

**BLACK SOLDIER FLY LARVAE-BASED FISH FEED PRODUCTION:
FINANCIAL FEASIBILITY AND ACCEPTABILITY ANALYSIS**

BY

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**THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN
PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF
MASTER OF PHILOSOPHY DEGREE IN AGRIBUSINESS**

**DEPARTMENT OF AGRICULTURAL ECONOMICS AND AGRIBUSINESS,
COLLEGE OF BASIC AND APPLIED SCIENCES, UNIVERSITY OF GHANA,
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JULY, 2017

DECLARATION

I, MIRIAM OPPONG, author of this thesis do hereby declare that except for references which have been duly cited, the work presented in this thesis, “**BLACK SOLDIER FLY LARVAE BASED FISH FEED PRODUCTION: FINANCIAL FEASIBILITY AND ACCEPTABILITY ANALYSIS**” was entirely done by me in the Department of Agricultural Economics and Agribusiness, College of Basic and Applied Sciences, University of Ghana, Legon from August 2016- July, 2017. This work has never been presented either in whole or in part for any other degree in this University or elsewhere.

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DEDICATION

This thesis is dedicated to the Almighty God

ACKNOWLEDGEMENTS

I wish to express my sincere gratitude to my supervisors Dr. (Mrs) Irene Egyir, Dr. Edward E. Onumah and Dr. Comfort Freeman for their supervision and immense contributions to my thesis work. I thank all lecturers and students in the department for their contributions to my work during seminar presentations.

I would also like to acknowledge and thank the Swiss National Science Foundation (SNSF) and the Swiss Agency for Development Corporation (SDC), Switzerland for suggesting this area of study and providing the grant for the research, which was done within the frame work of an ongoing project “Insect-based feed and fertilizer production via waste transformation for small holders in Ghana. The research was done by the following partners: Research Institute of Organic Agriculture (FiBL), University of Ghana (UG), Biotechnology and Nuclear Agriculture Research Institute (BNARI), the Water Research Institute of Council for Scientific and Industrial Research (WRI-CSIR), and University of Cape Coast (UCC).

I would like to thank Dr. Seth K. Agyakwah of the Water Research Institute (WRI), Christopher Teye Gaga (MPhil. Student) and Mr E. A. Ewusi (Research Scientist and Ph.D candidate) of the Biotechnology and Nuclear Agriculture Research Institute (BNARI), Ghana Atomic Energy Commission, for providing data needed for the financial feasibility studies.

I would also like to recognise Mr. Godfred Alimo, the head of Azofa farmer-based organisation in Asougyaman district for paving a way for me to interview members of the association. I would like to acknowledge Mr. Famous Gbetey for acting as a guide during my visits to the various farms in the district. My appreciation also goes to James Kofi Aggrey Junior and Salma Suhuyini Fuseini, my fellow M.Phil students, for their assistance in various ways to complete my research.

Finally, I am especially grateful to my family members; my husband, Thomas Amoako Kutin, my parents, Mr. Ernest Oppong and Ms. Doreen Oduro and my siblings John Abbebrese Boateng (Ph.D), Adwoa Serwaa Oppong, Esther Oppong, Akua Agyeiwaa Oppong and Raymond Amponsah for their support and prayers during the project period.

