with time to produce methane which escapes into the atmosphere (Glatz and Mioa, 2009). The ideal system in establishing a hatchery would be to incorporate separation and handling equipment to partition waste into its various components for further treatment. This would save disposal costs, produce biogas to reduce power costs at plants and produce a range of other value-added products (Glatz *et al.*, 2011).

In temperate zones or areas, the majority of hatcheries use a vacuum extraction system to move the waste into bins. Some hatcheries store the waste in a cool room and then place this into a Bio-Bin. Other hatcheries reportedly crush the waste first then, use a vacuum or auger system to transfer the waste into the bin (Glatz and Mioa, 2009). In the USA, one disposal option available is to transport the hatchery waste to a facility that separates the liquids from the solids by using a centrifuge (Cawthon, 1998).

Eggs are often rinsed with alkaline detergents and chlorine solutions to reduce microbial load on the shell (Bialka *et al.*, 2004). In developed countries like the United States, Canada and Japan microbial load on surface of table eggs is routinely evaluated before retailing (Arathy *et al.*, 2009). This practice is not quite common in developing countries especially those in Sub-Saharan Africa. In some countries, bacteria isolated from table eggs have been linked to some human illnesses. Increasing consumer awareness about food safety issues has changed the public perception of a good egg from just its shell cleanliness and physical properties to that of microbial integrity. Freshly laid eggs are generally devoid of microorganisms. However, following exposure to environmental conditions (for example, soil, dust and dirty nesting materials), eggs become contaminated with different types of microorganisms (Abdul *et al.*, 2012). Microbial contamination of eggs usually occurs few seconds after production, through processing and preparation, up till consumption (Indhu *et al.*, 2014).

Previously, it has been reported that several hatcheries in Ghana concentrated on producing chicks for farmers to rear for commercial purposes irrespective of the genetic merit (Aning, 2006). However, checks with the farms and poultry associations in Ghana as part of the current study has shown that majority of these hatcheries are out of business. In addition, the ones existing produced at about only 60 percent of their installed capacity because of low demand. Besides, most of these hatcheries are to produce a layer chick which continues to be a major setback for the broiler production industry. According to the GPRA (2013) report, only three hatcheries in Ghana have their own breeding stock for both breeds of broiler and layers. The rest of the

hatcheries import hatchable eggs directly from Europe or from neighbouring countries.

The objective of this section of study was to evaluate the nutritional value of processed HWM using three different techniques and their potential use as animal protein source in diet for grower-finisher pigs.

Materials and Methods

Study Area and Sample Collection

The study was conducted at the Council for Scientific and Industrial Research-Animal Research Institute (CSIR-ARI) located in the Adentan Municipal District (*5°42'25"N 0°10'15"W*), off the Dodowa road in the Greater-Accra Region (Wallace *et al.*, 2012). Nine (9) categories of samples were collected for proximate and microbiological analyses.

Processing of Hatchery Waste Meals

Hatchery waste (HW) was obtained from the CSIR – Animal Research Institute's Hatchery at Katamanso, and the NAT Hatchery farm at Kodiabe, Accra. The raw hatchery waste comprised infertile eggs, egg shells, dead-in-shells and low-grade unsalable chicks.

Equal quantities of 3 kg of raw mixture of hatchery waste were placed in three different polythene bags of different colours. The polythene bags containing the HW were then immersed in a steel drum containing boiling water. The steel drums together with its contents were subjected to a constant boiling temperature of 100°C for various periods of time.

Steaming / Boiling Periods

The samples were subjected to three different processing techniques (boiling periods). Hatchery waste was processed by simple steaming in a

covered steel drum for periods of 5, 10 and 15 minutes. The steamed samples were removed from the drum after the individual time frame and pulverized using the local wooden mortar and pestle. This was to reduce particle size of the hard tissue and potentially facilitate or aid fast drying.

Drying Temperatures and Duration

Samples from all the three different steaming procedure were then dried in a hot air oven set to three different temperatures regimes and duration namely 60 °C for 48 hrs, 70 °C for 36 hrs, and 80 °C for 24 hrs. The samples were then, ground in a JF automated machine (comex@jfmaquinas.brazil), using initially an 8 mm dial screen and subsequently, a 2 mm dial screen in a hammer mill. After drying, representative samples of the HWM prepared from the 9 previously described processing techniques were taken.

All samples were further sub-divided and placed into tared, zipper-locking plastic bags and weighed. Table 15 shows hatchery waste meal processed using three different steaming regime and three different drying methods. All sub-samples were subjected to proximate analyses (AOAC, 2000) and microbial analyses (Deere *et al.*, 2002). The processed HW were designated as 5M60T = 5mins 60 °C, 5M70T = 5mins 70 °C, 5M80T = 5mins 80 °C, 10M60T = 10 mins 60 °C, 10M70T = 10 mins 70 °C, 10M80T = 10 mins 80 °C, 15M60T = 15 mins 60 °C, 15M70T = 15 mins 70 °C, 15M80T = 15 mins 80 °C.

Table 15: Hatchery Waste Meal Processed using three different Temperature (Steaming) and Drying Regimes

No	Steaming Period (mins)	Drying Temperature (°C)	Drying periods (hrs)
1.	5	60	48
2.	5	70	36
3.	5	80	24
4.	10	60	48
5	10	70	36
6	10	80	24
7	15	60	48
8	15	70	36
9	15	80	24

Source: Field Survey, Asiedu (2020.Three (3) replicates per treatment; n = 9

Figure 4 is a pictorial representation of how the various processes of raw HWM were taken through to obtain a form in which it could be incorporated into diets

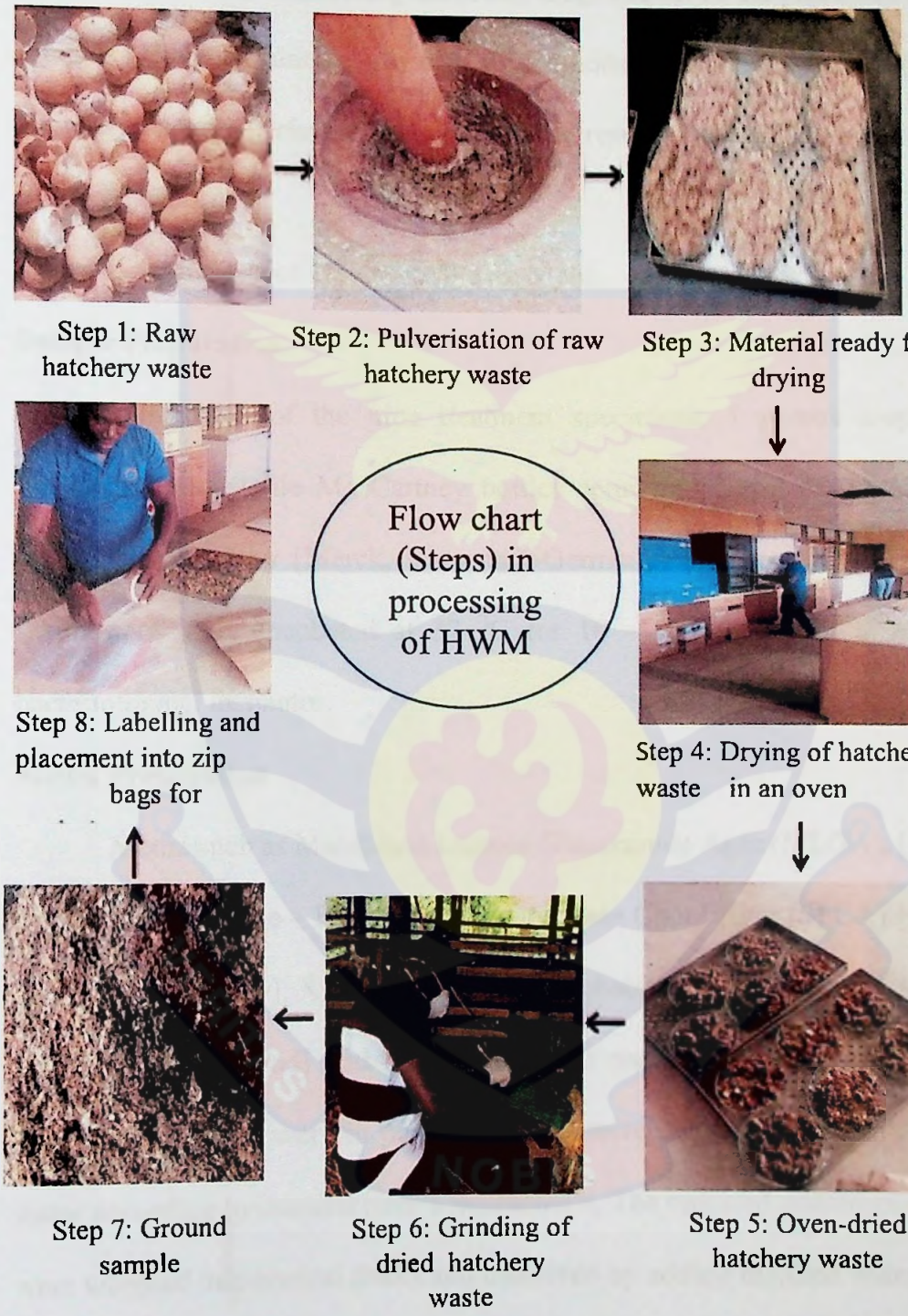


Figure 4: Steps involved in processing raw HW into HWM (hatchery waste meal)

Determination of Proximate Composition of Hatchery Waste Meal

All chemicals used during the study were of the analytical grade. The dry matter content, ash, crude protein and ether extract in the processed HWM samples were determined using standard methods, as described AOAC (2000). All analyses were performed in triplicate and results presented as mean values ± SD.

Microbial Analysis of Hatchery Waste Meal

Sample Preparation

From each of the nine treatment specimens, 1 g was aseptically transferred into sterile MacCartney bottles containing 9 ml of 0.1% sterile blank peptone water [Merck, Darmstadt-Germany] to form the neat. These suspensions were incubated at 37 ^{0}C for 10 - 15 minutes in a Wagtech bacteriological incubator.

Media Preparation

Media such as Membrane Lactose Glucorunide Agar (MLGA), [Oxoid, CM 1031 Hamsphire – England], Standard Plate Count Agar (SPCA) [Merck, Darmstadt-Germany], Xylose Lysine Desoxycholate (XLD) [Oxoid, CM 0469 Hamsphire – England] and blood agar were used for the microbial assay. These media which were in powder form(s) were reconstituted with distilled water according to manufacturer's instructions. The required quantities of agar were weighed into conical flasks and dissolved by adding distilled water. They were sterilized by autoclaving at different temperatures as stated by manufacturer prior to use.

Counting of Microorganisms

Bacterial enumeration was done using pour-plate and plate - count techniques. Samples were serially diluted using 10-fold serial dilution into nine (9) other sterile MacCartney bottles containing 0.1% 9 ml peptone water. Different pipette tips were used for each dilution.

Total Viable Count

For total aerobic mesophilic bacteria (TAMB) count, the pour - plate method was used. One (1) ml of each dilution was aseptically added to 9 ml of molten Standard Plate Count Agar [Merck, Darmstadt-Germany] kept at 45-50 ^{0}C in a water bath [Grant, OLS 200]. This was mixed by rotation and poured into 9 cm sterile petri dish. It was allowed to set and incubated at 37 ^{0}C for 18-24 hrs. After incubation, plates showing collonial growth were selected (Collins and Lyne, 1995) and counted using electronic colony counter [Stuart Scientific]. Colonies counted for each plate was multiplied by the dilution factor to obtain the number of colonies.

Total Coliform Count

Using the plate-count method, one (1) ml of each dilution was aseptically put into 9 cm petri dish. Nine (9) ml of molten Membrane Lactose Glucuronide Agar (MLGA) [Oxoid, CM 1031 Hamsphire – England] kept at 45-50 ^{0}C in a water bath was added, mixed by swirling and allowed to set. Plates were incubated at 37 ^{0}C for 24-48 hrs and examined for colonial growth.

E. coli Count

One (1) ml of each dilution was aseptically put into 9 cm petri dish using the plate-count technique. Into same plate, nine (9) ml of molten Membrane Lactose Glucuronide Agar (MLGA) [Oxoid, CM 1031 Hamsphire – England] and kept at 45-50 ^{0}C in a water bath was added. This was mixed by swirling and allowed to set after which plates were incubated at 37 ^{0}C for 24-48 hrs.

Salmonella Count

One (1) ml of the neat sample was added to 10ml of double strength Selenite F broth [Oxoid, CM 395 Hamsphire – England] for enrichment. This was mixed thoroughly and incubated at 37 ^{0}C overnight. After incubation, 1 ml of the culture (SF broth) was serially diluted using 10-fold serial dilution into nine (9) other sterile MacCartney bottles containing 0.1 % 9 ml peptone water. Using pour-plate technique, 1 ml of diluent was aseptically added to 9 ml of molten Xylose Lysine Deoxycholate (XLD) agar [Oxoid, CM 469, Hamsphire – England] and kept at 45-50 ^{0}C in a water bath. It was mixed by rotation and incubated at 37 ^{0}C for 24 hrs.

Culture Techniques

Using a sterile inoculating loop, the neat samples were plated-out onto blood agar [Merck, Darmstadt-Germany] and xylose lysine desoxycholate (XLD) agar [Oxoid, CM 0469, Hamsphire – England Plates were incubated aerobically at 37 °C for 24-48 hrs in a bacteriological incubator (Plate 4). Cultures were examined for colonial characteristics on the media. Impure cultures on primary media were purified by subculturing onto selected secondary media to obtain discrete colonies.

Isolation and Identification of Organisms

After overnight incubation, colonial morphology of organisms based on their physical characteristics was studied for size, shape, outline, colour and change in medium on various media. Standard microbiological techniques including Gram staining, cellular morphology [of organisms using compound microscope magnified at x100 with oil immersion] and biochemical tests such as Motility Indole Urea (MIU) [Lioflichems.r.l. Bacteriology Products, 610236, Italy], Catalase, Triple Sugar Iron (TSI) [Oxoid, CM 0277, Hamsphire – England], Indole Methyl Red Vorges-Proskeur Citrate [IMViC] test, carbohydrates Oxidation/Fermentation (O/F) test [to detect gas and or acid production] among others were applied to isolate and identify the organisms.

Culture, Isolation and Identification of *Salmonella*

Using the plate-out technique, subcultures were made from the Selenite F broth aseptically onto XLD agar [Oxoid, CM 469, Hamsphire– England]. Cultures were incubated at 37^0C for 24 -48hrs and examined for the physical characteristics of colonies on the media.

Culture, Isolation and Identification of *Escherichia coli*

All lactose fermenting colonies on MacConkey agar were selected and aseptically subcultured onto MLGA [Oxoid, CM 1031 Hamsphire – England] to isolate and identify *E. coli.* Cultures were incubated at 45 ^{0}C for 24-48 hours in a bacteriological incubator.

Data Analysis

The data obtained were subjected to analysis of variance (ANOVA) and the means of the treatments compared statistically using the Tukey's test at 95% confidence level.

The count obtained (cfu g^{-1}) for the microbial analysis were first converted to logarithmic form. The logarithmic was compared with the isolate identified according to relative linearity based on Statistical analysis of both results by using Microsoft Excel Statistics 2002 for Windows. Differences in results that exceeded 1 log CFU g^{-1} were classified as discrepancies (Campden and Chorleywood Food Research Association Group, 2001).

Results

Proximate Composition of Processed HWM

Proximate compositions of samples of HWM processed using different processing protocols or techniques are presented in Table 16. The results of the proximate analysis show that all the HWM samples are rich in protein, ash, dry matter and fat but at varying degrees. The processing techniques used in this study showed that protein content of the HWM varied depending on the drying temperatures and periods of exposure. The 5M60T, 5M70T, 5M80T, 10M60T, 10M70T, 10M80T, 15M60T, 15M70T and 15M80T HWM registered CP levels of 44.71, 38.57, 49.90, 48.82, 38.41, 46.24, 47.81, 38.26 and 45.63 respectively. Numerically the highest value for DM was from the 5M80T. However, ash content for 5M80T was the highest level recorded (33.46 %), followed closely by 15M70T (32.05 %), while the least was found in 15M60T (29.56 %). With respect to ether extract content, 10M70T had

statistically highest EE content (23.52 %) value while 5M80T had the least (17.72 %).

Comparison of Mean Bacterial Loads

The study was undertaken to evaluate microbial quality of HWM taken before storage and on day 90 in other to test for the presence of *Escherichia coli, Streptococci, Salmonella* (AOAC, 1990), and Lactobacillus (Vanderzant and Splitt-stoesser, 1992). Table 17 and 18 compares the mean bacterial loads on HWM from the nine different processing techniques. The mean total viable counts (Table 17) for 5M60T, 5M70T and 10M70T were 10.2, 10.5 and 10.2 respectively, and were higher than the accepted values of 6.0 (log) (cfu/g) according to Microbiological Specification for Food ICMSF (1998). On the contrary, the mean total viable count (Table 18) for 5M60T, 5M70T and 10M70T were 8.7, 8.0 and 8.1 respectively and were within the range, recommended by ICMSF (1998). Again, the mean total viable counts (Table 17) for 5M80T, 10M60T, 10M80T, 15M60T, 15M70T and 15M80T were 9.30, 9.80, 9.54, 9.40, 9.95 and 9.98 respectively and were within the range, recommended by the ICMSF (1998).

Table 16: Proximate Composition of Hatchery Waste Meal Processed at different Times and Temperature

samples	Treatments									
	5M60T	5M70T	5M80T	10M60T	10M70T	10M80T	15M60T	15M70T	15M80T	SEM
Dry Matter	98.88	97.25	99.51	97.69	96.54	99.42	97.30^{b}	96.26^{bc}	99.29^{a}	0.14
Crude Protein	44.71	38.57	49.90	48.82	38.41	46.24	47.81	38.26	45.63	0.18
Ether Extract	21.14	22.11	17.72	22.26	23.52	22.66	22.55	20.23	22.65	0.42
Ash	31.49	31.00	33.46	29.08	27.09	31.21	29.56	32.05	30.47	0.21
Ca	17.62	18.65	26.55	25.91	17.96	19.02	21.03	19.51	18.73	0.11
P	1.53	1.47	1.99	1.44	1.63	1.12	1.32	1.21	1.58	0.09

Source: Field Survey, Asiedu (2020). a,b- Means in a row with same superscript are not significantly (P>0.05) different; SE- Standard error

5M60T = 5mins 60 ºC, 5M70T = 5mins 70 ºC, 5M80T = 5mins 80 ºC, 10M60T = 10 mins 60 ºC, 10M70T = 10 mins 70 ºC,

10M80T = 10 mins 80 ºC, 15M60T = 15 mins 60 ºC, 15M70T = 15 mins 70 ºC, 15M80T = 15 mins 80 ºC

The importance of temperature for bacterial growth can be assessed at different critical points between processing and consumption of a product in particular during sample handling and storage of the product. The results from this study show that all the HWM samples from the 9 processed HWM were contaminated with some level of microbes of different genera (Table 17 and 18). The major contaminants were Gram positive bacteria.

Table 17: Mean populations of microorganisms recovered from the HWM on processing lines using three techniques

Boiling Period (mins)	Temperature	Mean (log) (cfu/g)	Species Identified
5	60	10.21±0.76	*Corynebacterium glutamicum*
	70	10.50±0.71	*Staph. aureus*
	80	9.30±0.99	*Corynebacterium spp*
10	60	9.80±0.81	*Corynebacterium spp*
	70	10.21±0.86	*Corynebacterium diphtheriae*
	80	9.54±	*Staph. aureus*
15	60	9.40±0.61	*Bacillus cereus*
	70	9.95±0.92	*Staph. aureus*
	80	9.98±0.74	*Corynebacterium spp*

Source: Field Survey, Asiedu (2020)

Table 18: Three Months Mean populations of microorganisms recovered from the HWM on processing lines using three techniques

Boiling Period (mins)	Temperature	Mean (log) (cfu/g)	Species Identified
5	60	8.7±0.45	*Corynebacterium glutamicum*
	70	8.0±0.21	*Corynebacterium spp*
	80	7.3±0.99	*Corynebacterium spp*
10	60	8.3±0.41	*Corynebacterium spp*
	70	8.1±0.16	*Corynebacterium spp*
	80	7.7±	*Corynebacterium spp*
15	60	8.3±0.61	*Bacillus cereus*
	70	7.8±0.32	*Corynebacterium spp*
	80	7.9±0.44	*Corynebacterium spp*

Source: Field Survey, Asiedu (2020)

Discussion

The highest crude protein content in the hatchery waste meal samples (49.90 %) was similar to values reported for hatchery waste of 48.25% by AACC, (2000), but higher than 44.3% reported by Rasool *et al.*, (1999). A report by Kundu *et al.*, (1986) and Abiola *et al.*, (2012) recorded crude protein content of 42.26% for HWM. These levels of CP suggest that HWM is likely to be highly nutritious and good for use in livestock feed, including those for pigs. This is in support of the findings of Rasool *et al.*, (1999) and Shahriar *et al.* (2008) that HWM has good nutritional attributes with the potential to be used as livestock feed. There are indications that factors which affect crude protein content in HWM are the proportion of egg shells processing technique (particularly the temperature) and treatment period (Khan and Bhatti, 2001). Dufloth *et al.*, (1987) indicated that HWM is highly nutritious and compared favourably with fish meal, and could be a good supplement for cereals or carbohydrate meals. However, while it is rich in calcium, it is low in phosphorus. Calcium level was variable and depended on the presence of shell moiety and hatch percentage. Schaafsma *et al.,* (2002) reported a positive effect of egg shell calcium supplementation (with added magnesium and vitamin D) on bone mineral density (BMD).

The ether extract content of 17.72% was lower than the 20.28% reported by Aydin and Gumus (2012), but higher than the report of Aliu *et al.*, (2014) who obtained a value 5.45%. The higher ether extract content of HWM in this study could be attributed to a higher egg yolk content of infertile eggs in the processed samples.

The average ash content of 27.09-33.46% which could be due to the high content of eggshell at the time of processing. AFRIS (2007) indicated that approximately 84% of the egg shell is ash, of which most is calcium carbonate. In general, the inconsistency in value reported in Table 16 could be attributed to the extremely long steaming periods and drying times to which the hatchery waste was subject to in this study.

In the present study, the processing techniques did not eliminate the viable counts of bacteria completely but managed them to safe levels. All 3 types of processing techniques were found effective in counter acting TCC, as there were no significant ($p > 0.05$) differences in TCC levels in the processed meals. Hatchery waste meal processed for 5 mins at 80°C appears to have the best bacterial load reduction effect. According to USDA (2011), micro-organisms can be found on the outside and inside of the egg shell. The bacteria genera that were isolated were identified as *Corynebacterium glutamicum, Corynebacterium diphtheria, Corynebacterium spp, Bacillus cereus and Staph. aureus*. There was no isolation of enterobacteria species. Results of the present study are in line with findings of Haque *et al.* (1991) who determined total number of aerobic micro-organisms present in unextruded poultry by-product meal diets and reported levels of 47000 cfu/g which could be completely eliminated by a high temperature and short time extrusion process. According to Miller (1984) when hatchery wastes were processed through high temperature extrusion, no *Salmonella* organisms were found. In a similar study, Dhaliwal *et al.* (1996) concluded that *Bacillus* and *Streptococcus* species in raw HW could be eliminated after processing with extrusion. These also agreed with Osei-Somuah (2003) who isolated and identified similar

microorganisms during work in the southern part of Ghana, confirming that these organisms can survive under different temperature conditions (i.e. from 4 °C to 60°C). However, *Salmonella spp.,* a common pathogen of poultry was not isolated in this study suggesting that the organism could not survive the temperatures the HMW were subjected to. The presence of environmental organisms such as *Bacillus, Staphyloccocus and Corynebacterium* spp. in HWM is an indication that these microbes were isolated from the shell surfaces of eggs sampled and also possibly from the deep litter system where eggs are laid on the floor.

Conclusions

The results of this study indicate that HWM which is economically cheaper and regarded presently as waste in the hatchery industry could be possibly used as a feed ingredient for farm animals.

Hatchery waste meal was observed to be highly nutritious. It compared favourably with protein level in fish meal (49.90 Vrs 52.04 %). The study again showed that HWM after simple processing (steaming) ended up without much loss in protein content (5M80T). Hatchery waste meal processed at 5M80T appeared to have the best bacterial load reduction effect as well as highest crude proten level. This processing technique was therefore the selected option to generate HWM to be incorporated in compounding diets for pigs in the production phase of the work reported in the next chapter.

CHAPTER FIVE

Objective 3: Growth performance and cost benefit analysis of using HWM in place of FM in formulating diets for grower-finisher pigs

Introduction

Pig production is a growing enterprise in Ghana. A major limitation however, has been the cost of feeding because of the expensive nature and varying availability of the conventional energy and protein sources used. Feeding costs could be as high as 65-70% in the fattening phase (Rhule *et al.*, 2007) partly due to competition between humans, poultry and livestock for some of these conventional feed ingredients particularly maize and fish meal. It must be noted that fish meal (FM) is the most attractive animal protein source used in Ghana for pig diets mainly because of its high protein content, well balanced amino acid and fatty acid composition, high digestibility and palatability.

However, the high cost of FM and its supply availability are making it impracticable to use regularly in pig feeds. In recent years, a decline in fish stocks on which FM production depend, as well as the increased consumption of fish by a growing human population have intensified the search for alternative animal protein sources (Akiyama *et al.*, 1995). It is therefore economically expedient to explore the use of non-conventional feed resources (NCFR) for animal production. These are mainly agro-industrial animal by-products (AIABP) which are abundant and relatively cheap (Okai *et al.*, 2006). These are also regarded as unused feed resources as they are currently least used for human consumption or nutrition and hence their non-competitive status (Adesehinwa, 2008).

The particular use of animal wastes or by-products has a considerable potential in the diets of livestock (Sonaiya, 1997). Consequently, researchers are currently focusing a lot on replacing fish meal with relatively cheaper animal protein sources (Harlıoğlu *et al.*,2011; Yiğit *et al.*, 2012; Bulut *et al.*, 2014). One such animal product is hatchery waste meal (HWM), a hatchery by-product or waste generated from the poultry industry. Hatchery waste meal consists of shells of hatched eggs, unhatched eggs, dead chicks, unsaleable chicks and embryonic fluids. Hatchery waste meal is partially an animal protein supplement that is readily available from hatcheries. Presently, a huge quantity of hatchery waste is produced that is difficult to properly dispose off and this is adding to the problem of environmental pollution. Successful conversion of this material into a feedstuff suitable for pigs would not only reduce the pollution problem but make available another animal protein source which is cheap and of high biological value for feeding pigs.

Hatchery waste meal after processing reportedly contained about 32% crude protein, 16% ether extract, 0.9% crude fibre, 40% total ash, 11.1% nitrogen free extract, 20% calcium and 0.6% available phosphorus with little or no *Escherichia coli* and *Salmonella* residues (Khan *et al.*, 2007). Apparent metabolisable energy (AME) value of the hatchery waste by-product meal was 23.9 MJ/kg with an apparent amino acid availability of 73.5% (Sharara *et al.*, 1992c).

General Objective

The main aim of this study was to investigate the use of processed HWM to partially or completely replace fish meal as a feed ingredient (source of protein) in formulating diets for pigs

Specific Objectives

The specific objectives of this aspect of the study were to:

- determine the suitability of HWM as protein source in pig diets
- establish the optimum inclusion levels of HWM in the diets of grower-finisher pigs
- determine the effect of including HWM in place of FM on growth and carcass characteristics of grower-finisher pigs
- determine the cost-benefit analysis of replacing fish meal partially or wholly with HWM

Materials and Methods

Study and Location

The study was carried out at the Piggery Section of the Council for Scientific and Industrial Research - Animal Research Institute (CSIR-ARI), Katamanso, Accra, from February, 2018 to July, 2018. The location of the farm is in the coastal savannah zone and situated at the Adentan Metropolitan Assembly area of the Greater Accra Region of Ghana. The average relative humidity for the year is about 65% (mid-afternoon) and 95% (night time) while wind speed usually ranges between 8 and 16 km/h. The monthly temperature varies between 26 and 29 °C. The highest mean monthly temperature of 29 °C occurs during March and April while the lowest of 26 °C is in August. The zone has a bimodal rainfall pattern with the major rainy

season occurring between April and July while the minor season occurs between September and October. A short dry period separates the two periods in August. The major dry season lasts from November to February (Wallace *et al.*, 2012).

Figure 5: Experimental Housing Unit

Source of Hatchery Waste Meal and Processing for Use as Feed Ingredient

Hatchery waste (HW) was obtained from the CSIR-Animal Research Institute's Hatchery at Katamanso, and the NAT Hatchery at Kodiabe, Accra. The hatchery waste (HW) comprised unhatched eggs, infertile eggs, shells, dead-in-shells and low-grade unsalable hatched chicks. **(The details of the preparation procedures have already been previously described in Chapter 4).**

Other ingredients used for the formulation of the experimental diets included palm kernel cake, wheat bran, maize bran, soybean meal, fishmeal, as well as the micro-ingredients (i.e. oyster shells, common salt and vitamin-trace

mineral premix). These were all purchased from accredited feed ingredient suppliers in Ashiaman in the Greater-Accra Region of Ghana.

Experimental Diets

Five (5) diets were formulated to contain 0%, 2.5%, 5.0%, 7.5% and 10.0% HWM, as direct replacement for fish meal (Table 19). All diets were formulated to meet total requirements for essential nutrients by grower-finisher pigs, as recommended by NRC (1998). All the diets were formulated to be isocaloric and isonitrogenous. The processing procedure found to retain most nutrients and reduce most microbial load in HWM was from steaming for 5 mins and subsequently drying at 80 0C for at least 24 hrs. (See Chapter 4, for work on different processing procedures). Table 19 shows the feed ingredients, levels of inclusion and the calculated composition of selected nutrients in the five experimental diets formulated. Batches of the experimental diets were compounded to last for the entire feeding period. Each formulated experimental diet was then, put in sack and labeled appropriately. Table 20, presents a summary of cost per kg of each ingredient used in the formulation of the five diets.

Table 19: Composition of experimental diets containing varying levels of hatchery waste meal (%)

Diet	Levels of HWM inclusion in the diet				
	0% HWM	2.5% HWM	5.0% HWM	7.5% HWM	10.0% HWM
Fish meal	10.00	7.50	5.00	2.50	0.00
Hatchery waste meal	0.00	2.50	5.00	7.50	10.00
Maize bran	60.00	39.00	32.00	28.00	18.25
Wheat bran	2.25	14.25	16.25	18.25	25.00
Soybean meal	0.50	5.00	10.00	12.00	15.00
Palm kernel cake	25.50	30.00	30.00	30.00	30.00
Oyster shell	1.00	1.00	1.00	1.00	1.00
Salt	0.50	0.50	0.50	0.50	0.50
Premix	0.25	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00	100.00
Calculated composition % (as fed/DM)					
ME (MJ/kg)	13.90	13.75	13.99	13.50	13.43
Crude protein	16.43	16.40	16.41	16.44	16.43
Ether extract	7.67	8.05	8.66	8.91	9.32
Crude fiber	6.80	6.58	7.81	8.40	8.37
Lysine	0.61	0.51	0.40	0.30	0.19
Methionine	0.28	0.23	0.19	0.15	0.11
Methionine+Cysteine	0.34	0.31	0.27	0.22	0.19
Calcium	0.83	1.69	2.63	1.73	3.49
Available phosphorus	0.32	0.27	0.22	0.19	0.13
Analysed composition % (as fed/DM)					
Dry Matter	89.11	89.27	89.80	89.64	90.04
Ash	7.30	8.22	9.48	9.60	10.25
Crude Protein	15.56	17.35	15.30	15.96	16.11
Ether extract	7.73	8.23	8.44	8.76	8.87
Crude Fibre	11.48	12.44	14.25	14.69	13.33
NFE	48.14	43.03	42.33	41.63	41.48
ME (Kcal/Kg)	13.11	12.98	13.20	13.41	13.23
Minerals					
Mg	0.22	0.13	0.24	0.17	0.17
Ca	1.34	1.91	1.92	1.99	2.05

**Vitamin and TMP (Trace Mineral Premix): Inclusion rate is 25 kg/tonne to supply the following per tonne of feed: Vit.A, 2,000,000 IU; Vit.E, 15000 mg; Vit.B1, 1500 mg; Niacin 30,000 mg; Vit.B6, 1500 mg; Vit.D3, 4500,000 mg; Vit. K3, 3,000 mg; Pantothenic acid,12000 mg; Vit.B12, 10,000 mg; Vit. B2,6000 mg; Folic acid, 800 mg, Iron, 60,000 mg; Copper 75,00 mg; Iodine, 750 mg; Manganese, 130,000 mg; zinc, 70,000 mg; Selenium, 300mg. calcium,17.50%, Lysine,1,330 mg; Methionine, 1,075 mg; B-Corotenic acid, 350 mg.*

Table 20: Cost of individual ingredients used in the formulation of the experimental diets

Feed ingredient	Price/ kg (GH₵)
*Hatchery waste meal	0.27
Soybean meal	2.60
Maize bran	1.00
Wheat bran	0.65
Palm kernel cake	0.37
Fish meal	3.2
Oyster shell	0.24
Salt	2.00
Vitamin-trace mineral premix	6.00

Source: Field Survey, Asiedu (2020). * *Cost of materials such as polythene sheet, fire wood and transportation of raw HW*

Experimental Animals

Sixty (60) cross-bred Large White grower entire male pigs (average live weight of 17.55 ± 0.1 kg) were selected from the herd at the Katamanso Piggery Section of the CSIR-Animal Research Institute farm for the feeding trial.

Experimental Design and Dietary Treatments

The 60 pigs were randomly allocated to the five dietary treatments in a completely randomized design (CRD) experiment. Each treatment was replicated 4 times, with 3 pigs per replicate. The pigs were group housed in pens partitioned with wire mesh fitted with wood (Figure 5). The 5 dietary treatments were designated: 0.0 % HWM (Control-no inclusion of HWM; i.e

10.0 % FM); 2.5 % HWM (2.5 kg of HWM and 7.5 % FM); 5.0 % HWM (5.0 kg of HWM and 5.0 % FM); 7.5 % HWM (7.5 kg of HWM and 2.5 % FM); and 10.0 % HWM (10kg of HWM and 0.0 % FM) (Table 19). The level of inclusion of HWM was proportional to the FM replaced.

Housing and Management of Experimental Animals

The pigs in each replicate were housed in concrete-floored, well-ventilated pens each measuring 2 x 1.75 m. Each pen had both a nipple drinker and a concrete water trough, as well as molded galvanized plates used as feeding troughs. The walls and floors of the pens as well as feed and water troughs were thoroughly cleaned and disinfected (with Quincide) prior to the start of the study. The pigs were cleaned with water every morning. Routine health and management practices such as the control of endo-parasites and ecto-parasites were initially carried out before the beginning of the study using **Levamisole powder (for treatment of anthelmintic infections caused by adult and larvae stages of gastro-instestinal nematodes and longworms) and *Ivomec, ® (for the control of both endoparasite and ectoparasite; longworms, and lice respectively).* The pigs were ear tagged individually for easy identification.

Feeding and Watering Regime

At the start of the feeding trial, the pigs were weighed individually with a Gascoigne weighing scale to obtain the initial body weights. The pigs were adjusted to the experimental diets for 7 days before data collection commenced. The experimental pigs were fed on restricted basis ie a daily quantity of feed equivalent to 5% of the individual live weight every morning (at 9:00 a.m). Daily feeding ration was measured at the beginning of every

week using the weighing scale (OHAUS MODEL Cs 5000, Capacity 5000×2 g). Water was provided *ad libitum*. The pigs were individually weighed weekly and the daily feed allocation adjusted for the group accordingly for the following week. The pigs were fed until each of them attained a target market live weight of 70 ± 3 kg.