Miriam Oppong

ABSTRACT

Conventional feed, which uses fishmeal is expensive and expected to be limited in the future due to potential decline in capture fisheries. Researchers have suggested the use of insects such as the Black Soldier Fly larvae (BSFL) as an alternative to fishmeal in fish feed. The major objective of the study was to ascertain the financial viability of BSFL meal and BSFL-based fish feed production and fish farmer's acceptance of BSFL-based fish feed. Indicators such as Net Present Value (NPV), Benefit Cost Ratio (BCR) and Internal Rate of Return (IRR) were used for the financial viability analysis. A sample of 150 farmers were interviewed and a three point Likert scale used to solicit farmer's responses to perception statements. The bidding game and the Tobit regression model were used to determine the maximum amount farmers were willing to pay and factors influencing the willingness to pay (WTP) amount respectively. Finally, a partial budget was used to estimate the gains made by fish farmer from substituting conventional feed with BSFL-based feed. The results of the study showed that the production of BSFL meal is viable with NPV of GH¢5.7m, BCR of 2.4, IRR of 32%. The production of BSFL-based fish feed is viable with NPV of GH¢8.1m, BCR of 1.95 and IRR of 30%. There was a high degree of acceptance amongst fish farmers as farmers perceived BSFL feed to be beneficial and were willing to pay an average of GH¢186.00/20Kg for the BSFL-based feed. The factors affecting WTP were marital status, annual income and awareness of insects as feed. A gain of GH¢6.53 can be made by fish farmers in replacing 14.6kg of conventional feed with 14.6 kg of BSFL-based fish feed. The study recommended the sensitization of entrepreneurs on the profitability of BSFL meal and BSFL-based fish feed production in order to encourage investment. Also, potential entrepreneurs should recognise the mean WTP amount when making pricing decisions in order to penetrate the market and allow fish farmers to make savings from substituting conventional fish feed with BSFL-based fish feed.

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LIST OF ACCRONYMS

BCR	Benefit Cost Ratio
BSFL	Black Soldier Fly Larvae
BSF	Black Soldier Fly
BNARI	Biotechnology and Nuclear Agriculture Research Institute
FASDEP	Fisheries and Aquaculture Sector Development Plan
FAO	Food and Agricultural Organisation
FIBL	Research Institute of Organic Agriculture
GBN	Ghana Business News
GSS	Ghana Statistical Service
IRR	Internal Rate of Return
MoFAD	Ministry of Fisheries and Aquaculture Development
MWTP	Mean Willingness to Pay
NPV	Net Present Value
WRI	Water Research Institute
WTP	Willingness to Pay

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Globally, fish production has increased steadily in the last five years from 145.9 million tonnes in 2009 to 167.2 million tonnes in 2014 (FAO, 2016). Capture fisheries remained fairly stable with a minimal increase from 90.2 million tonnes to 93.4 million tonnes within the five years. This is because the world's oceans have been exploited to its maximum potential and beyond and currently 30% of fish stocks are fished at unsustainable levels (FAO, 2014). The increase in fish production has been mainly due to increase in aquaculture's contribution to fish production from 55.7 million tonnes to 73.8 million tonnes (FAO, 2014). Fish production has increased in response to increased demand for fish with an increase in consumption from an average of 9.9 kg in the 1960's to 19.2kg in 2012. This is as a result of population growth, urbanisation and increased income (FAO, 2014). To reduce the pressure on the world's oceans and seas, aquaculture is expected to expand further to meet growing demand.

In Ghana, the fish production industry is a steadily growing sector that contributes significantly towards GDP and employment. This steady increase is as a result of increase in the production of aquaculture from 19,091 metric tonnes in 2011 to 44,515 metric tonnes in 2016 (MoFAD, 2016). On the other hand, capture fisheries production has declined from about 402,000 metric tonnes in 2010 to 370,000 metric tonnes in 2014 (MoFAD, 2016). The growing demand for fish protein in Ghana has motivated active development of aquaculture both at the commercial and peasant levels. The contribution of aquaculture production to the Ghanaian economy has grown over the past decade, with an annual average growth rate of 12.4% (FAO, 2012). Aquaculture is seen as an important foreign exchange earner,

contributing to food security as well as providing much needed employment to many people in Ghana.

Most aquaculture operators (fish farmers) in Ghana use earthen ponds and rely on mother nature while others supplement with agricultural by-products. Other systems of culture include the cages, pens and raceway systems, which are not commonly practised nationwide (Awity, 2005). In terms of numbers, cages come after ponds. For instance, in 2012, a total of 2, 278 cages whilst 4, 749 ponds were recorded in the country (FD, 2013). However, fish production during the same 2012 year was higher in cages than in ponds. Production from ponds was 1, 771.50 and that of cages was 24, 248.50 metric tonnes.