Figure 6: A sty demarcated with wire mesh to serve as replicate pen for pigs

Laboratory Evaluation of Feeds

Ground samples of the five experimental diets were analyzed in triplicate for CP, CF, EE, Ash, NFE and DM, using the standard methods of AOAC (2000) at the National Animal Feed Quality Control Laboratory, CSIR- Animal Research Institute and the Nutrition Laboratory of the School of Agriculture, University of Cape Coast. Metabolizable Energy (ME) and Nitrogen free extract (NFE) were calculated according to the procedures of NRC (1994), as follows:

NFE (%) = 100 - (%moisture + %CP + %EE + % CF + %Ash); whereas,

ME (Kcal/Kg) = 35×Protein (%) + 85×Fat (%) + 35×NFE (%)

Growth Measurements

Live Weight and Live Weight Gain

The initial weight of each pig was taken at the beginning of the study, and subsequentely once every week in order to determine body weight changes for the week. The average daily gain (ADG) was then, calculated by dividing the weekly gain by seven (days). The live weight gained for the week was the difference between the previous week's and the current weight. The difference between the final weight (70 ± 3 kg) and the initial weight of each pig was the total weight gain (TWG) over the entire experimental period.

ADG = final weight (kg) – initial weight (kg)/ Age (Days)

Feed Conversion Ratio

Feed conversion ratio (FCR) defined as the quantity of feed (kg) consumed to gain a unit of live weight (kg) was computed as a ratio of total feed consumed to total weight gained for each pig over the entire experimental period.

Feed Conversion Ratio = feed intake /weight gained

Feed Intake

The weekly feed intake (WFI) was computed every Tuesday throughout the study period. The WFI was obtained by summing the quantities of feed fed to each group of pigs during the week. Feed intake per animal per day was calculated as the difference between feed offered and the spilled/leftover feed (after 24 hours). The summation of WFI for the period a

particular pig stayed on the experiment was described as the total feed intake (TFI) for that pig. Average daily feed intake (ADFI) was determined by dividing average TFI by the number of days the pig took to reach the target weight of 70 ± 3kg.

ADFI = Total feed intake / number of days to target market weight

Feed Cost and Feed Cost per kg Live Weight Gain

Feed cost was the sum total of the prevailing prices of each ingredient used in formulating 100 kg of the experimental diet multiplied by the quantities (kg) of the individual experimental diets consumed by pigs in each treatment over the entire feeding period. The feed cost per kg live weight gain for each pig was calculated as the feed cost/kg live weight gain (i.e. the price of 1kg of compounded feed multiplied by the feed conversion ratio on the corresponding diet).

Feed cost per kg live weight gain = feed to gain ratio (FCR) x price per kg of feed.

Statistical Analyses

Data from the experiment were subjected to analysis of variance (ANOVA) using Generalized Linear Model of the Genstat (2012). Differences among treatment means were determined by Tukey's test and compared at 5 % level of significance.

Results

Proximate Composition of Hatchery Waste Meal and Experimental Diets

Proximate analysis of samples indicated that HWM used for experimental diets contained 99.51 (DM), 49.90 (CP), 17.72 (EE), 33.46 (Ash), 10.20 (Ca) and 5.24 % (P). See (Chapter 5, Table 19). Again, all the diets were formulated to be isocaloric and isonitrogenous (Table 19). Table 21 shows the chemical composition of raw HWM and FM.

Table 21: Chemical Composition of raw HWM and FM (% DM)

Parameters	HWM %	FM %
Crude Protein	49.90	52.04
Ether Extract	17.72	10.37
Dry Matter	99.51	93.24
Ash	33.46	24.15
Ca	10.20	3.30
P	5.24	2.44

Source: Field Survey, Asiedu (2020). n=3; values are means of triplicate determination

Body Weight Change in Pigs

Some growth performance characteristics of the grower-finisher pigs fed on the different experimental diets are presented in Table 22. The initial live weights were similar ($p > 0.05$) across the dietary treatments. There were also no significant ($p > 0.05$) differences in the average final body weights of the pigs fed the five experimental diets. The pigs fed the control diet (0 % HWM) had the lowest ($p>0.05$) average final body weight value (68.17 Kg) in absolute terms compared with those fed the HWM-based diets. The pigs fed

10.0% HWM diet had a comparable ($p > 0.05$) average final weight (68.92 kg) to those fed the 7.5% HWM diet (68.33 Kg).

Average Daily Gain and Feed Intake

Significant ($p < 0.05$) differences in ADG were observed between the control and some of the HWM-based diets (0.48 and 0.49 kg liveweight gain/ day), at 7.5% and 10% inclusion levels respectively. Maximum absolute weight gain (0.58) was observed in pigs fed the 2.5 % HWM diet; but differences were not significantly different ($p > 0.05$) from the control and 5.0% HWM diet.

The data on total feed intake (TFI) of pigs fed the experimental diets revealed that the groups fed on 7.5% HWM (210.49 kg) and 10% HWM (210.92) were significantly ($p< 0.05$) higher compared with those on 0 % HWM (175.12 kg), 2.5 % HWM (172.87 kg) and 5.0% HWM (190.49 kg). Non-significant ($p>0.05$) differences were found among the pigs fed the control diet and the groups fed 2.5 % HWM and 5% HWM diets.

The daily feed intakes by all the pigs were similar ($p>0.05$), being 1.98, 2.03, 1.97, 2.00 and 2.06 kg for 0% HWM, 2.5% HWM, 5% HWM, 7.5% HWM and 10.0% HWM respectively. Daily feed consumption was lowest in absolute terms ($p>0.05$) for pigs fed the 0.0% HWM and 5.0% HWM diets, compared to the other test diets.

Feed Conversion Ratios (FCR)

The feed conversion ratios (FCR) of the diets are presented in Table 22. These were 3.44, 3.40, 3.70, 4.12 and 4.09 for 0% HWM, 2.5% HWM, 5% HWM, 7.5 % HWM and 10.0% HWM respectively. The FCR for pigs fed treatment 0% HWM, 2.5% HWM and 5%, HWM were similar ($p > 0.05$) but

significantly ($p < 0.05$) better than those fed the 7.5% HWM and 10.0% HWM diets.

Days to Slaughter

The mean number of days taken by the grower-finisher pigs to attain the target live weight of 70 ± 3 kg being fed the five experimental diets are shown in Table 22. The pigs were fed the experimental diets over a period from an initial live weight range of 17.55 ± 0.1 kg to a final body weight of 70 ± 3 kg. The pigs fed 0.0%, 2.5 and 5.0% HWM diets took similar periods to reach the target weight and these were relatively shorter ($p < 0.05$) than that taken by pigs on dietary treatment 7.5% HWM and 10% HWM. Pigs fed 2.5% HWM diet took significantly shorter ($p < 0.05$) period to attain the target slaughter weight compared to those fed the 7.5% HWM and 10% HWM diets, but were not significantly ($p > 0.05$) different from pigs fed the 5% HWM and the control (0% HWM) diet.

Table 22 influence of dietary treatments on some growth performance traits of pigs fed HWM

Parameters	Dietary Treatments						
	0% HWM	2.5% HWM	5.0% HWM	7.5% HWM	10.0% HWM	SEM	P-Value
Number of pigs	12	12	12	12	12		
Av. Initial Live Weight (kg)	17.57	18.10	17.34	17.35	17.54	0.336	0.52
Av. Final Live Weight (kg)	68.17	68.75	68.75	68.33	68.92	0.325	0.46
Total Weight Gain (kg)	50.60^{b}	50.65^{b}	51.41^{a}	50.98^{b}	51.38^{a}	0.433	0.55
Av. Daily Gain (kg)	0.55^{a}	0.58^{a}	0.54^{a}	0.48^{b}	0.49^{b}	0.024	0.02
Total Feed Intake (kg)	175.12^{c}	172.87^{c}	190.49^{bc}	210.49^{a}	210.92^{a}	7.220	0.005
Av. Daily Feed Intake (kg)	1.90	1.98	1.90	1.96	2.00	0.055	0.78
Feed Conversion Ratio (feed/gain)	3.46^{b}	3.41^{b}	3.70^{b}	4.12^{a}	4.10^{a}	0.144	0.008
Days to Slaughter	92^{c}	87^{cd}	100^{bc}	107^{a}	105^{ab}	3.767	0.01

Source: Field Survey, Asiedu (2020.) **SEM**– Standard Error of Mean **a, ab**- means in the same row with a common letter superscript are not significantly different ($p > 0.05$). *G-F – Grower-finis*

Feed Costs, Live Weight Gain and Cost Benefit Analyses

The effect of the inclusion of HWM in place of FM on feed cost and cost-benefit analysis of pig production are presented in Table 23. The feed cost per kg for the dietary treatments seem to decrease in absolute terms as the inclusion level of HWM increased in the diets.

The pigs fed the control diet (0 % HWM) had, however, similar ($p > 0.05$) total live weight value compared to those fed the HWM - based diets. The pigs fed the 2.5% HWM diet had a comparable ($p > 0.05$) feed cost per kg live weight to all the others. The revenue generated for the entire production period for pigs fed the dietary treatment HWM 0% (control) was lower (GHC 320.58) in absolute terms than the revenue generated for pigs raised on HWM – based diets although differences were not significant ($p > 0.05$).

Table 23: Cost- Benefits Analysis of grower-finisher pigs fed experimental diets

Parameter	Level of HWM inclusions in the diet /100kg					SEM	P-Value
	0% HWM	2.5% HWM	5.0% HWM	7.5% HWM	10.0% HWM		
Number of pigs	12	12	12	12	12	-	
(a) Cost of pig (GHs)	175.5	175.5	175.5	175.5	175.5	-	
Total Feed Intake/ kg/ pig	175.12	172.87	190.49	210.49	210.92	7.22	0.005
Feed cost per kg (GHs)	1.06	0.99	0.99	0.84	0.90	0.34	0.32
Feed cost/kg gain, GH¢	3.66	3.37	3.66	3.46	3.69	0.48	0.22
(b) Total feed Cost (GHs)	185.62	171.14	188.58	176.81	189.82	-	
(c) Total Costs of G-F (a+b)	361.12	346.64	364.08	352.31	365.32	-	
(d) Selling Price Per Kg live wt (kg) pig (GH¢)	10.00	10.00	10.00	10.00	10.00	-	
(e) Total Weight Gain (kg)	50.60	50.65	51.41	50.98	51.38	0.43	0.55
(f) Av. Final Live Weight (kg)	68.17	68.75	68.75	68.33	68.92	0.32	0.46
(g) Total Income Per Pig (d× f)	681.70	687.50	687.50	683.30	689.20	-	
(h) Revenue generated (g-c)	320.58	340.86	323.42	330.99	323.88	-	

Source: Field Survey, Asiedu (2020). **SEM**– Standard Error of Mean **a, ab**- means in the same row with a common letter superscript are not significantly different (p > 0.05). *G-F – Grower-finisher*

Discussion

Chemical Composition of Hatchery Waste Meal and Experimental diets

The crude protein values for fish meal (52.04 %) and HWM (49.90 %) indicates that the two were comparable and high in protein (Table 21) and could likely be used as protein source in place of each other for pig feeding. The proximate composition of the HWM and FM used in this study was different from those reported earlier (Swain, 2016). These differences in nutrient composition could possibly be attributed to differences in composition, storage conditions and procedures used in the preparation of the product and notably, the drying method used for both HWM and FM. This notwithstanding, the fairly comparable composition of HWM and FM used in the current study suggests that it could likely be used as an alternative to FM which is relatively more expensive (Abiola *et al.*, 2012), thus resulting in a decrease in the cost of feeding pigs.

The analysed value of the control diet could be considered similar to the calculated values (Table 19), as recommended by NRC (1998) similar CP values had been established in other environments. The requirements for nutrients by pigs are influenced by several factors, including temperature, breed, housing and management (Rhule and Asiedu, 2012).

The ash content varied among all the experimental diets. The study recorded a higher ash value for the dietary treatments 7.5%, 5.0% and 2.5% HWM (9.60, 9.48 and 8.22 respectively), compared to the control (7.30). This could be due to increasing shell output. Rasool *et al., (*1999) reported ash contents of between 14.2 and 27.2 among raw hatchery waste cooked at 100°C for 15 minutes and then oven-dried compared to values obtained in this study

which ranged from 27.09 to 33.46. In another study, Kundu *et al.,* (1986) attained lower total ash value of 9.43 in raw poultry hatchery waste, whereas Khan and Bhatti (2002) obtained still lower values of 8.90.

In the present study, 7.5% HWM diet had the highest crude fibre value (14.69) which was significantly ($p < 0.05$) higher than those determined in 10.0% and 5.0% HWM diets (13.33 and 12.44) respectively; followed by the 2.5% HWM and 0 % HWM (12.44 and 11.48) respectively. This implies that increasing levels of the HWM resulted in increasing levels of fibre in diet.

The calcium content of the hatchery waste meal were lower in previous studies (Khan and Bhatti, 2002) than those obtained in the present study (Table 16). Values for inorganic P from this study are similar to those reported by Khan and Bhatti (2002), but lower than those reported by Shahriar *et al.* (2008). The differences in nutrient profile of HWM meal could be explained based on differences in composition of HMW and the conditions and techniques used in processing it.

Calculated metabolizable energy (ME) values for HWM (Table 19) ranged from 2,725.25 to 2,848.05 kcal/kg. In a similar study, the ME content of hatchery by-product (HBP) was found to be 2850 kcal/kg according to Pesti *et al.,* (1986), the value obtained in this study are also comparable to the ME value of 2795 kcal ME/kg diet reported by Sathishkumar and Prabakara (2008), using the same equation. On the other hand, Shahriar *et al.,* (2008) reported values of 3520 kcal/kg based on use of another equation by Rose (1997). In this study, the slight differences observed in ME value among the treatment diets could be ascribed to differences in raw HWM used, state of the materials, ether extract, ash and calcium content (Sathishkumar and Prabakara,

2008; Shahriar *et al.*, 2008). Moreover, differences in processing techniques used could be a contributory factor.

Feed Intake, Average Daily Gain and Body Weight Changes in Pigs

Intake and Average Daily Gain

There is lack of adequate information on the usability of hatchery waste meal in place of fish meal in pig's diets. The level of acceptance or rejection of feed is a common problem when non-traditional feed sources are initially used in monogastric diets (Rodriguez *et al.*, 1996). The pigs were therefore adjusted to the novel ingredient for some days before data collection began. In the present study, it was observed that, all the five experimental diets were equally well accepted by the pigs and so inclusion of graded levels of HWM did not appear to affect the palatability of the experimental diets formulated from it.

Total feed intake values similar to those recorded in this study have been reported earlier when pigs were fed diets containing HWM (Khan and Bhatti, 2002). It has been stated that animals eat to satisfy their energy and protein requirements (Sathishkumar and Prabakara, 2008). The fact that there were no significant differences in average daily feed intake by pigs fed all the experimental diets indicated that HWM had comparable protein content, quality and energy level as FM (Table 21). The results again showed that HWM up to 10% level of inclusion did not appear to affect feed palatability. This trend was also demonstrated by Sathishkumar and Prabakara (2008). Shahriar *et al.*, (2008), however, reported differences i.e the incorporation of broiler hatchery waste in feed resulted in lower feed intake in pigs.

Body Weight Change

In a related study, it was observed that ADG was not significantly ($p > 0.05$) affected by inclusion of varying levels of HWM in diets fed to laying hens (Abiola *et al.*, 2012). In another study it was observed that rations containing hatchery waste meal elicited a better performance in terms of weight gain and feed efficiency in broilers, fed up to 12 % HWM than in others fed similar amounts of fish meal. However, another study using HWM in pig diets had shown a decrease in average daily live weight gain (Orozco-Hernandez *et al.*, 2003). The literature therefore indicates a non-consistent effect of body weight to feeding HWM to poultry and pigs.

The comparison of means (Table 22) revealed that the body weight gain of pigs fed 7.5 % HWM was significantly ($p < 0.05$) lower than pigs fed 5 % and 10 % HWM but similar to those fed 2.5 % and 0 % HWM. These findings indicate that pigs could generally be fed HWM in place of FM without affecting growth performances and survivability.

Feed Conversion Ratios (FCR)

The FCR of pigs fed the diet with 2.5% HWM was better in comparison with that obtained on the control (0% HWM). This could be attributed to differences in the composition and likely protein-sparring effects and subsequently, on feed utilization (Acikgoz *et al.*, 2003). Aggoor *et al.* (2000) and Kim and Easter (2001) argued that the apparent digestibility of poultry hatchery meal (PHM) and subsequently growth response in young pigs could vary depending on the temperature used in drying the meal. Dhaliwal (1998) on the hand, reported that both body weight gains and feed conversion ratio revealed no statistically marked differences among different treatment

groups when HWM replaced fishmeal at 0, 33.3, 66.6 and 100% levels in broiler rations. In a related study, Sathishkumar and Prabakara (2008) reported that PHM waste used in rations (up to 9%) did not negatively affect FCR in laying hens and Japanese quail hens. However, including PHM at 7.25 % and 10.5 % of the diet impaired FCR in laying hens according to Acikgoz *et al.*, (2003).

Feed conversion ratio is the feed consumed per unit weight gain and therefore measures how efficient pigs are at converting feed consumed into meat. The FCR obtained in this study could indicate the possibility of differences in the availability of the nutrients in the diets predominantly amino acids and energy in relation to the requirements of pigs (Gore *et al.*, 1990; Martinez and Knabe, 1990).

Days to Reach Targeted Slaughter Weight

The time of slaughter in this work depended on when each pig on a treatment reached the targeted/set market weight of 70 ± 3 kg. Pigs fed dietary treatments with 0% HWM and 5% HWM took an average of 96 days to attain the target live weight compared to 105 days on the diet with the highest inclusion level of 10 % of HWM. In another study Rhule *et al*, (2006), observed that pigs fed cassava-based diets took an average of 131 days to attain the live weight of 70 kg. Ziema (2017) on the other hand, reported days to slaughter values of 79 to 92 (over initial live weight range of 27±5 kg) when pigs were fed a corn cob-based diet. Amoah (2010) recorded a duration of 115 days when grower-finisher pigs were fed a cereal-based diet supplemented with a direct-fed microbial (over initial live weight range of 10.38 kg to a final body weight of 70 ± 0.3 kg).

The profitability of the pig enterprise depends to a large extent, among other factors, on the duration or time the pig takes to mature, so as to be sold on the market, or the volume of pork produced within the shortest period that can be put through the existing facility. The present study indicated the feasibility of attaining about two times the turn-over of pork within a year using the HWM-based diets. The profitability of using the HWM-based diets (at least up to 2.5 % level of inclusion) has thus been amply demonstrated in this study.

Feed Cost, Live Weight Gain and Economic Benefit Analyses

The dietary treatment with 0% HMW (control) had the highest feed cost per kg (of GHs 1.06). This could be attributed to the high price of fish meal (GHs 3.2) and maize bran (GHs 1.0) when included at 10 and 60 % of total ration (Table 20). It was interesting to note that these economic levels were achieved even when pigs had no significant differences in their daily feed intakes. Although the feed cost/kg of the control diet was higher than those for the other test diets, the live weight gains in pigs were similar for all the dietary treatments. The reduction in feed cost with the higher inclusion levels of HWM in pig diets implies that HWM, as a feed ingredient used in place of FM, has the potential of saving cost, thereby increasing the profit margins of farmers. These agree with findings of Prabakara (2008) who observed that hatchery by-products could be effectively utilized to reduce feed cost in birds. With the exception of the inclusion level of 10% HWM, the control diet (0% HWM) was found to be more expensive ($p<0.05$) than 2.5% level of HWM and 7.5% HWM diet which were in turn also cheaper than the

5% HWM level of replacement for FM. The live weight gain in the pigs was generally improved on the HWM diets compared to that of the control.

Economic Benefit Analysis

The present study indicates that it could be economically feasible and more profitable to feed pigs with HWM-based diets instead of FM, to produce more pigs at a much reduced total cost of production instead of FM. Hatchery waste meal is presently relatively cheaper and might be responsible for the observed decrease in feed cost/kg gain. The high feeding costs observed relative to the control diet as well as on some of the test diets, may be likely due to the higher total feed intake from longer duration or number of days taken to reach the target slaughter weight. The results agree with previous research work by Ugwuene (2002), using high levels of brewers' dried grain (BDG) based diets, and Amaeful *et al.,* (2006) utilizing high levels of palm kernel meal (PKM) plus brewers dried grain (BDG) in diets.

Table 23 further illustrates that the revenue generated per pig was relatively higher for the pigs raised on the HWM-based diets compared to pigs raised without HWM. This observation may likely be due to the differences in cost per kg of all the five experimental diets, as well as the nutritional profile of the ingredients. These likely influenced the rate of gain and the efficiency of utilization of the feeds, consequently affecting the final target weight of the pigs (Abiola *et al.,* 2001). Although the major factors affecting pig performance such as genetics, nutrition and feeding, housing conditions and health are known (*Losinger*, 1998; Cline and Richert, 2001 and Gispert *et al.*, 2007), pigs with higher body weights are generally sold at higher prices, hence increasing the profitability of farm operations.

Conclusions

The results of this phase of the study show that HWM is comparable in proximate composition to FM.

Hatchery waste meal is economically cheaper and profitable (presently regarded as waste in poultry hatchery industry) and can be used successfully in replacing fish meal up to level of 5% in the diets without any adverse effects on the growth performance of grower-finisher pigs.

CHAPTER SIX

Objective 4: Determine the Possible Adverse Effect on Pig fed HWM-Based Diets through the Assessment of some Haematological and Biochemical Studies

Introduction

The intensification of pig rearing has created complex animal health and production problems for which there are no simple and reliable therapeutic and pre-emptive procedures (Ugwuene, 2002). One of the best indicators of an animal's well-being and its potential for production, is its health status. Blood parameters have been shown to be major indices of physiological, pathological and nutritional status of an organism. Any changes in the constituent compounds of blood when compared to normal values could be used to interpret the metabolic state of an animal as well as the quality of the feed (Nasyrova *et al.,* 2006).

According to Okonkwo *et al.*, (2004), blood as a complex mixture has a number of functions in the body. The biochemistry of the blood for example, may bring about significant changes in the structure, function, metabolic transformation and concentration of biomolecules and enzymes pathways (Murray *et al.*, 2000). According to Madubuike and Ekenyem (2006), serum biochemical assay in livestock indicates the physiological disposition of the animal to nutrients. Hence, it is always possible to collect samples of blood from animals and analyze them to find out if a non-conventional feed ingredient has had any negative effects on the blood profile or physiology of the animal.

Disease conditions adversely affect the health or welfare of animals and impair their homeostatic mechanisms, resulting in body disfunctions which may be deadly (Adenkola *et al.,* 2009). The blood, consisting of blood cells and plasma fulfils the transport, regulatory, protective and homeostatic functions in animals (Nasyrova *et al.,* 2006).

Assessment of heamatological parameters on the other hand, can be used to determine the extent of deleterious effect of foreign compounds, including plant extracts on the blood. Such laboratory investigations have been reported to be highly sensitive, accurate and reliable, and remain the bedrock of ethical and rational research, disease diagnosis, prevention and treatment (Okonkwo *et al.*, 2004, Yakubu *et al.*, 2007). Haematological profiles are also important indicators of health and disease in animals, and have become indispensable in the diagnosis, treatment or prognosis of many diseases (Mbanasor *et al.,* 2003).

Determination of the haematological profile reflects the physiological responsiveness of the animal to its internal and external environment (Esonu *et al.,* 2001). Haematological parameters in pigs have been widely studied and have been reported to vary, depending on sex, age, geographical location and experimental procedures adopted (Radostits *et al.,* 1994; Aladi *et al.,* 2008).

However, there is paucity of information on some of the haematological and serum parameter and values in pigs raised on non-conventional diets such as HWM in Ghana. This study therefore, investigated the effect of fishmeal replacement with hatchery waste meal on some selected haematological and biochemical parameters, to be used as indices of the health status of grower-finisher pigs.

Materials and Methods

Study and Location of Experiment

The details of the location have been described earlier in Chapter five.

Experimental Animals and Diets

The details of the experimental animals and diets fed have been described earlier in Chapter five.

Experimental Design and Dietary Treatments

The details of the experimental design and dietary treatments have been described earlier in Chapter five.

Housing and Management of Experimental Animals

The details of the housing and management of experimental animals have been described earlier in Chapter five.

Haematological and Serum Biochemical Studies

Blood Samples Collection

Blood samples were collected from forty (40) experimental animals out of the sixty (60) pigs at the end of the 16 week feeding trial i.e., eight (8) pigs from each treatment. The pigs were placed in a recumbent position on a 4 square-shaped table to restrict their movement. Each pig was bled using a sterile needle and syringe via the ear (auricular) and tail (coccygeal) vein, to collect about 4 ml of blood into labeled sterile ethylene diamine tetra acetic acid (EDTA) vacuum tubes, for haematological analysis. All the forty selected experimental animals were also bled through the ear (auricular) vein and tail (coccygeal) vein to collect about 4 ml of blood into labeled sterile vacutainer gel tubes, for blood biochemical studies.

Figure 7: Experimental pig bled via tail (coccygeal) vein

Figure 8: Experimental pig bled via ear (auricular) vein

Haematological Studies

For each sample, Mindray BC-2800Vet ® automated haematology analyser was used to obtain the full blood count (FBC) following the

manufacturer's instructions. The following haematological parameters were determined: Haemoglobin (Hb), Haematocrit (HCT), Red Blood Cell (RBC), Mean Cell Volume (MCV), Mean Cell Haemoglobin (MCH), Mean Cell Haemoglobin Concentration (MCHC), Platelets, White Blood Cell (WBC), Mean Platelet Volume (MPV) and Procalcitonin (PCT).

Serum Biochemical Studies

The blood samples for serum metabolites were placed in vacutainer tubes, without anticoagulants, and sent to the laboratory. The tubes were kept on a wooden rack, and the blood samples were allowed to clot. The serum (supernatant) was separated by decanting, after the blood samples were spun in a centrifuge, at 3000 rpm for 10 minutes. The serum samples were kept in sterile eppendorf tubes and deep frozen at -35C, prior to analysis. For each sample, Mindray Semi-auto Chemistry (model: BA-88A) analyzer was used, with *in-vitro* diagnostic kits, to obtain the quantitative serum profile, following the manufacturer's instructions. Parameters determined were; urea, total cholesterol, aspartate aminotransferase (AST), and alanine aminotransferase (ALT), total protein (TP), albumin, globulin, creatinine, high density lipo protein (HDL), low density lipo protein (LDL), total bilirubin, direct bilirubin and triglyceride.

Statistical Analyses

Data from the experiment were subjected to analysis of variance (ANOVA) using Generalized Linear Model of the Genstat (2012). Differences among treatment means were determined by Tukey's test and compared at 5 % level of significance.

Results

Haematological Indices in blood of pigs fed HWM-based diets

Table 24 shows the haematological profile in the blood of pigs fed the five dietary treatments. The results did not show any significant ($p>0.05$) difference among the grower pigs fed all the dietary treatments except for the plateletcrit. The plateletcrit values were significantly influenced ($p<0.05$). The highest plateletcrit value was recorded for pigs fed diets with 10.0% HWM (0.84) while the lowest was registered in those fed 2.5% HWM-based diets. The level recorded in the pigs fed the 10% HWM-based diet was significantly ($p > 0.05$) different from the rest.

Table 24: Haematological indices in blood of pigs fed varying levels of HWM in diets

Parameters	0% HWM	2.5% HWM	5.0% HWM	7.5% HWM	10.0% HWM	Range of Values (normal)	SEM	P- value
Haemoglobin (g/dl)	11.46	10.29	12.57	11.09	11.88	10.0-16.0	0.56	0.08
Hematocrit (pg)	34.41	31.06	31.06	33.26	36.95	28.0 -51.0	1.94	0.19
Lymph ($10^3/\mu L$)	11.37	9.59	10.26	9.84	10.20	40.0 – 60.0	0.55	0.21
Pack cell volume	44.12	42.44	41.94	42.84	43.23	32.0 – 50.0	0.88	0.49
Mean platelet volume	14.53	10.36	11.93	14.64	16.28	5.0 – 20.0	1.81	0.18
Mean Corpuscular Haemoglobin	19.04	18.74	22.34	18.96	18.86	17.0 – 24.0	1.44	0.35
Mean Corpuscular Haemoglobin Concentration	44.25	44.27	44.49	44.50	44.29	30.0 – 54.0	0.38	0.98
Mean Corpuscular Volume	43.23	42.44	41.94	42.84	44.12	40.0 – 68.0	0.88	0.49
Plateletcrit	0.53^{bc}	0.42^{c}	0.45^{c}	$0.62b^{c}$	0.84^{a}	0.0 – 2.0	0.08	0.01
Platelet count	809.	530.	590.	918.	1166.	325 – 715	185.3	0.134
Red blood cell ($x10^{12}/L$)	6.01	5.48	6.60	5.83	9.72	5.0 – 10.0	1.548	0.317
White blood cell ($x10^9/l$)	19.88	18.14	17.54	17.19	16.68	7 – 22	1.165	0.366

Source: Field Survey, Asiedu (2020). ***SEM****– Standard Error of Mean* ***a, ab****- means in the same row with a common letter superscript are not significantly different (p > 0.05). Values quoted for normal range of haematological indices are from Merck manual (2017)*

Effects of HWM in the Diet on Some Serum Metabolites Levels in Pigs

The results from the serum biochemical assays for total protein, globulin, albumen, total cholesterol, triglycerides, sodium, potassium, chlorine and both high and low lipoproteins in the blood of the experimental pigs fed varying levels of HWM are presented in Table 25. The values for ALT in the serum of pigs fed 0% HWM (control), 2.5% HWM, 5.0% HWM, 7.5% HWM and 10.0% HWM (at 29.60 mmol/l, 34.00 mmol/l, 38.10 mmol/l, 27.20 mmol/l and 37.90 mmol/l respectively) were significantly different from each other ($p < 0.05$). Pigs fed 5.0% HWM had the highest ALT level, while pigs fed 7.5% HWM diet had the lowest ALT level. Creatinine levels in pigs fed 5.0%, 7.5% and 10% HWM diets were similar ($p>0.05$), at 1.02 umol/l, 0.97 umol/l and 0.90 umol/l respectively. The highest value of 1.17 umol/l was obtained for pigs on the 2.5% HWM diet, which was significantly different ($p< 0.05$) from the other treatments. Pigs on 10.0% HWM had the lowest value for creatinine (at 0.90 umol/l).

There were significant differences ($p < 0.05$) in the HDL cholesterol contents in the sera of pigs fed 0.0% HWM (control), 2.5% HWM, 5.0% HWM, 7.5% HWM and 10.0% HWM diets in a decreasing order of 32.98 umol/l, 32.85 umol/l, 30.72 umol/l, 29.91 umol/l and 29.03 umol/l respectively.

Table 25: Biochemical indices in blood of pigs fed varying levels of HWM in their diet

Parameters	0% HWM	2.5% HWM	5.0% HWM	7.5% HWM	10.0% HWM	Range of Serum constituents	SEM	P- value
ALP (unit/l)	172.9	190.4	223.6	212.2	209.5	120-400	21.86	0.510
ALT (unit/l)	29.6^{bc}	34.0^{bc}	38.1^{a}	37.9^{a}	27.2^{c}	31-58	2.42	0.010
AST (unit/l)	32.4	26.8	28.5	23.9	20.4	32-84	2.98	0.080
G G T (unit/l)	36.9	33.6	46.4	40.4	41.0	-	4.67	0.400
Total Protein (g/l)	69.00	70.10	69.60	65.70	63.60	20-80	3.10	0.519
Albumin (g/l)	4.67	4.70	4.80	5.44	5.92	2-8	0.619	0.536
Glogbin (g/)	64.3	64.9	65.3	59.8	58.2	-	3.00	0.334
Total Cholesterol (mmol/L)	157	137	119	117	105	28-48	32.3	0.817
HDL (mmol/L)	32.98^{a}	32.85^{a}	30.72^{bc}	29.91^{c}	29.03^{c}	21-43	0.691	<.001
LDL (mmol/L)	58.4	54.5	53.0	51.6	46.7	-	5.74	0.695
Direct Bilirubin (mmol/L)	0.311	0.275	0.300	0.180	0.313	0.01-0.5	0.0375	0.103
Total Bilirubin (µmol/L)	0.850	0.562	0.812	0.436	0.562	-	0.1089	0.053
Triglyceride (mmol/L)	2.23	2.52	2.60	1.96	1.30	-	0.337	0.070
Creatinine (µmol/L)	1.00^{bc}	1.17^{a}	1.02^{bc}	0.97^{bc}	0.90^{c}	-	0.06	0.046
Urea (mmol/L)	5.24	6.80	6.37	5.19	5.14	10-30	0.454	0.067

Source: Field Survey, Asiedu (2020). **SEM**– Standard Error of Mean **a, ab**- means in the same row with a common letter superscript are not significantly different ($p > 0.05$). *Values quoted for normal range of haematological indices are from Merck manual (2017)*

Haematological Parameters

The blood cells and plasma fulfil transport, regulatory, protective and homeostatic funtions in the body (Nasyrova *et al.*, 2006). Normal blood parameters of pigs have been reported from many parts of the world including Ghana (Adenkola and Durotoye, 2004). Haematological values in farm animals are influenced by nutritional status as well as other factors (Church *et al.*, 1984). The various haematological parameters are therefore, good indicators of the physiological and pathological changes in animals (Hawkey and Dennett, 1989; Adenkola and Durotoye, 2004) and are also, an excellent means for the measurement of potential biomarkers (Adenkola *et al.*, 2009). The values for haemoglobin (Hb) recorded by all the treatment groups (Table 24) were, however, within the normal range for pigs (Research Animal Resources, 2009; Merck, 2017). The mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC) values obtained in this study were not affected by dietary treatments. The mean cell haemoglobin concentration (MCHC) values were within the normal ranges for pigs (Merck, 2017), compared to the work of Eze *et al.*, (2010) but lower than the ranges reported by Frienship *et al.* (1984). The values were, however, higher than those recorded by Rispat *et al.*, (1993). The differences could be as a result of differences in the diet, environmental, seasonal variations and other factors (Harapin *et al.*, 2003).

The red blood cell indices (MCH, MCV, and MCHC) are reported to be important morphological characteristics of anaemia (Etim *et al.*, 2013). Values for white blood cell (WBC) count for the HWM groups compared

favourably with of the control, and were within the normal range (11-22). The highest HWM inclusion level (10%) had no negative effect on the WBC.

The levels of lymphocytes were equally not affected by the dietary treatments. Haematological values are of great diagnostic importance in practical husbandry since they reflect the response of the animal to its environment and diseases (Etim *et al.*, 2013). They can also act as useful aids to prognosis and may reveal adverse conditions even when the animal does not display obvious clinical signs of ill-health (Adenkola *et al.*, 2009). A deviation from normal haematological values (Table 24) is, therefore, a good indication of what is happening in the body. It has been observed that when haematological values are within the standard range, it is a fair indication that dietary treatment did not have any negative influence on haematological indices during the period of the study. However, when the values are below the standard range then it is a likely sign of anaemia (Togun *et al.*, 2007).

Packed cell volume (PCV) has reportedly been used used as an index of toxicity and its reduction in blood concentration usually suggests the presence of toxic factors such as haemaglutinin which has adverse effect on blood formation (Jiwuba *et al.*, 2016). Though the PCV values obtained for all the treatment groups in this study fell within the reported values for apparent healthy pigs according to Merck (2017) the range of PCV in this study was different and higher than those reported (29.0-38.0%) by Iheukwumere and Herbert (2003). However, the figures are similar to the reported value of 41.50% (Nworgu *et al.*, 2007) when weaner pigs were fed similar diets. According to Nwanbe and Elechi (2009), lower values of PCV and Hb imply

high level of blood dilution and thus, low efficiency of cellular oxygen transportation.