Traditionally, aquaculture depends capture fisheries that is fish that has been captured from the sea such as pout, capelin, sand eel, and mackerel amongst others for feed supplement namely fishmeal (Olsen & Hasan, 2012). Fishmeal is a ground solid product obtained from removing the water and oil from fish or fish waste. Fishmeal has been an ideal protein supplement for fish feed due to its high protein content, balanced amino acids, vitamins and minerals, fatty acid content and cheap price (Gatlin et al., 2007). The use of fishmeal as the main protein supplement to fishmeal has been touted as unsustainable and expensive. Around 10% of global fish produced is reused as fishmeal and most of this is used in aquaculture (FAO, 2012). This is unsustainable since capture fisheries, which is the main source of fishmeal is declining in the face of increasing demand. As a result, Researchers have tried various feed supplements to replace fishmeal such as bean meal, soybean meal, sunflower meal and other agricultural products. However, these are resources with a lot of competing uses both by humans and animals. As another alternative, researchers are currently revisiting the use of insects, specifically the use of black soldier fly Larvae (BSFL) in aquaculture feed.

This is known to be able to replace fishmeal successfully in aquaculture diet and is ideal for industrial scale production (Burtle, 2008; Diener et al., 2011).

The black soldier fly is a non-pest fly usually found in the tropics. It is originally a native of temperate zones in America but has moved to other temperate regions around the world including Africa (Leclercq, 1997). Its larvae feeds on organic waste reducing the waste by 50% and converting it into biomass rich in protein and fat. Various research has suggested that the black soldier fly larvae meal, that is the larvae of the black soldier fly when grounded into meal, can successfully replace fishmeal in the diet of fish. Research has shown successful feeding trials of fishmeal replacement by BSFL meal in rainbow trout, blue tilapia and channel catfish (Bondari & Sheppard, 1987; Stamer et al., 2014; St-Hilaire et al., 2007).

1.2 Problem Statement of the Study

Feed is pertinent to the success of aquaculture development. It accounts for 60 to 70% of total cost of production (FAO, 2012). With increasing demand for fish and decline of capture fisheries, fish production in Ghana is shifting to commercial high intensive fish farming. This means that the demand for commercial formulated feed is rising. However, the sector has not reached its full potential since it is constrained by high costs of feed (Hiheglo, 2008). In 2016, Ghana's aquaculture production of 44, 919 tonnes fell short of the 100,000 metric tonnes projected in Ghana's FASDEP report (MoFAD, 2011)

Fishmeal is the main source of protein in formulated fish feed and it makes up to 20- 60% of fish diets (Glencross et al., 2007; Watanabe, 2002). The continuous use of fishmeal for aquaculture production is however not sustainable, currently since water bodies are heavily exploited in order to feed the fishmeal industry (FAO, 2012). In recent times due to

increasing pressure on water bodies, tightened controls and increased quotas on world fisheries, the supply of fishmeal has declined whilst the demand for fish has increased, resulting in higher prices (FAO, 2012). This has caused fish feed to be expensive on the market since dietary protein is the major and most expensive component of formulated fish feeds (Wilson, 2002). For instance, the cost of fish feed on the international market increased by 73 % from 2005 to 2008 due to increase in fishmeal prices (FAO, 2012).

The implication of the high cost of feed for fish farmers is that fish feed is less accessible and aquaculture production unsustainable. A locally manufactured feed that uses a more cost effective supplement, with sustainable supply and socially acceptable method of production than fish meal is therefore a much welcome intervention to curtail this problem. The mass rearing of insect larvae as an alternative to fishmeal has been suggested by researchers (Sheppard et al., 1994). The black soldier fly is the preferred insect because it is easy to handle and it does not spread diseases. The larvae of the BSF feeds on waste reducing it by up to 50% and the larvae is rich in protein and fat of 43% and 35% respectively (Sheppard et al., 1994; Stamer et al., 2007). The production of BSFL meal on an industrial scale has therefore been suggested by researchers as the sustainable alternative to fishmeal. According to Stamer et al. (2007), the production of BSFL meal can be realised below the cost of production of existing fishmeal. Research on feeding trials has shown that BSFL meal can successfully replace fishmeal in fish diet (Diener et al., 2011; Stamer et al., 2014).