Biochemical Parameters

The results for the serum biochemical assay are shown in Table 25. Values for urea were higher in pigs fed HWM diets compared to the control diet. The values for urea, which ranged from 5.14 to 6.80 mmol/l in this study, were considerably lower than the 21.01 to 24.00mmol/l when pigs were fed poultry waste meal (Nworgu, 2004); 10.01 to 19.00 mmol/l when weaner pigs were served HWM; but similar to 3.72 to 6.04 mmol/l when pigs were fed Poultry waste meal (Fasuyi and Ibiayo, 2013). Iyayi and Tewe (1998) had earlier reported that the blood urea level depended on both the quality and quantity of the protein supplied in the diet of pigs. Higher levels of urea in the blood could be attributed to the presence of some anti-nutritional factors which might have compromised the quantity and hence the quality of the protein.

The liver enzymes namely alanine amminotransferase (ALT) and aspartate amminotransferase (AST) had the lowest values when the 10.0% inclusion level of HWM is considered. The value of ALT was significantly higher in pigs fed 5.0% HWM compared to those fed the control diet. The range of ALT values (27.2-38.1 mmol/l) in this study was found to be higher than the previously reported values of 23.50-24.84 mmol/l (Nworgu, *et al.*, 2007).

Albumin value was observed to be lowest at 0.0% HWM inclusion level and highest at 10.0% HWM inclusion (Table 25). The non-significant ($p > 0.05$) albumin variation for all diets in this study contradicted a report when

poultry waste meal was used as protein supplement to pigs (Fasuyi and Nonyerem, 2007) but similar to the significant difference reported when HWM supplement was fed to grower finisher pigs (Nworgu, *et al.*, 2007). The results indicate that cholesterol levels were not significantly affected by the five dietary treatment but there was a decreasing trend as the level of HWM increased and this could suggest a dietary influence.

Cholesterol is an essential structural component of the cell membrane and lipoproteins serve as the base for steroid hormones and bile acids (Yeagle, 1998). It has been shown that there is an association between blood levels of cholesterol and the risk of coronary heart disease in humans (Stamler *et al.*, 1986) as well as premature development of atherosclerosis (Oliver, 1990). There was a decreasing trend in the mean values of total cholesterol as the level of HWM increased and this could suggest that HWM can produce pork with reduced cholesterol level. This also means that coronary artery diseases which are associated with high levels of blood cholesterol and fat from animal products may be reduced with inclusion of HWM in the diet of pigs.

According to Lewis *et al.*, (2002), having higher values of high-density lipoprotein (HDL) is associated with better health. The values obtained in this study were below those reported by Tengan *et al.*, (2012) but were within the normal range (Table 25). High density lipoprotein is believed to transport cholesterol back to the liver for excretion or to other tissues that use cholesterol to synthesize hormones in a reverse cholesterol transport. On the contrary, it is interesting to note that, a high value of low-density lipoprotein-cholesterol (LDL-cholestrol) is related to the cause of strokes, heart attacks, and other severe medical problems Lewis *et al.*, (2002). The values obtained

for both LDL and HDL-Cholesterol in this study agree with Nworgu *et al.*, (2007) who reported that higher mean values for HDL and lower values for low density lipoprotein are associated with better health outcome.

Serum total protein steadily decreased with increase in dietary HWM levels although the differences were not statistically significant (Table 25). The total protein, albumin, creatinine, urea and glucose concentrations are reportedly good indices of protein and energy metabolism and tissue wastage; while the serum enzymes such as ALP, ALT and AST are indicative of hepatic function or injury (Nworgu, *et al.*, 2007). This implies that the HWM inclusion in the diet of grower-finisher pigs had no deleterious effect on the tissues and organs as well as energy and protein metabolism in the grower-finisher pigs.

Conclusions

In conclusion, all the haematological parameters and serum metabolites examined in the test animals compared with the control which indicated that the inclusion of HWM up to 10% was safe nutritional regime that would not impact adversely on haematology and biochemical indicators of the used animals. Again, it can be concluded that HWM could be a suitable ingredient in a healthy diet to replace fish meal (up to 10% inclusion levels). Finally, the result is also a demonstration that pigs used in this experiment were apparently healthy throughout the study period as buttressed by the growth profile, haematological and biochemical principles assayed and evaluated.

CHAPTER SEVEN

Objective 5: Carcass Evaluation of Pigs fed Diets in which HWM Replaced Fishmeal at Varying Levels

Introduction

The increasing cost of feed resources in pig production have been identified as a serious impediment in meeting the demand for animal protein particularly in developing countries (Colpoys *et al.,* 2016). The search for alternatives feed ingredients has been the focus of animal nutritionists for a long time (Onyimonyi and Okeke, 2005). De Haer *et al.*, (1993) found that pigs with different nutritional motivations and feed intake patterns have different carcass and meat quality characteristics. In a related study, the pigs with the lowest rate of feed intake and the lowest feed consumption recorded lower carcass characteristics over the period of study (Colpoys *et al.*, 2016). In a related study, the pigs with the lowest rate of feed intake and the lowest feed consumption recorded lower carcass characteristics over the period of study Colpoys *et al.*, 2016).Pigs with the fastest feeding rates or highest feed consumption might also be those with the greatest feed intake, growth rates and carcass fatness, which would in turn affect the lipid content and hence quality of the meat. However, few studies have examined the effect of the feeding behaviour on carcass traits and meat quality.

Pigs have the ability to grow and reach market weight much faster than ruminants (Madubuike and Ekenyem, 2001). Meat plays a significant role, as animal protein source in human diets, by supplying essential amino acids needed for growth, development and repair of worn out tissues. Meat is an

important foodstuff but one of the most expensive components of human nutrition (Šubrt and Mikšik, 2002).

Meat provides valuable amounts of protein, fatty acids, vitamin, minerals and other bioactive compounds. The demand for lean pork is rapidly increasing since consumers have become more health conscious (Onyimonyi and Okeke, 2005). Quality pork evaluation is however very important in improving meat production (Bulens *et al.*, 2017) as well as carcass palatability and acceptability to the consumer (Renand and Fisher, 1997). An early Swedish study (Edwards, 2003) indicated that price and taste of pork were the main concerns when it came to the consumers' choice of meat. The study again showed that the consumers preference regarding pork was dictated by freshness and appearance. The aim of this study was to determine some carcass characteristics of pork produced from pigs fed on the five experimental diets in which FM had been replaced at varying levels with HWM.

Materials and Methods

Study and Location of Experiment

The details of the location have been described earlier in Chapter five.

Experimental Animals and Diets

The details of the experimental animals and diet have been described earlier in Chapter five.

Experimental Design and Dietary Treatments

The details of the experimental design and dietary treatments have been described earlier in Chapter five.

Housing and Management of Experimental Animals

The details of the housing and management of experimental animals have been described earlier in Chapter five.

Slaughtering and Dressing of Pigs

Pigs were slaughted on attaining an individual target or market live weight of 70 ± 3 kg after the weekly weighing, for the carcass quality evaluation. Eight (8) grower-finisher pigs were randomly selected from each dietary treatment, weighed on a Gascoigne weighing scale. Before slaughter, the pigs were fasted overnight but had access to water and they were slaughtered at the Meat Processing Center of the Council for Scientific and Industrial Research-Animal Research Institute (CSIR-ARI).

An electric stunner was used to stun the pigs, stuck with a sharp knife to cut the jugular vein and carotid artery and allowed to bleed for about 2 minutes. The dead pigs were scalded (100 ^{o}C) immediately after bleeding and the bristle scraped off with sharp knives. The remaining hairs were singed with a blow pump flame using liquefied petroleum gas (LPG) as fuel. The carcasses were then hanged washed and eviscerated.

Warm dressed weight was determined as the whole carcass weight after the removal of the viscera. The viscera (internal organs) were collected into a weighing container and after washing off the clots of blood and fluids, the weight was determined and recorded using a table top scale[1](*CAMRY Scale of 441bs x 202/20kg x 50g capacity Made in China).* The liver, kidneys, heart, spleen, thymus gland and respiratory organs were separated and

weighed individually, as described by Bridi and Silva (2007). After the removal of the visceral organs, the remaining part was designated as carcass weight. This was later expressed as a percentage of the live weight to obtain the dressing percentage. The head was removed by cutting off at the occipito-atlas joint and the feet by sawing through the hock joint at a right angle to the long axis of the leg. The warm carcass was chilled in a freezer for 24 hours at 4 ^{o}C to obtain the chilled carcass weight.

The chilled carcass was divided longitudinally and the left half of the carcass was used for the carcass evaluation as described by Barca *et al.*, (2006). The ham was separated by locating the division between the 2nd and 3rd sacral vertebrae and sawn perpendicularly along the axis of the ham. The shoulders of the carcass were separated from the loin and belly by a straight cut between the second and third ribs, and a straight cut 2.5 cm ventral to the ventral edge of the scapula. The individual parts were then weighed and recorded. The backfat depth was measured from these three points i.e the first rib, last rib and rump. The P^2 value was assessed by measuring the depth of back-fat at the P^2 position (taken 6.5 cm from the dorsal mid-line and at the head of the last rib) according to the method describe by Merkel *et al.*, (1993).

Statistical Analyses

Data from the experiment were subjected to analysis of variance (ANOVA) using Generalized Linear Model of the Genstat (2012). Differences among treatment means were determined by Tukey's test and compared at 5 % level of significance.

Results

Physical Measurement

The carcass characteristics of the pigs as affected by dietary inclusion of HWM are presented in Table 26a and 26b. The results from this study shows that the five dietary treatments did not have significant influence ($p > 0.05$) on the live weight prior to slaughter, carcass length, warm carcass weight and chilled carcass weight of the grower-finisher pig.

Backfat Thickness, P2 Measurement and Loin Eye Area

The mean backfat thickness (BFT), P2 measurement and loin eye area (LEA) for the pigs fed the dietary treatments HWM 0%, HWMM 2.5%, HWM 5%, HWM 7.5 and HWM 10.0% were 1.12, 1.20, 1.13, 0.93 and 1.48 cm (BFT); 0.82, 0.62, 0.70, 070 and 0.91 cm (P^2) and 5.59, 5.62, 5.73, 5.61 and 5.60 cm^2 (LEA) respectively (Table 26a). Although there were no significant ($p > 0.05$) differences among the mean values for backfat thickness, P2 and loin eye area across the five dietary treatments, pigs on the HWM dietary treatments had larger loin areas and less fat (backfat thickness and P2) in their carcasses.

Weight of some organs and Prime Cuts

Values recorded for the internal organs, i.e. heart, spleen, empty stomach, thymus gland, empty GIT, full GIT, liver, respiratory tract, kidney and mesenteric lymph are shown in Table 26a. For prime cut, pigs fed 7.5 % HWM had significantly ($p < 0.05$) heavier head weight than pigs fed 2.5 % HWM but similar to their counterparts fed 0, 5 and 10% HWM.

There were no significant ($p > 0.05$) dietary treatment effects on all the parameter mentioned above except empty stomach, empty GIT and the thymus gland.

Table 26a: Carcass Characteristics of grower finisher Pigs fed the Five Different Experimental Diets

Parameters	Dietary treatment					LSD	SED	P. value
	0% HWM	2.5% HWM	5.0% HWM	7.5% HWM	10.0% HWM			
Physical measurements								
Live weight (kg)	68.25	68.50	68.75	68.75	68.62	1.46	0.50	0.951
Warm weight (kg)	47.38	46.75	47.31	47.81	46.38	1.35	0.46	0.244
Chilled weight (kg)	45.44	44.34	45.12	45.50	44.00	1.25	0.43	0.072
Carcass length (cm)	72.00	71.38	72.00	73.69	70.75	2.12	1.03	0.092
Measurement of Fat								
Backfat average (cm)	1.12	1.20	1.13	0.93	1.48	0.61	0.35	0.379
P2 measurement (cm)	0.82	0.64	0.70	0.70	0.91	2.43	0.84	0.389
Exposed surface								
Loin eye area (cm^2)	5.59	5.62	5.73	5.61	5.60	0.44	0.15	0.6925
Weight of Prime Cuts								
Hand (kg)	2.67	2.81	2.81	2.91	2.81	0.33	0.11	0.702
Head (kg)	6.03^{ab}	5.53^{a}	5.81^{ab}	6.33^{b}	5.78^{ab}	0.44	0.15	0.012
Rib back (kg)	2.63	2.54	2.54	2.48	2.57	0.24	0.08	0.806
Rib steak (kg)	1.58	1.61	1.46	1.45	1.41	0.15	0.05	0.052
Rump back (kg)	2.45	2.61	2.34	2.48	2.58	0.34	0.11	0.522
Rump steak (kg)	1.20^{ab}	1.38^{b}	1.09^{a}	0.95^{a}	1.15^{ab}	0.19	0.06	0.002
Thigh (kg)	5.01	5.21	5.21	5.17	5.21	0.21	0.07	0.300
Trotters (kg)	0.82	0.80	0.77	0.82	0.77	0.09	0.03	0.692

*Source: Field Survey, Asiedu (2020. **SEM**– Standard Error of Mean **a, ab**- means in the same row with a common letter superscript are not significantly different ($p > 0.05$).*

Table 26b: Carcass Characteristics of grower finisher Pigs fed the Five Different Experimental Diets

Parameters	Dietary treatment					LSD	SED	P. value
	0% HWM	2.5% HWM	5.0% HWM	7.5% HWM	10.0% HWM			
Weight of organs								
Viscera (kg)	13.39	12.26	13.39	14.49	12.56	1.67	0.57	0.087
Empty GIT (kg)	2.76^{a}	3.15^{ab}	3.38^{b}	3.18^{ab}	3.05^{ab}	0.38	0.13	0.043
Empty stomach (kg)	0.46^{a}	0.52^{ab}	0.53^{ab}	0.61^{b}	0.63^{b}	0.08	0.03	0.003
Fillet (kg)	0.21	0.21	0.21	0.19	0.20	0.02	0.01	0.403
Full GIT (kg)	7.30	7.80	7.70	8.90	14.70	8.25	2.85	0.335
Liver (kg)	1.19	1.05	1.18	1.21	1.17	0.21	0.07	0.583
Respiratory tract (kg)	0.52	0.65	0.68	0.81	1.66	1.18	0.41	0.317
Thymus gland (g)	25.20^{ab}	34.00^{b}	23.00^{ab}	22.90^{ab}	19.40^{a}	9.30	3.21	0.038
Spleen (g)	116.60	118.90	80.10	84.00	85.20	36.57	12.62	0.085
Heart (g)	319.00	316.00	222.00	236.00	188.00	96.10	33.20	0.310
Kidney (g)	278.00	292.00	232.00	229.00	212.00	89.80	31.00	0.313
Mesenteric lymph (g)	780.20	738.90	572.00	547.90	448.60	254.60	87.90	0.067
Collar (kg)	2.20	2.14	2.14	2.21	2.16	0.30	0.10	0.982

Source: Field Survey, Asiedu (2020). **SEM**– Standard Error of Mean **a, ab**- means in the same row with a common letter superscripts are not significantly different ($p > 0.05$).

Discussion

Physical Measurement

The indices considered for the pig carcass evaluation were found to be similar for all the dietary treatments. This implies that pigs can tolerate up to 10% inclusion level of HWM in their diets. These findings also confirm the findings of previous researchers such as Lantei (2008) and Asiedu (2014) who reported no significant differences ($p > 0.05$) in dressed weight and dressing percentage when starter-grower pigs were fed agro-industral by- product-based diet.

The dietary treatment with 7.5% HWM had the highest warm weight, chilled weight and carcass length and these were, however, not significantly ($p > 0.05$) different from pigs fed the control and other experimental diets. Perhaps this was as a result of the varying termination prriod or time allowed for all pigs to attain the target slaughter weight of 70 ± 3 kg. It also suggests that all HWM based diets had similar nutritional effects on pigs as that of the control diet.

Backfat Thickness, P^2 Measurement and Loin Eye Area

Pigs fed the HWM-based dietary treatments tended to have leaner carcasses as they had less backfat and P2 measurements and larger loin eye areas. Adams *et al.*, (1972); cited by Amoah (2010), had earlier made a similar observation. This again suggests that pigs fed the HWM-based diets may have used much of the energy in their feed for muscle tissue development rather than for fat deposition. Also, the lower energy level in the HWM-based diets meant that there were less excess energy to be converted into fat, therefore pigs were leaner. Generally, consumers prefer lean meat and tend to

discriminate against high fat meat due to health concerns. These findings are in agreement with the work of Fombad and Maffeja (2000); cited by Ziema, (2017) who reported that the high fibre diets (as in HWM-diet) given *ad libitum* usually result into lean pork carcasses.

Weight of Internal Organs and Primal Cuts

There were no significant ($p > 0.05$) dietary treatment effects on all the organ parameters measured, except for weight of empty stomach. These suggest that HWM-based diets fed to pigs had little influence on their internal organ weights and thus conforms with work done by Tengan *et al.*, (2012) In a similar study, Mehdipour *et al.*, (2009) observed that HWM in diets of pigs had no significant effects ($p > 0.05$) on the weights of internal organs. The non-significant ($P > 0.05$) difference recorded in this study for the major internal organs of pigs fed both the control and HWM-based diets further agrees with the works of Shahriar *et al.*, (2008). Work done by Tengan *et al.*, (2012) observed a similar pattern when they fed varying levels of African Locust Bean Fruit Pulp (which is high in fibre) to growing pigs. Additionally, Abiola (2001) and Shahriar *et al.*, (2008) similarly reported non-significant effects ($p>0.05$) on the eviscerated weights when cockerels were fed hatchery waste meal-based diets, which undoubtedly affirms results from this study. The mean weight values recorded for empty stomach as shown in Table 26, was significantly ($p<0.05$) different. The rump steak in pigs fed 2.5% HMW was significantly ($p<0.05$) heavier than those fed treatments 5.0% HWM and 7.5% HWM but similar ($p>0.05$) to treatment 0% HWM and 10.0%. HWM. Although, the difference observed in this study could not be conclusively

attributed to any one factor since they are all in line with those reported by Abiola (2012).