Against this background, the Research Institute of Organic Agriculture (FiBL), a Swiss organisation, in 2014, funded a project in Ghana at BNARI and WRI to establish a colony of BSFL and convert it into BSFL meal and BSFL-based fish feed. The aim of the project was to produce fish feed that is sustainable, cost effective and socially acceptable. The beginning

stages of the project entailed scientist on the field establishing a colony of the BSFL, turning it into BSFL meal and BSFL-based fish feed and performing feeding trials on fish growth performance (Yield). The final stage of the research, which is the basis of this study, was to perform: 1) A financial analysis of the BSFL meal and BSFL-based fish feed production and 2) An analysis of fish farmers' acceptance of BSFL-based fish feed pertaining to their perception of the feed and their willingness to pay for the feed.

This study seeks to answer the following questions:

1. Is it profitable for entrepreneurs to invest in BSFL meal and BSFL-based fish feed production?
2. What is the perception of fish farmers towards the use of BSFL in fish feed?
3. What is the mean amount fish farmers are willing to pay for the BSFL-based fish feed and the factors influencing the amount they are willing to pay?
4. Will fish farmers gains or lose by substituting the conventional feed with BSFL-based fish feed?

1.3 Objectives of the Study

The major objective of the study is to determine the financial viability of BSFL meal and BSFL-based feed production and the acceptance of the BSFL-based fish feed by fish farmers.

The specific objectives are as follows:

1. To determine the level of profitability of BSFL meal and BSFL-based fish feed production,
2. To determine the perception of farmers toward the use of BSFL in fish feed,
3. To determine the mean amount farmers are willing to pay for BSFL-based feed and the factors influencing the amount they are willing to pay

4. To estimate the gains or losses made by fish farmers in substituting the conventional fish feed for BSFL- based fish feed.

1.4 Justification of the Study

The study was undertaken with the intention of providing empirical evidence on the financial viability of BSFL meal and BSFL-based fish feed production. The results from the profitability analysis will serve as a referral point for entrepreneurs hoping to invest in BSFL meal and BSFL feed production. If such a project is taken up, at any scale of production, the socio-economic opportunities in developing countries for such a project are immense. These include bridging the aforementioned supply deficit through local feed production, creation of jobs, enterprise development, increased global trade and waste management.

The results from the perception of farmers towards the use of BSFL in fish feed, this study can serve as a manual and guideline for the sensitization of farmers towards the use of BSFL in fish feed. The results from the study on farmers perceived benefit and risk of the use of BSFL in fish feed will provide insight into the specific areas that more information is needed on the part of Ghanaian fish farmers so that sensitization can become more targeted.

The results from the WTP analysis will inform entrepreneurs and other stakeholders on the amount that farmers are willing to pay for the BSFL-based fish feed and the factors that influence their decisions. Pricing is a major decision for any enterprise since that is one of the main drivers of revenue. However, pricing should not be made in isolation from the consumers since they may not patronise the product at a particular price. The study into the mean price that farmers are willing to pay is therefore relevant since it will enable entrepreneurs to fix prices that are acceptable to the market. The Tobit model used to analyse

the WTP revealed the factors that influence farmers' decision to pay this price and this can be incorporated into promotional and marketing strategies.

The results from the study on gains made from substitution will inform farmers as to which feed to use in order to reduce cost and maximise profit. Unfortunately, the profit from fish farming in Ghana is low due to increasing cost and decreasing revenue. Due to this, aquaculture in the country has not met expectations for expansion. The results of the study will allow farmers to switch to a feed which will increase the gains made from fish farming and increase their profit. These results will also boost investor confidence in the fact that there will be demand for the product since there is gain in substituting with existing feed.

Finally, there is little available literature on the financial feasibility of BSFL meal and BSFL-based fish feed production and farmers perception of the feed. The results of the study will contribute towards existing literature on BSFL meal and feed production and farmers perceived benefit and risks of the product.

1.5 Organisation of Thesis Report

The study is divided into five parts. The first Chapter is the introduction of the study, a review of existing literature relevant to the study forms the second chapter. The third chapter explains the methodology used to achieve the objectives of the study and the fourth chapter shows the results and a discussion of the results. Finally, the fifth chapter summarises and provides conclusions and recommendations arrived at by the study.

CHAPTER TWO

LITERATURE REVIEW

Introduction

This chapter presents a review of existing literature relevant to the study. The review covers the state of aquaculture in Ghana, current fish feed produced and the various ingredients of fish feed. It is followed by a review of BSF and the technique for its production and harvest into valuable feedstuff. The impact of BSFL production on the socioeconomic, health and environment is also reviewed. The review further looks at empirical results on the financial feasibility of BSFL production and empirical results on the perception and knowledge of consumers towards the use of insects in feed. Finally, the various analysis; feasibility, perception, WTP and partial budget analysis are reviewed.

2.1 State of Aquaculture in Ghana

2.1.1 Overview

Aquaculture contribution to GDP in Ghana has not been separated from total fisheries; however, total fisheries contributes 1.1% towards total GDP (GSS, 2015). As at 2016, aquaculture contributed 11.3% towards total fisheries production (MoFAD, 2016). The main type of fish cultured is tilapia and catfish with the majority of culture fish either in ponds or in cages (Rurangwa et al., 2015). Cage farmers contribute more than 80% towards total production (Rurangwa et al., 2015). The commercial operators do not make their own feed but rather buy feed from fish feed companies. In recent years, as seen in Figure 2.1, aquaculture production has increased steadily. The sector is constrained by subsistence farming, lack of inputs and high cost of commercial feed production.

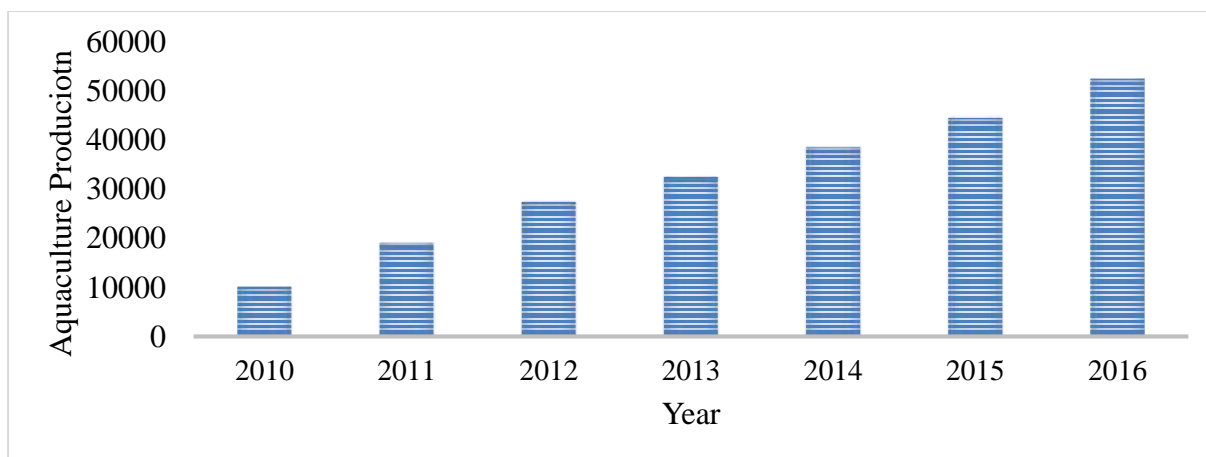


Figure 2.1: Growth trend of aquaculture production (2010-2016)

Source: MoFAD (2016)

2.1.2 Fish feed production

Development and manufacture of fish feed play a vital role in aquaculture growth and expansion. According to EL-Sayed (2013), fish feed production is one of the least developed sectors in aquaculture in developing countries including Ghana. Ghana currently has locally produced and imported feed on the market. There is no readily available statistics on the fish feed produced in the country though currently. Some farmers in Ghana rely on imported feed from developed countries as the main source of feed (Rurangwa et al., 2015). This is because the country's production of fish feed is not enough to meet demand. The main companies selling on the market are Raanan Feed (local manufacture), Agricare feed (local manufacturer), Multi Feed, Coppens Feed and Cargill Feed. Raanan feed is the only company that manufactures the feed in the country on a large scale using some local ingredients, the rest of the feed is currently imported (Rurangwa et al., 2015).