Conclusions

The study shows that HWM had no effects on the carcass characteristics, internal organ weights and some primal cuts measured, except for rump steak and empty stomach weight. Whereas empty stomach weight values were markedly heavier in pigs fed the HWM based diets compared to those on the control, rump steak was best on HWM 2.5 %.

CHAPTER EIGHT

General Discussion, Conclusions and Recommendations

A step towards answering questions raised at the start of this thesis was to identify how Greater Accra hatcheries handled and disposed off hatchery wastes and also determine quantities of hatchery waste generated per year. A qualitative survey data collected from five HPs was used to estimate the quantities of hatchery waste generated and also helped in assessing the procedures of handling and disposing off these waste materials.

The outcome of the questionnaire led to a reviewed of alternate method of handling and processing HW which could render it safe for use as an ingredient for livestock feed. The results indicated that an annual average of 25 tonnes of waste was produced from the 5 hatcheries surveyed in Greater Accra Region. Only one of these hatcheries was operating at 60% of its full capacity, based on the quantities of eggs that could fully fill available incubator space. This is an indication, comfirmed by Poultry Site (2014) and cited by Djang-Fordjour, (2016) to the effect that Ghana's hatchery industry is operating well below expectations due to unrestricted trade liberalization that permits the uncontrolled importation of avian products.

It was well established from the studies that waste produced in the hatchery was mostly disposed of using garbage collectors. Such waste was directly applied into the soil (at dumping sites), which subsequently pollutes the environment, including the ground water. It was however; clear from the study that the cost of waste disposal was not known because most hatchery operatives disposed of their waste by incineration and others placed their waste manually into a bin to be collected and sent to the land fill sites. Most of

the hatcheries had no environmental issues with hatchery waste on site, although some reported challenges with bad odour. On the contrary, Glitz and Miao (2009) reported that the costs of disposing hatchery waste to land fill is very high, which was not the case observed during the survey. At the end of the trial, the preparatory technique found to retain most desirable nutrients was from steaming at 5 mins and subsequently, drying at 80 ^{0}C for at least 24 hrs. This was therefore adopted to generate HWM for incorporation into feeds.

Proximate analysis of processed HWM in this study showed that the material contained 49.90 (CP), 17.72 (EE), 33.46 (Ash), 26.55 (Ca) and 1.99 % (P). A related study recorded lower values of 36 % CP, 27 % ether extract, 17 % ash, 10 % calcium and 0.6 % phosphorus by Kirkpinar *et al.*, (2004), when hatchery waste was cooked with water (at 2:1 ratio), at 100 ^{o}C for 5 hours followed by boiling at 130 ^{o}C for 1 hour; then dehydrating to a dried product. The long processing method appears unfavourable in processing HWM. The level of CP obtained in this study suggests that HWM was comparable to fish meal and can conveniently be used as replacement for fish meal. Unfortunately, the discovery that the processed HWM was contaminated with some microbes could be of some health concern. Several factors have been implicated in egg contamination. Among these were faeces of the birds, litter material, egg crates, packing and storage. Others are from clothing and hands of poultry workers, dust, environment, weather conditions, transporting and marketing. In this study, the low mean log of 9.30 (5M80T = 5mins 80 °C) recorded for the isolate of HWM is above the ICMSF value of 6.00. The common isolates identified in this study were *Corynebacterium glutamicum, Corynebacterium diphtheriae, Staph. Aureus, Bacillus cereus and*

Corynebacterium spp. However, *E. coli and Salmonella* bacteria of public concern, were not isolated; and this suggests that all the eggs were *enterobacteria species* free. In a similar study, Dufie (2003), also isolated and identified similar microorganism.

The introduction of an entirely new feed ingredient to partially or wholly replace fish meal especially in the diet of pigs is welcome news as it will lead to decrease in feeding costs and associated poor growth rate problem In this experiment, the pigs fed the HWM-based diets readily consumed the feed just like those fed the control diet. The HWM by itself has a very good odour and appears to taste good hence, its high acceptability by the pigs. In view of this, it is definitely a very good and promising feed ingredient for feeding pigs in areas where it is readily available.

The nutritionally rich hatchery waste meal obtained in this study could be incorporated in pig diets because it has great potential (protein, energy and mineral) as feed for animal. Based on the findings of the present study, the inclusion of HWM up to a level of 10.0%, did not affect average final weight as well as average daily feed intake of pigs. This is similar to observation made by Shahriar *et al.,* (2008) who investigated the effect of different levels of hatchery waste meal (HWM) in broiler chicken diets and observed non-significantly differences among treatments in terms of weight gain, feed intake and feed conversion ratio (FCR).

In a related feeding trial, significantly higher weight gain was observed for a diet containing 12% HWM compared to that containing a similar amount of fish meal. A performance trial on broiler chickens also revealed better weight gain and feed efficiency on a diet containing 12% HWM than that

containing a similar level of fish meal (Rasool *et al.*, 1999). The average daily feed intake increased and the time spent eating decreased with increasing number of days on the HWM feed. In the present study, a reduced feed intake was observed at the highest dietary inclusion level (10.0 % HWM). A drop in feed intake and a concurrent reduction in growth performance at that level was also observed. It cannot be excluded that the high inclusion level of HWM in the diet may have affected palatability causing a reduction in overall feed intake. In this study, the formulation of appropriate and cost-effective diets from as much as possible locally available feedstuffs together with the HWM, improved the carcass characteristics of grower-finisher pigs compared with control pigs.

Blood haematological parameters are important in assessing the response of pigs to various physiological situations (Etim *et al.*, 2014). Merck manual (2016) reported the normal range of values for pigs. There were higher mean values in HWM for almost all the parameters measured compared to the control ($p > 0.05$). Haematological traits are reportedly essential parameters for evaluating the health and physiological status of pigs that can reflect their physiological responsiveness to disease (Etim *et al.*, 2014). All the haematological parameters evaluated however fell within the normal range for apparently healthy pigs as reported by Merck, (2017) and Johnson *et al.*, (2013) indicating that the diets were nutritionally adequate in providing a sound plane of nutrition for the pigs.

The biochemical profile of blood received great significance in the literature, as it serves as valuable guidelines in evaluating the nutritional adequacy of the diet as well as the health status of the animal (Baruah *et al.*,

1988). In the present study, level of serum albumin (g/dl) increased while serum globulin decreased, as the level of HWM included in diet increased. No significant differences ($p > 0.05$) were however observed amongst the dietary treatments. Significantly ($p < 0.05$) higher level of serum creatinine (µmol/L) and ALT were recorded in pigs fed higher HWM-based diet. These findings are in good agreement with the findings of Saikia et *al.*, (2003).

Conclusions

It can be concluded from the series of studies constituting this thesis that estimates from the five hatcheries alone gave quantities of about 15 tons of HW per annum indicating the possibility of large quantities of HWM being generated around Ghana. The study again shows that HWM could be processed into a form that can be used after simple processing (steaming) without much loss in nutrient content, particularly protein.

Hatchery waste meal processed at 5M80T appears to have the best bacterial load reduction effect as well as crude protein level. It can be concluded from these series of studies therefore that HWM could be included in pig diets at least up to 5.0% without any adverse effects on growth performance and carcass characteristics. The results also demonstrate that pigs fed on HWM diets in this work were apparently healthy throughout the study period, from haematological and biochemical studies undertaken.

Recommendations

1. Research is necessary on HWM to determine its shelf-life after processing using the developed technology as well as different packaging materials.
2. From the study conducted, surveys should be carried out in other regions of the country in other to determine actual quantities of HW generated nation-wide.
3. Amino acid profile determination is recommended to be carried out to assess further the quality of the protein in HW and the impact of the preparatory protocol on the amino acid status (quality and quantity).
4. Further research should target slaughtering pigs using same age as parameter to fine-tune growth rate indices as well as to undertake sensory analysis of meat produced thereafter.
5. Investigate the use of HWM in feeding the other physiological age groups of pigs ie. Reproductive phase, weaner phase etc.

CONTRIBUTION TO SCIENTIFIC KNOWLEDGE

These series of studies that formed the basis of the write-up of this thesis has:

1. established that HWM is a viable protein/energy non-conventional ingredient that could be used in formulating pig diets in place of more expensive FM in Ghana
2. developed a simple, convenient hands-on and safe method to handle or process HW into a form suitable for incorporating into animal feed, as well as rendering it free from public health pathogens/bacteria such as *E. coli* and *Samonella*
3. established that hatchery waste meal could replace (expensive) FM up to 10% of total ration, reducing competition between animals and humans for fish as well as reducing cost of production of pigs.
4. meat products obtained from pigs raised using HMW is of comparable carcass quality characteristics, as those fed on FM diet.

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APPENDICES

APPENDIX 1: HATCHERY WASTE BASELINE SURVEY QUESTIONNAIRE

HATCHERY WASTE BASELINE SURVEY QUESTIONNAIRE

Notes: This information is to be used for purposes of research to estimate the quantities of hatchery waste generated in the Greater Accra Region and thus all information provided by you is strictly confidential and will not be shared with other Hatcheries except the final report

HATCHERY WASTE CHECKLIST

Date: .....

Name of Respondent: .....

1. Name of Hatchery .....
2. Location of Hatchery.....
3. How long have you been in the hatchery business?.....
4. What previous background/training did you have in hatchery operations?

   .....
5. Do you know of any hatcheries in or close to your locality/community/town?

Handling of solid waste on site

1. Source of eggs for setting? .....
2. Cost of hatching eggs? .....
3. What is the full operational capacity of your hatchery i.e. at a setting?
4. How many eggs do you often set at a time?

5. How do you assess egg quality, before setting? .....
6. Reasons for not operating at full capacity (if so)? .....
7. Estimated quantity of eggs rejected before setting in incubator?.....
8. Are eggs rejected before setting)? .....
9. What type of wastes do you most handle after a hatch? .....
10. Which of the rejects (waste) are mostly produced after a hatch? .....
11. Do you measure the actual volume or quantity of waste generated after each hatch? .....
12. Describe the major components of the waste
13. What are the major components of the solid hatchery waste.....
14. How are waste products used? .....
15. How is the solid waste handled at the hatchery.....

Environmental Issues

16. How often do you remove waste from hatchery to disposal site
17. How is hatchery waste disposed of? .....
18. Is the waste disinfected or treated before disposal?.....
19. Do you pay for waste disposal?.....

20. Estimated costs of disposal after each hatch (i.e. cost for labour, transportation, disinfectants, dumping fees etc)?

.....

21. What are the major difficulties associated with handling of the waste?

.....

22. How often is solid waste removed from the hatchery?.....

23. Is the solid waste processed on site before? Or after? .....

24. What other techniques do you know of, or have heard about (in Ghana and elsewhere), used to manage waste? .....

25. What are the major issues related to waste management on site (e.g. contamination or pollution of land, water, air)

26. Are there any complaints from staff or neighbours?

27. Does land fill site for the disposal of waste need an Environmental Management Plan ....

Attitudes to waste

28. Is hatchery waste easy to manage at the hatchery in terms of smell?

29. Do you think managing waste at the hatchery require training of staff?.....

30. Training of staff is necessary to properly manage the waste on site?

31. It is not worth developing alternative methods to manage the hatchery waste on site?...

32. Would you be interested in investing in a system that treats the waste on site and stabilizes the waste?

APPENDIX 2: PROXIMATE ANALYSIS OF HATCHERY WASTE MEAL

ANOVA TABLES:

Variate: % Crude Protein (CP)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	1470.524005	183.815501	39.31	<.0001
Error	9	42.086411	4.676268		
Corrected Total	17	1512.610416			

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Time	2	487.0630831	243.5315416	52.08	<.0001
Temp	2	795.8152861	397.9076431	85.09	<.0001
Time*Temp	4	187.6456356	46.9114089	10.03	0.0023

Variate: % Ether Extract (EE)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	88.14248100	11.01781013	12.72	0.0005
Error	9	7.79775300	0.86641700		
Corrected Total	17	95.94023400			

Source	DF	Type I SS	Mean Square	F Value	Pr > F

Time	2	4.30040700	2.15020350	2.48	0.1386
Temp	2	48.14846400	24.07423200	27.79	0.0001
Time*Temp	4	35.69361000	8.92340250	10.30	0.0021

Variate: % Dry Matter

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	53.13725800	6.64215725	273.55	<.0001
Error	9	0.21853000	0.02428111		
Corrected Total	17	53.35578800			

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Time	2	1.88881233	0.94440617	38.89	<.0001
Temp	2	42.66680833	21.33340417	878.60	<.0001
Time*Temp	4	8.58163733	2.14540933	88.36	<.0001

Variate: % Ash

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	1185.915019	148.239377	2.51	0.0962
Error	9	531.567166	59.063018		
Corrected Total	17	1717.482185			

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Time	2	44.3038214	22.1519107	0.38	0.6975
Temp	2	644.9827508	322.4913754	5.46	0.0280
Time*Temp	4	496.6284469	124.1571117	2.10	0.1630

APPENDIX 3: PROXIMATE ANALYSIS OF DIETARY FEED

ANOVA TABLES FROM STATISTICAL ANALYSES OF DATA

Variate: % Ash

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.60220	0.30110	5.58	
TRT	4	16.97891	4.24473	78.66	<.001
Residual	8	0.431	0.053		
Total	14	18.012			

Variate: % Ca

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.006040	0.003020	0.44	
TRT	4	0.972830	0.243208	35.07	<.001
Residual	8	0.055475	0.006934		
Total	14	1.034346			

Variate: % DM

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.01606	0.00803	0.10	
Rep.*Units* stratum					

TRT	4	1.74114	0.43528	5.58	0.019
Residual	8	0.62413	0.07802		
Total	14	2.38133			

Variate: % Ether Extract

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.09960	0.04980	1.58	
Rep.*Units* stratum					
TRT	4	2.50491	0.62623	19.89	<.001
Residual	8	0.25192	0.03149		
Total	14	2.85643			

Variate: % Fibre

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.1508	0.0754	0.70	
Rep.*Units* stratum					
TRT	4	20.5901	5.1475	47.69	<.001
Residual	8	0.8635	0.1079		
Total	14	21.6044			

Variate: % Mg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.0003114	0.0001557	0.25	
Rep.*Units* stratum					
TRT	4	0.0248695	0.0062174	9.86	0.003
Residual	8	0.0050429	0.0006304		
Total	14	0.0302238			

Variate: % NFE

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.4427	0.2214	0.63	
Rep.*Units* stratum					

TRT	4	76.3093	19.0773	54.05	<.001
Residual	8	2.8237	0.3530		
Total	14	79.5757			

Variate: % Crude Protein

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.2953	0.1477	0.77	
Rep.*Units* stratum					
TRT	4	15.3374	3.8343	19.98	<.001
Residual	8	1.5353	0.1919		
Total	14	17.1680			

Variate: % K ug/g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	41799.	20900.	1.11	
Rep.*Units* stratum					
TRT	4	599356.	149839.	7.93	0.007
Residual	8	151152.	18894.		
Total	14	792307.			

Variate: Na ug/g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	3110.	1555.	0.06	
Rep.*Units* stratum					
TRT	4	594345.	148586.	5.60	0.019
Residual	8	212263.	26533.		
Total	14	809718.			

Variate: P ug/g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	12267.	6133.	0.35	
Rep.*Units* stratum					

TRT	4	5950618.	1487655.	85.74	<.001
Residual	8	138798.	17350.		
Total	14	6101683.			

PPENDIX 4: CARCASS EVALUATION OF GROWER-FINISHER PIGS

Variate: Backfat_1

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	7	1.1640	0.1663	1.14	
Replicate.*Units* stratum					
Treatment	4	0.8185	0.2046	1.41	0.258
Residual	28	4.0735	0.1455		
Total		39	6.0560		

Variate: Backfat_2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	7	0.40975	0.05854	0.97	
Replicate.*Units* stratum					
Treatment	4	0.29350	0.07337	1.22	0.325
Residual	28	1.68650	0.06023		
Total	39	2.38975			

Variate: Backfat_3

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	7	9.208	1.315	0.94	
Replicate.*Units* stratum					
Treatment	4	4.303	1.076	0.77	0.554
Residual	28	39.165	1.399		
Total	39		52.676		

Variate: Carcass_length_cm

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	7	13.494	1.928	0.45	
Replicate.*Units* stratum					
Treatment	4	38.350	9.588	2.22	0.092
Residual	28	120.850	4.316		
Total		39	172.694		

Variate: Chilld_weight_kg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	7	5.998	0.857	0.57	
Replicate.*Units* stratum					
Treatment	4	14.538	3.634	2.43	0.072
Residual	28	41.963	1.499		
Total		39	62.498		

Variate: Collar_kg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	7	0.40700	0.05814	0.64	
Replicate.*Units* stratum					
Treatment	4	0.03625	0.00906	0.10	0.982
Residual	28	2.55175	0.09113		
Total		39	2.99500		

Variate: Empty_GIT_kg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	7	0.8374	0.1196	0.83	
Replicate.*Units* stratum					
Treatment	4	1.6341	0.4085	2.83	0.043
Residual	28	4.0429	0.1444		
Total		39	6.5144		

Variate: Empty_Stomach_kg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	7	0.093750	0.013393	1.80	
Replicate.*Units* stratum					
Treatment	4	0.155875	0.038969	5.24	0.003
Residual	28	0.208125	0.007433		
Total	39	0.457750			

Variate: Fillet_kg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	7	0.0040000	0.0005714	0.68	
Replicate.*Units* stratum					
Treatment	4	0.0035000	0.0008750	1.04	0.403
Residual	28	0.0235000	0.0008393		
Total	39	0.0310000			

Variate: Full_GIT_kg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	7	579.20	82.74	1.28	
Replicate.*Units* stratum					
Treatment	4	309.98	77.49	1.20	0.335
Residual	28	1815.26	64.83		
Total	39	2704.43			

Variate: Hand_kg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	7	0.2629	0.0376	0.36	
Replicate.*Units* stratum					
Treatment	4	0.2300	0.0575	0.55	0.702
Residual	28	2.9380	0.1049		
Total	39	3.4309			

Variate: Heart_g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	7	65221.	9317.	1.06	
Replicate.*Units* stratum					
Treatment	4	109794.	27448.	3.12	0.031
Residual	28	246675.	8810.		
Total	39	421690.			