Fish feed ingredients

The ingredients used to prepare fish feed for the aquaculture production can be categorised into three: animal nutrient source, plant nutrient source and microbial nutrient source (Tacon et al., 2012).

Animal Nutrient sources

The main animal protein that is used in making of feed is fish meals and oils and zooplankton meals and oils (FAO, 2012). Fishmeal and oils have been preferred by commercial operators due to its high level of protein, fats and oils and omega three. Volumes of fishmeal has originated from fisheries specifically from capture fisheries and aquaculture. According to Tacon et al. (2012), although some zooplankton have the potential to be used as feed, there is only a small number of commercial operators producing feed with zooplankton.

Plant nutrient sources

The plants used in making compound fish feed is cereals, including by-products of cereals in the form of meals and oil, pulses and protein concentrate meals. When plants are used for feed it should meet a particular nutritional characteristics including low levels of fibre, starch and anti-nutritional compounds. It must be high in protein, be palatable, easy to digest and contain amino acid (Lim et al., 2008).

Microbial Ingredient sources

This type of feed is feed made from sources such as algae, fungi and yeast (Tacon et al., 2011). However, these sources are not available in commercial quantities except the yeast derived feed (FAO, 2012). These cost less in production than the aforementioned nutritional sources.

2.2 Rearing of Insects as Fish Feed

Rearing of insects for various purposes has been with us for a while dating back 7000 years (Rumpold & Schuler, 2013). For example, the rearing of bees for honey and of silk worm for silk, and rearing of other insects for medicinal purposes has always been with us. Researchers are currently experimenting on insects as animal feed. A review of literature reveals that insects historically have been used to feed fish and farm animals. Research has revealed that silkworm pupae is important in the diet of carp in China (Hickling, 1962). Heidinger (1971), reported that aerial insects attracted to light traps increased bluegill production significantly. In recent times more research has been concentrated on BSFL as fish feed. Research showed successful feeding trial in rainbow trout (Stamer et al., 2014; St-Hilaire et al., 2007).

2.2.1 The Black Soldier Fly (BSF)

The black soldier fly is a non pest fly usually found in the tropics. It is originally a native of temperate zones in America but has currently moved to other temperate regions around the world including Africa (Leclercq, 1997). The black soldier fly is a wasp like sleek looking fly, however, unlike wasp they have two wings and do not have a stinger (Diclaro & Kaufman, 2009). Adult larvae vary in colour ranging from black, metallic blue, green or purple to brightly collared black and yellow patterns (Drees, 1998). It is 15-20 mm long (Sheppard et al., 2002). They have antennae that are elongated with three segments, and legs have a white coloration near the end of each leg (Diclaro & Kaufman, 2009). The adults are rather lethargic and poor flyers. They engage in mating and females oviposit in preferably cracks and crevices near feed source (Diclaro and Kaufman, 2009). When the egg is hatched, the larvae goes through various stages before it reaches maturity state. According to Hardouin and Mahoux (2003), the larvae may mature in two weeks under ideal conditions but may take up to 4 months depending on feed and temperature (Makkar et al., 2014). The larvae in their

last larval stage can reach up to 27mm in length and 6 mm in width and weigh up to an average of 220mm. The larvae contains up to 43% to 35% protein and fat respectively (Sheppard et al., 1994). This can serve as a nutritional replacement for fishmeal in the diet of fish. The larvae is dull whitish in colour, and possess a small head that contains its mouthpiece for feeding. At this state the larvae feeds rapidly and stores up the fat for use as an adult since they do not feed when they mature (Diclaro & Kaufman, 2009). At the prepupal stage, the larvae move away from the feed source in search of dry place (Sheppard et al., 1994). Upon maturity, the adult fly can only live up to a few days or weeks.