Variate: Kidney_g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	7	64065.	9152.	1.19	
Replicate.*Units* stratum					
Treatment	4	38437.	9609.	1.25	0.313
Residual	28	215373.	7692.		
Total	39	317875			

Variate: Live_weight_kg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	7	17.375	2.482	1.22	
Replicate.*Units* stratum					
Treatment	4	1.400	0.350	0.17	0.951
Residual	28	57.000	2.036		
Total	39	75.775			

Variate: Liver_kg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	7	0.31700	0.04529	1.06	
Replicate.*Units* stratum					
Treatment	4	0.12412	0.03103	0.72	0.583
Residual	28	1.19988	0.04285		
Total	39	1.64100			

Variate: Loin_eye_area_cm_1

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	7		1.2797	0.1828	0.86
Replicate.*Units* stratum					
Treatment	4		0.3440	0.0860	0.41	0.802
Residual	28		5.9240	0.2116	
Total	39		7.5478		

Variate: Loin_eye_area_cm_2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	7		1.0310	0.1473	0.91
Replicate.*Units* stratum					
Treatment	4		0.4685	0.1171	0.72	0.583
Residual	28		4.5315	0.1618	
Total	39		6.0310		

Variate: Messenteric_lymph_g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	7		653220.	93317.	1.51	
Replicate.*Units* stratum					
Treatment	4		613249.	153312.	2.48	0.067
Residual	28		1730494.	61803.	
Total	39		2996962.		

Variate: P2_measuement_cm

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	7		46.527	6.647	1.18	
Replicate.*Units* stratum					
Treatment	4		24.236	6.059	1.07	0.389
Residual	28		158.155	5.648	
Total	39		228.919		

Variate: Respiratory_tract_kg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	7	9.196	1.314	0.98	
Replicate.*Units* stratum					
Treatment	4	6.675	1.669	1.24	0.317
Residual	28	37.711	1.347		
Total	39	53.582			

Variate: Rip_back_kg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	7	0.52494	0.07499	1.37	
Replicate.*Units* stratum					
Treatment	4	0.08812	0.02203	0.40	0.806
Residual	28	1.53788	0.05492		
Total	39	2.15094			

Variate: Rip_streak_kg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	7	0.25486	0.03641	1.54	
Replicate.*Units* stratum					
Treatment	4	0.25402	0.06350	2.69	0.052
Residual	28	0.66131	0.02362		
Total	39	1.17018			

Variate: Rump_back_kg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	7	0.8220	0.1174	1.04	
Replicate.*Units* stratum					
Treatment	4	0.3696	0.0924	0.82	0.522
Residual	28	3.1474	0.1124		
Total	39	4.3390			

Variate: Rump_streak_kg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	7	0.15175	0.02168	0.59	
Replicate.*Units* stratum					
Treatment	4	0.81462	0.20366	5.50	0.002
Residual	28	1.03638	0.03701		
Total	39	2.00275			

Variate: Spleen_g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	7	11820.	1689.	1.32	
Replicate.*Units* stratum					
Treatment	4	11644.	2911.	2.28	0.085
Residual	28	35691.	1275.		
Total	39	59155.			

Variate: Thigh_kg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	7	0.74668	0.10667	2.40	
Replicate.*Units* stratum					
Treatment	4	0.22797	0.05699	1.28	0.300
Residual	28	1.24344	0.04441		
Total	39	2.21808			

Variate: Thymus_gland_g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	7	840.00	120.00	1.46	
Replicate.*Units* stratum					
Treatment	4	969.35	242.34	2.94	0.038
Residual	28	2308.25	82.44		
Total	39	4117.60			

Variate: Trotters_kg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	
Replicate stratum	7	0.036000	0.005143	0.58		
Replicate.*Units* stratum						
Treatment	4	0.020000	0.005000	0.56	0.692	
Residual	28	0.249000	0.008893			
Total	39	0.305000				

Variate: Viscera_kg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	
Replicate stratum	7	9.193	1.313	0.49		
Replicate.*Units* stratum						
Treatment	4	24.334	6.084	2.27	0.087	
Residual	28	75.101	2.682			
Total	39	108.628				

Variate: Warm_weight_kg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	
Replicate stratum	7	9.975	1.425	0.81		
Replicate.*Units* stratum						
Treatment	4	10.188	2.547	1.45	0.244	
Residual	28	49.213	1.758			
Total	39	69.375				

APPENDIX 5: HAEMATOLGY AND SERUM ANALYSIS OF GROWER-FINISHER PIGS

Variate: GRAN

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	7	35.795	5.114	0.99	
REP.*Units* stratum					
TRT	4	43.187	10.797	2.09	0.109
Residual	28	144.557	5.163		
Total	39	223.539			

Variate: HB

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr
REP stratum	7	18.594	2.656	1.03	
REP.*Units* stratum					
TRT	4	23.432	5.858	2.26	0.088
Residual	28	72.493	2.589		
Total	39	114.518			

Variate: HCT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	7	257.64	36.81	1.22	
REP.*Units* stratum					
TRT	4	196.45	49.11	1.63	0.195
Residual	28	845.08	30.18		
Total	39	1299.16			

Variate: LYMPH

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr
REP stratum	7	10.284	1.469	0.60	
REP.*Units* stratum					
TRT	4	15.018	3.755	1.54	0.219
Residual	28	68.478	2.446		
Total	39	93.780			

Variate: LYMPH%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	7	116.07	16.58	0.57	
REP.*Units* stratum					
TRT	4	306.03	76.51	2.64	0.055
Residual	28	811.99	29.00		
Total	39	1234.09			

Variate: MCH

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	7	98.16	14.02	0.84	
REP.*Units* stratum					
TRT	4	76.03	19.01	1.14	0.359
Residual	28	467.93	16.71		
Total	39	642.12			

Variate: MCHC

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	7	3.208	0.458	0.38	
REP.*Units* stratum					
TRT	4	0.483	0.121	0.10	0.981
Residual	28	33.685	1.203		
Total	39	37.376			

Variate: MCV

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	7	6.040	0.863	0.14	
REP.*Units* stratum					
TRT	4	21.998	5.499	0.87	0.493
Residual	28	176.586	6.307		
Total	39	204.624			

Variate: PCT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	7	0.40184	0.05741	0.90	
REP.*Units* stratum					
TRT	4	0.91356	0.22839	3.60	0.017
Residual	28	1.77804	0.06350		
Total	39	3.09343			

Variate: PLT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	7	1839431.	262776.	0.96	
REP.*Units* stratum					
TRT	4	2117199.	529300.	1.93	0.134
Residual	28	7693964.	274784.		
Total	39	11650594.			

Variate: RBC

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	7	126.50	18.07	0.94	
REP.*Units* stratum					
TRT	4	94.94	23.74	1.24	0.317
Residual	28	536.75	19.17		
Total	39	758.19			

Variate: WBC

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	7	31.83	4.55	0.42	
REP.*Units* stratum					
TRT	4	48.76	12.19	1.12	0.366
Residual	28	304.14	10.86		
Total	39	384.74			

Variate: U_L_ALP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	7	6529.	933.	0.24	
rep.*Units* stratum					
ANIMAL_I_D	4	12896.	3224.	0.84	0.510
Residual	28	107021.	3822.		
Total	39	126446.			

Variate: U_L_ALT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	7	402.97	57.57	1.22	
rep.*Units* stratum					
ANIMAL_I_D	4	758.25	189.56	4.03	0.010
Residual	28	1316.15	47.01		
Total	39	2477.38			

Variate: U_L_AST

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	7	869.38	124.20	1.75	
rep.*Units* stratum					
ANIMAL_I_D	4	663.25	165.81	2.33	0.080
Residual	28	1990.75	71.10		
Total	39	3523.38			

Variate: U_L_G_G_T

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	7	1238.3	176.9	1.01	
rep.*Units* stratum					
ANIMAL_I_D	4	732.6	183.2	1.05	0.400
Residual	28	4892.2	174.7		
Total	39	6863.1			

Variate: mg_DL_TOTAL_PROTEIN

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	7	252.72	36.10	0.47	
rep.*Units* stratum					
ANIMAL_I_D	4	253.69	63.42	0.83	0.519
Residual	28	2146.54	76.66		
Total	39	2652.94			

Variate: mg_Dl_ALBUMIN

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	7	22.200	3.171	1.03	
rep.*Units* stratum					
ANIMAL_I_D	4	9.799	2.450	0.80	0.536
Residual	28	85.909	3.068		
Total	39	117.908			

Variate: mg_Dl_GLOGBIN

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	7	191.88	27.41	0.38	
rep.*Units* stratum					
ANIMAL_I_D	4	344.02	86.00	1.20	0.334
Residual	28	2013.13	71.90		
Total	39	2549.02			

Variate: mg_dL_CREATININE

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	7	0.04700	0.00671	0.23	
rep.*Units* stratum					
ANIMAL_I_D	4	0.32600	0.08150	2.79	0.046
Residual	28	0.81800	0.02921		
Total	39	1.19100			

Variate: mg_dL_HDL_C

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	7	13.742	1.963	0.51	
rep.*Units* stratum					
ANIMAL_I_D	4	99.601	24.900	6.52	<.001
Residual	28	107.002	3.821		
Total	39	220.345			

Variate: mg_dL_LDL_C

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	7	2392.8	341.8	1.30	
rep.*Units* stratum					
ANIMAL_I_D	4	587.6	146.9	0.56	0.695
Residual	28	7374.8	263.4		
Total	39	10355.2			

Variate: mg_dL_TOTAL_CHOLESTEROL

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	7	43787.	6255.	0.75	
rep.*Units* stratum					
ANIMAL_I_D	4	12881.	3220.	0.39	0.817
Residual	28	233720.	8347.		
Total	39	290388.			

Variate: mmol_L_Cl

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	7	705.8	100.8	0.36	
rep.*Units* stratum					
ANIMAL_I_D	4	2975.1	743.8	2.67	0.053
Residual	28	7808.1	278.9		
Total	39	11489.0			

Variate: mmol_L_DIRECT_BILIRUBIN

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
rep stratum	7		0.07465	0.01066	0.95	
rep.*Units* stratum						
ANIMAL_I_D	4		0.09837	0.02459	2.19	0.103
Residual	23	(5)	0.25886	0.01125		
Total	34	(5)	0.36971			

Variate: mmol_L_K

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	7	12.336	1.762	1.20	
rep.*Units* stratum					
ANIMAL_I_D	4	1.716	0.429	0.29	0.880
Residual	28	41.028	1.465		
Total	39	55.080			

Variate: mmol_L_Na

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	7	46.163	6.595	1.54	
rep.*Units* stratum					
ANIMAL_I_D	4	6.521	1.630	0.38	0.820
Residual	28	119.527	4.269		
Total	39	172.211			

Variate: mmol_L_TRIGLYCERIDE

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	7	7.1964	1.0281	1.13	
rep.*Units* stratum					
ANIMAL_I_D	4	8.8832	2.2208	2.44	0.070
Residual	28	25.4445	0.9087		
Total	39	41.5240			

Variate: mmol_L_UREA

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	7	30.548	4.364	2.64	
rep.*Units* stratum					
ANIMAL_I_D	4	19.578	4.895	2.96	0.037
Residual	28	46.233	1.651		
Total	39	96.360			

APPENDIX 6: GROWTH PERFORMANCE OF PIGS USING HWM IN PLACE OF FM IN FORMULATING DIETS FOR GROWER-FINISHER PIGS.

Variate: ADFI

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	3	0.93055	0.31018	26.07	
REP.*Units* stratum					
TRT	4	0.02073	0.00518	0.44	0.781
Residual	12	0.14276	0.01190		
Total	19	1.09404			

Variate: Days_to_Slaughter

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	3	8940.59	2980.20	52.51	
REP.*Units* stratum					
TRT	4	1183.08	295.77	5.21	0.011
Residual	12	681.10	56.76		
Total	19	10804.77			

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	3	0.57610	0.19203	2.30	
REP.*Units* stratum					
TRT	4	1.89288	0.47322	5.67	0.008
Residual	12	1.00111	0.08343		
Total	*19*	*3.47010*			

Variate: Initial_Wt

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	3	344.8929	114.9643	254.70	
REP.*Units* stratum					
TRT	4	1.5270	0.3817	0.85	0.523
Residual	12	5.4166	0.4514		
Total 19	351.8364				

Variate: TFI

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	3	10550.2	3516.7	16.87	
REP.*Units* stratum					
TRT	4	5411.6	1352.9	6.49	0.005
Residual	12	2502.1	208.5		
Total	19	18463.9			

Variate: Total_WG

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	3	328.1140	109.3713	146.17	
REP.*Units* stratum					
TRT	4	2.3603	0.5901	0.79	0.554
Residual	12	8.9788	0.7482		

APPENDIX 7: TRANSCRIPTION OF QUALITATIVE DATA

I=Interviewer

R=Respondent

	First Respondents	code
	Hatchery information	
	Name of Hatchery	
R	Privately owned (No name)	
I	**Location of Hatchery**	
R	Abokobi Ga East	
I	**How long have you been operating**	
R	For the past 10 years	
I	**What previous background/training did you have in hatchery operations?**	
R	No formal training whatsoever, just the interest. Then decided to buy the incubators and try it myself.	
I	**Do you know of any hatcheries in or close to your locality/community/town? (It will be good to know the distance)**	
R	No, none that I know of.	
	Handling of solid waste on site	
I	**What is the source of eggs for setting?**	
R	I have small layers and then pick it from there then do the settings	

	myself	
I	**What is the cost of hatching eggs?**	
R	Since I really do not buy, I cannot really give you any cost component to it.	
I	**What is the full operational capacity of your hatchery i.e. at a setting?**	
R	One incubator at a setting can take 2000 (two thousand) eggs	
I	**Are eggs rejected before setting?**	
R	Yes, some of the eggs when taken from the floor are very dirty and sometimes cracked. These ones are the ones we reject before setting.	
I	**How many eggs do you often set at a time?**	
R	About thousand and two eggs	
I	**What are your Reasons for not operating at full capacity (if so)?**	
R	My layers are not up to 2000, they are only 1500, so I am not able to get 2000 eggs for full capacity.	
I	**Estimated quantity of eggs rejected before setting in incubator? (compute into percentage)**	
R	I haven't really taken proper count of that. But maybe if I set 1002 eggs in the incubator, about 100 (10%) would be rejected.	
I	**How often do you set eggs?**	
R	Every week	
I	**How do you assess egg quality, before setting?**	
R		
I	**What type of wastes do you most handle after a hatch? (List)**	
R	Solid waste and Liquid waste. The waste that comes out after washing the machines and the one that comes out of the eggs.	
I	**Which of the rejects (waste) are mostly produced after a hatch?**	
R	The dead-in-shells are often more compared to the dead chicks or unsalable chicks and also shells are also waste produced,	
I	**Do you measure the actual volume or quantity of waste generated after each hatch?**	
R	No I do not really measure	
I	**Describe the major components of the waste**	
R		
I	**What are the major components of the solid hatchery waste**	
R	I often get the shells, dead-in-shells, some clear eggs and at times unsalable chicks	
I	**What do you do with the waste?**	
R	They are mostly thrown into the dustbin for the Zoomlions' to come and pick it away (both liquid and solid)	
I	**How is the solid waste handled at the hatchery**	
R	They are mostly thrown in the dustbin	
	Environmental Issues	
I	**How often do you remove waste from hatchery?**	
R	After every hatch, at times one or two weeks depending on the time of set	
I	**How is hatchery waste disposed of?**	

R		
I	**Is the waste disinfected or treated before disposal?**	
R	No, I do not treat the waste	
I	**Do you pay for waste disposal?**	
R	No, I do not pay for the disposal	
I	**Estimated costs of disposal after each hatch (i.e. cost for labour, transportation, disinfectants, dumping fees etc)? (have the cost of each of the items)**	
R	Since I often do all the work myself, I haven't taken time to calculate the cost of component.	
I	**How often is solid waste removed from the hatchery?**	
R		
I	**Is the solid waste processed on site before or after?**	
R	No, the solid waste are not processed, because it is waste what I do is that I throw them into the dustbin	
I	**What other techniques do you know of, or have heard about (in Ghana and elsewhere), used to manage waste?**	
R	Some people cook the solid waste and feed it to their pigs whiles others give it raw to their pigs, and some uses it as compost	
I	**What are the major issues related to waste management on site (e.g. contamination or pollution of land, water, air)**	
R	Since I normally dispose them off, I can't really tell if there are issues related to it.	
I	**Are there any complaints from staff or neighbours?**	
R	When the Zoomlion disposers delays in coming for the waste, it produces a bad stench of which I could even perceive from my house. So definitely, neighbours will complain but I have heard them complain, and it doesn't often happen. For now I can say I am operating a very safe level.	
I	**Do land-fill sites for the disposal of waste need an Environmental Management Plan**	
R	No	
	Attitudes to waste	
I	**Is hatchery waste easy to manage at the hatchery in terms of smell and volume?**	
R	Yes, initially it doesn't smell but after 5 hours it start producing bad smell, so it would be easier if you dispose it early	
I	**Do you require training of staff to manage hatchery waste?**	
R	Yes, it is very important, it was initially difficult for me managing this, therefore if I the opportunity to be trained I would appreciate it.	
I	**Do you know of any waste management techniques?**	
R	No, I do not.	
I	**Would you be interested in investing in waste treatment? (a system the treats the waste on site and stabilizes the waste)**	
R	Yes, in the near future I plan on getting a big incubator so that I can operate in that level and be very interested in investing in waste treatment.	
I	**What are the major challenges you do encounter in handling**	

	your waste?	
R	For now since I am operating very small I do not really encounter any waste.	
	Second Respondents	
	Hatchery information	
I	**Name of Hatchery**	
R	Nat-Farms	
I	**Location of Hatchery**	
R	Kordiabe, in the Greater Accra Region	
I	**How long have you been operating**	
R	For the past 8 years	
I	**What previous background/training did you have in hatchery operations?**	
R	No, I had just the interest.	
I	**Do you know of any hatcheries in or close to your locality/community/town? (It will be good to know the distance)**	
R	Yes, I had the opportunity of going to the CSIR and I saw that they have one at the institute. (I cannot really tell the distance from here to the CSIR, but it is quite far)	
	Handling of solid waste on site	
I	**What is the source of eggs for setting?**	
R	At the back of the hatching, I have almost 10,000 (ten thousand) layers.	
I	**What is the cost of hatching eggs?**	
R	It is about GHC 3.50, but I do not buy.	
I	**What is the full operational capacity of your hatchery i.e. at a setting?**	
R	The hatchery I have can take about 20,000 eggs at a time	
I	**Are eggs rejected before setting?**	
R	Yes, some of them are rejected. This could be because some are already cracked, or very dirty or too small or too big.	
I	**How many eggs do you often set at a time?**	
R	About 10,000 because the stuff that we have are a little above 10,000	
I	**What are your Reasons for not operating at full capacity (if so)?**	
R	If I had the means I will set at full capacity because my incubator can take up to 20,000, but the stock that i have is little over 10,000, so there is no way I could get the full capacity unless I out source from somewhere, but for now putting 10,000 eggs on set is okay.	
I	**Estimated quantity of eggs rejected before setting in incubator? (compute into percentage)**	
R	About 500 (5%) eggs will certainly be rejected.	
I	**How often do you set eggs?**	
R	I do set every week	
I	**How do you assess egg quality, before setting?**	
R		
I	**What type of wastes do you most handle after a hatch? (List)**	
R	For the hatch mostly dead-in-shells are mostly produced, followed	

	by the clear eggs and then the normal shells.	
I	**Which of the rejects (waste) are mostly produced after a hatch?**	
R		
I	**Do you measure the actual volume or quantity of waste generated after each hatch?**	
R	We do not often measure, but there is a young man who normally comes here to pick up the waste to feed to his pigs, when he doesn't come, it is dispose off.	
I	**Describe the major components of the waste**	
R		
I	**What are the major components of the solid hatchery waste**	
R	The dead-in-shells, the shells itself, the clear shells and dead chicks – some of them do not survive.	
I	**What do you do with the waste?**	
R	For now we dispose them off.	
I	**How is the solid waste handled at the hatchery**	
R		
	Environmental Issues	
I	**How often do you remove waste from hatchery?**	
R	Weekly	
I	**How is hatchery waste disposed of?**	
R	At the end of the day we put the waste into sacks and place them in front of the dustbin	
I	**Is the waste disinfected or treated before disposal?**	
R	No, we do not disinfect the waste, but we disinfect the machine	
I	**Do you pay for waste disposal?**	
R	Indirectly yes, because we give out money at the end of the month to the person who normally collects it.	
I	**Estimated costs of disposal after each hatch (i.e. cost for labour, transportation, disinfectants, dumping fees etc)? (have the cost of each of the items)**	
R	For transportation there is no cost to it because I move it from my hatchery straight to where i place them. Disinfection at the end of the day we buy common soap to wash our hands (GHC 2.00). Every month for the waste to be collected we pay GHC 15.00 There is not cost attached to labour	
I	**How often is solid waste removed from the hatchery?**	
R		
I	**Is the solid waste processed on site before or after?**	
R	No we do not process, we just dump them.	
I	**What other techniques do you know of, or have heard about (in Ghana and elsewhere), used to manage waste?**	
R	I heard some of them boil the waste and give it to their pigs whilst others just dump it.	
I	**What are the major issues related to waste management on site (e.g. contamination or pollution of land, water, air)**	
R	Here, if the waste is not properly cleared the place becomes very smelly to the extent that you cannot even stay there to work. And	

	so, with the management, we are very much interest in it.	
I	**Are there any complaints from staff or neighbours?**	
R	Yes, sometimes neighbours complains when the bin has been there for too long, not bitterly but you see them pointing fingers that it saying that the materials there are smelling.	
I	**Do land-fill sites for the disposal of waste need an Environmental Management Plan**	
R	No, I do not	
	Attitudes to waste	
I	**Is hatchery waste easy to manage at the hatchery in terms of smell and volume?**	
R	It is very easy to manage, if you get the waste, you have to just dispose it early. If you do not do that definitely it would go bad.	
I	**Do you require training of staff to manage hatchery waste?**	
R	Yes, it is key and I would be very interested in.	
I	**Do you know of any waste management techniques?**	
R	Some use it as compost and some too boils it and give it to their pigs.	
I	**Would you be interested in investing in waste treatment? (a system the treats the waste on site and stabilizes the waste)**	
R	Yes, if I get the opportunity it is something I would like to do.	
I	**What are the major challenges you do encounter in handling your waste?**	
R	I do not really encounter challenges because i have done this over and over again, so i don't really have issues when it comes to managing waste.	
	Third Respondent	
	Hatchery information	
I	**Name of Hatchery**	
R	God's Love Hatchery	
I	**Location of Hatchery**	
R	Amrahia Baron Greater Accra	
I	**How long have you been operating**	
R	For the past 15 years	
I	**What previous background/training did you have in hatchery operations?**	
R	Yes, I have had some form of training at Legon	
I	**Do you know of any hatcheries in or close to your locality/community/town? (It will be good to know the distance)**	
R	Yes, I know of about two hatchery one at Kordiabe and the other at CSIR	
	Handling of solid waste on site	
I	**What is the source of eggs for setting?**	
R	I normally import them (I buy them).	
I	**What is the cost of hatching eggs?**	
R	It is GHC 3.20	
I	**What is the full operational capacity of your hatchery i.e. at a setting?**	
R	I do about 10,000 eggs at a time.	

I	**Are eggs rejected before setting?**	
R	Not really because they were imported, the selection has been done already	
I	**How many eggs do you often set at a time?**	
R	I often buy like about 9,000 and then set, sometimes 8,000 and set.	
I	**What are your Reasons for not operating at full capacity (if so)?**	
R	The cost of one egg alone is GHC 3.20, so imagine the cost alone of buying 9,000 or 8,000 eggs, it is quite a lot.	
I	**Estimated quantity of eggs rejected before setting in incubator? (compute into percentage)**	
R	No, here I don't reject any set of them because they are already selected and I set all of them. But again, on the eighteenth day I do my counting and the eggs that do not pass are rejected, but before that I do not.	
I	**How often do you set eggs?**	
R	I set them every month, because importing them takes a while.	
I	**How do you assess egg quality, before setting?**	
R		
I	**What type of wastes do you most handle after a hatch? (List)**	
R	The first one that is of large quality is the dead-in-shell and then the clear shell, these are the two most rejected waste after the hatch.	
I	**Which of the rejects (waste) are mostly produced after a hatch?**	
R		
I	**Do you measure the actual volume or quantity of waste generated after each hatch?**	
R	No you do not, but one can calculate if you know the weight and number of eggs you set. We were thought all this but I have forgotten, for now I do measure.	
I	**Describe the major components of the waste**	
R		
I	**What are the major components of the solid hatchery waste**	
R	The dead-in-shells and clear shells	
I	**What do you do with the waste?**	
R	We dump them into the dustbin	
I	**How is the solid waste handled at the hatchery**	
R		
	Environmental Issues	
I	**How often do you remove waste from hatchery?**	
R	At every cycle, that is at least every 21 days for the waste to be removed.	
I	**How is hatchery waste disposed of?**	
R		
I	**Is the waste disinfected or treated before disposal?**	
R	No, they are not treated	
I	**Do you pay for waste disposal?**	
R	Yes, at the end of the month we pay a little money to the waste collectors. When the waste collectors delay to come, we contract some of these boys who use the motor-king tricycle to collect it and	

	we pay like GHC 5 or 10.	
I	**Estimated costs of disposal after each hatch (i.e. cost for labour, transportation, disinfectants, dumping fees etc)? (have the cost of each of the items)**	
R	Looking at the cost of disposal and disinfectant let's say about GHC 10 or 15.	
I	**How often is solid waste removed from the hatchery?**	
R		
I	**Is the solid waste processed on site before or after?**	
R	No it is not processed we just dump.	
I	**What other techniques do you know of, or have heard about (in Ghana and elsewhere), used to manage waste?**	
R	I was taught that some of them autoclave it, other too boil and give it to their animals and some use it as compost and fertilizer for their crops whilst others give it to their animals raw without any treatment.	
I	**What are the major issues related to waste management on site (e.g. contamination or pollution of land, water, air)**	
R	For sometime past it was an issue because my neighbours complain about the smell especially when the waste collectors do not come for them early, but now I do it fast anytime I have to dispose the waste I call the waste collectors to come fast and pick it up from there.	
I	**Are there any complaints from staff or neighbours?**	
R		
I	**Do land-fill sites for the disposal of waste need an Environmental Management Plan**	
R	Yes, but I do not know where they normally dispose the waste they take from my end but I can say that it is important because it is something that if we produce in large quantity, it can be used.	
	Attitudes to waste	
I	**Is hatchery waste easy to manage at the hatchery in terms of smell and volume?**	
R	Yes very easy, just pick it fresh and put it into a bag and dispose them	
I	**Do you require training of staff to manage hatchery waste?**	
R	Yes, sure, we need to improve upon our techniques of handling waste	
I	**Do you know of any waste management techniques?**	
R	No, I do not.	
I	**Would you be interested in investing in waste treatment? (a system the treats the waste on site and stabilizes the waste)**	
R	Yes, it is something that every country would love to, so yes i would be very interested.	
I	**What are the major challenges you do encounter in handling your waste?**	
R	The liquid aspect of the waste, at times you have to mop and clean, but for the solid waste it is far easier to handle.	
	Fourth Respondent	

	Hatchery information	
I	**Name of Hatchery**	
R	CSIR Animal Research Haatso	
I	**Location of Hatchery**	
R	Located within the premise of the CSIR Haatso	
I	**How long have you been operating**	
R	For the past 10 years	
I	**What previous background/training did you have in hatchery operations?**	
R	We are all trained here	
I	**Do you know of any hatcheries in or close to your locality/community/town? (It will be good to know the distance)**	
R	Yes, we know of Kordiabe, if we have any challenges we take our eggs to Kordiabe to be hatched.	
	Handling of solid waste on site	
I	**What is the source of eggs for setting?**	
R	We have so many breeding animals, we also have the arable	
I	**What is the cost of hatching eggs?**	
R	We do not buy since it is our own eggs	
I	**What is the full operational capacity of your hatchery i.e. at a setting?**	
R	It is 30,000 (Thirty thousand) capacity incubator.	
I	**Are eggs rejected before setting?**	
R	Yes, when they are very dirty, cracked, and too small or too big – they are rejected.	
I	**How many eggs do you often set at a time?**	
R	At times we set to full capacity and sometime we do 20,000 at a time.	
I	**What are your Reasons for not operating at full capacity (if so)?**	
R	Sometimes because of the rejected eggs we would not get the full 30,000 to set	
I	**Estimated quantity of eggs rejected before setting in incubator? (compute into percentage)**	
R	I can like about 10% is rejected before setting into the incubator	
I	**How often do you set eggs?**	
R	The eggs are set every three weeks.	
I	**How do you assess egg quality, before setting?**	
R		
I	**What type of wastes do you most handle after a hatch? (List)**	
R	The dead-in-shell is more; also the clear eggs are also high.	
I	**Which of the rejects (waste) are mostly produced after a hatch?**	
R	That is the dead-in-shell waste is produced after a hatch	
I	**Do you measure the actual volume or quantity of waste generated after each hatch?**	
R	No, we do not really measure but we can estimate the quantity using the weight of the egg and number of eggs that are set at a time.	
I	**Describe the major components of the waste**	

R		
I	**What are the major components of the solid hatchery waste**	
R	We have the solid waste were we talk about the dead-in-shell, clear eggs and the shell itself. The other aspect is the liquid waste	
I	**What do you do with the waste?**	
R	The waste are disposed, we have a dumping site down there where we dispose our waste, at times we give it to our pigs	
I	**How is the solid waste handled at the hatchery**	
R		
	Environmental Issues	
I	**How often do you remove waste from hatchery?**	
R	Every week we clean	
I	**How is hatchery waste disposed of?**	
R		
I	**Is the waste disinfected or treated before disposal?**	
R	Not really, I wouldn't say we treat them because they are waste and after putting them in the sack we just send them to the piggery and if they do not need them, then we send it to the site.	
I	**Do you pay for waste disposal?**	
R	No we do not pay for the waste disposal.	
I	**Estimated costs of disposal after each hatch (i.e. cost for labour, transportation, disinfectants, dumping fees etc)? (have the cost of each of the items)**	
R	There is no cost attached to it, because this is the government entity.	
I	**How often is solid waste removed from the hatchery?**	
R		
I	**Is the solid waste processed on site before or after?**	
R	No, we dispose them raw	
I	**What other techniques do you know of, or have heard about (in Ghana and elsewhere), used to manage waste?**	
R	The waste is been used as compost (Manure)	
I	**What are the major issues related to waste management on site (e.g. contamination or pollution of land, water, air)**	
R	For this institute we do not issue with waste management, we have the channel; we put them in a sack and take them to the piggery or the dumping site if they do not need it.	
I	**Are there any complaints from staff or neighbours?**	
R	No complain we dispose them when they are fresh. And within the enclave there is no one that stays around because it is an institute.	
I	**Do land-fill sites for the disposal of waste need an Environmental Management Plan**	
R	Yes, it gets to a point where we have to burn otherwise the water we like into the other streams that we have.	
	Attitudes to waste	
I	**Is hatchery waste easy to manage at the hatchery in terms of smell and volume?**	
R	Yes, it is very easy, you just remove them and put it in the sack and dispose them.	

I	**Do you require training of staff to manage hatchery waste?**	
R	Yes, more training is required, especially when you have much waste, you cannot dispose them alone. They need to be trained.	
I	**Do you know of any waste management techniques?**	
R	No i do not.	
I	**Would you be interested in investing in waste treatment? (a system the treats the waste on site and stabilizes the waste)**	
R	Yes, as an institute factory we will be very interested to invest.	
I	**What are the major challenges you do encounter in handling your waste?**	
R	When there is a lot of waste, putting them in a sack is very tedious. If there is others ways of disposing it without putting it in a sack would be of a great advantage.	
	Fifth Respondent	
	Hatchery information	
I	**Name of Hatchery**	
R	Privately owned (No name)	
I	**Location of Hatchery**	
R	Medina	
I	**How long have you been operating**	
R	For the past 6 years	
I	**What previous background/training did you have in hatchery operations?**	
R	I would say yes, because I attended some training program which the ministry of food organized. After that I developed the interest and decided to buy the incubator and try my hands on it.	
I	**Do you know of any hatcheries in or close to your locality/community/town? (It will be good to know the distance)**	
R	No, not that I know of	
	Handling of solid waste on site	
I	**What is the source of eggs for setting?**	
R	I buy my eggs from people who normally produce like Legon and bring it to hatch; sometimes I get it from a friend at Kumasi.	
I	**What is the cost of hatching eggs?**	
R	Mostly at GHC 3.20 and sometimes it fluctuate and I get it at GHC 3.50. For the cost of hatching, I do not add cost to it.	
I	**What is the full operational capacity of your hatchery i.e. at a setting?**	
R	It takes about 5,000 at a time.	
I	**Are eggs rejected before setting?**	
R	No, because I buy I am been given correct ones and i set everything at once.	
I	**How many eggs do you often set at a time?**	
R	4,000 at a time	
I	**What are your Reasons for not operating at full capacity (if so)?**	
R	Financial related.	
I	**Estimated quantity of eggs rejected before setting in incubator? (compute into percentage)**	

R	Before setting none is rejected.	
I	**How often do you set eggs?**	
R	Every month	
I	**How do you assess egg quality, before setting?**	
R		
I	**What type of wastes do you most handle after a hatch? (List)**	
R	Dead-in-shells and clear shells are mostly occur.	
I	**Which of the rejects (waste) are mostly produced after a hatch?**	
R		
I	**Do you measure the actual volume or quantity of waste generated after each hatch?**	
R	No I do not measure	
I	**Describe the major components of the waste**	
R		
I	**What are the major components of the solid hatchery waste**	
R	Dead-in-shell is the major ones.	
I	**What do you do with the waste?**	
R	I put them into a sack and into the dustbin	
I	**How is the solid waste handled at the hatchery**	
R		
	Environmental Issues	
I	**How often do you remove waste from hatchery?**	
R	At the end of a particular cycle about 21 – 22 days.	
I	**How is hatchery waste disposed of?**	
R		
I	**Is the waste disinfected or treated before disposal?**	
R	No, I just pick them and put them into the dustbin and it is taken every day and we pay every month.	
I	**Do you pay for waste disposal?**	
R	No	
I	**Estimated costs of disposal after each hatch (i.e. cost for labour, transportation, disinfectants, dumping fees etc)? (have the cost of each of the items)**	
R	I do not associate cost to this.	
I	**How often is solid waste removed from the hatchery?**	
R		
I	**Is the solid waste processed on site before or after?**	
R	Just as the waste comes I put it in the sack and dispose it.	
I	**What other techniques do you know of, or have heard about (in Ghana and elsewhere), used to manage waste?**	
R	No, not that I know of.	
I	**What are the major issues related to waste management on site (e.g. contamination or pollution of land, water, air)**	
R	When it is there for some times it becomes very disturbing	
I	**Are there any complaints from staff or neighbours?**	
R	Nobody is complaining yet because of how early i dispose it.	
I	**Do land-fill sites for the disposal of waste need an Environmental Management Plan**	
R	No, but if we get some were we can place it, it will be helpful	

	Attitudes to waste	
I	**Is hatchery waste easy to manage at the hatchery in terms of smell and volume?**	
R	Yes, when it is volumuos, it becomes very difficult to manage	
I	**Do you require training of staff to manage hatchery waste?**	
R	Yes training is always good to advance ones knowledge so i will embrace it.	
I	**Do you know of any waste management techniques?**	
R	No i do not.	
I	**Would you be interested in investing in waste treatment? (a system the treats the waste on site and stabilizes the waste)**	
R	If i get the opportunity i will embrace it	
I	**What are the major challenges you do encounter in handling your waste?**	
R	For now the quantity i operate in is not much, so i will say it is under control.	