2.2.2 Socio economic, health and environmental impact (risk or benefit) of using BSFL in fish feed (production via waste conversion)

The use of BSFL in fish feed gives rise to some social, economic, health and environmental impact (risk or benefit) such as:

Diseases

BSF is a non pest insect that is not attracted to human habitat. The BSF does not have mouths to feed and rely on the fat stored from the larval stage. As a result, unlike houseflies, the BSF cannot feed on unsanitary waste and transfer it to food therefore they are not a vector of diseases (Leclercq, 1997). On the contrary, the larvae of BSF is known to reduce the oviposition of housefly (a disease vector especially in developing countries where open defecation and inappropriate sanitation account for dangerous sources of pathogens) thereby serving as a disease control (Graczyk et al., 2001). According to Erickson et al. (2004), BSFL is able to inactivate E. coli 0157:H7 in chicken manure. BSFL is also proved to be able to inactivate the zoonotic bacteria such as Salmonella spp. (Lalander et al., 2013). This means that risk of transmission of diseases from animal to animal or animal to human is reduced.

Nutritional level

An analysis of dried Black Soldier Fly larvae (ESR International, 2008) showed that it contains: 42.1% crude protein, 34.8% ether extract (lipids), 14.6% ash, 7.9% moisture, 7.0% crude fibre, 5.0% calcium, 1.5% phosphorus. In conjunction with these findings, various research has been done that essentially validate these statistics. For example according to St-Hilaire et al. (2007), the average prepupae is composed of 30% lipid and omega 3 acid.

Waste management (BSF Bioconversion)

BSFL are voracious feeders and are able to reduce waste by up to 50% and more and turning it into a rich biomass of 35% and 45% fats and protein respectively (Sheppard, 1994). This is known as the bioconversion technology of BSFL. Since the 1990s, BSFL has been suggested as a way to dispose organic waste by allowing BSFL to feed on it, converting it into biomass and the resultant waste used as fertilizer (Diener et al., 2011; van Huis et al., 2013). As a waste reduction scheme, a BSFL plant can serve as a collection place for disposal of organic waste thereby reducing the negative impact on the environment (UN-HABITAT, 2010).

Noxious smell

Organic waste naturally produces noxious smell and bad odour. As a result, the presence of vile smell is usually associated with any production which involves the use of organic waste. However, the black soldier fly restrains bacterial growth and therefore reduces odour of waste (van Huis et al., 2013). This means that BSFL can be successfully reared on waste without fear of noxious smell disrupting the environment.

Consumer demand

In terms of demand, people who feel that the use of fishmeal causes overexploitation of water bodies may shift to the purchase of BSFL-based fish feed thereby creating a whole new demand (Tiu, 2012). The exploitation of water bodies has been of major concern to various citizens, government organisations and NGO's. Various stakeholders are expected to demand

more of BSFL-based fish feed based on the contributions it will make to sustainable aquaculture. This may however not be true of all regions since some countries are more particular about environmental sustainability than others

2.3 Empirical Results on the Technology for Production and Harvest of BSFL for Fish Feed

The conversion of organic waste into insect proteins for feed using larvae of the BSF is an emerging and promising technology producing an appealing alternative to other protein sources in animal feedstuff such as soybean meal and fishmeal. The prepupae contain 40% crude protein and 30% fat and can easily be used as a valuable feedstuff in fish (St-Hilaire et al., 2007).

Sheppard et al. (1994) conducted a research inoculating BSFL on hen manure. The results show that the manure accumulation was reduced by at least 50%". The chicken manure could be converted to a "42% protein and 35% fat feedstuff".

Newton et al. (2005) conducted an experiment using the black soldier fly larvae to treat hen and swine manure. Their developed swine and layer hen systems could convert the manure into larval mass which contained of "40+% protein and 30+% fat" and also reduced the manure mass by about 50%.

Barry (2004) successfully converted food waste from university cafeteria into valuable feed stuff. This was done by introducing BSFL into containers filled with organic waste from the cafeteria of three universities.

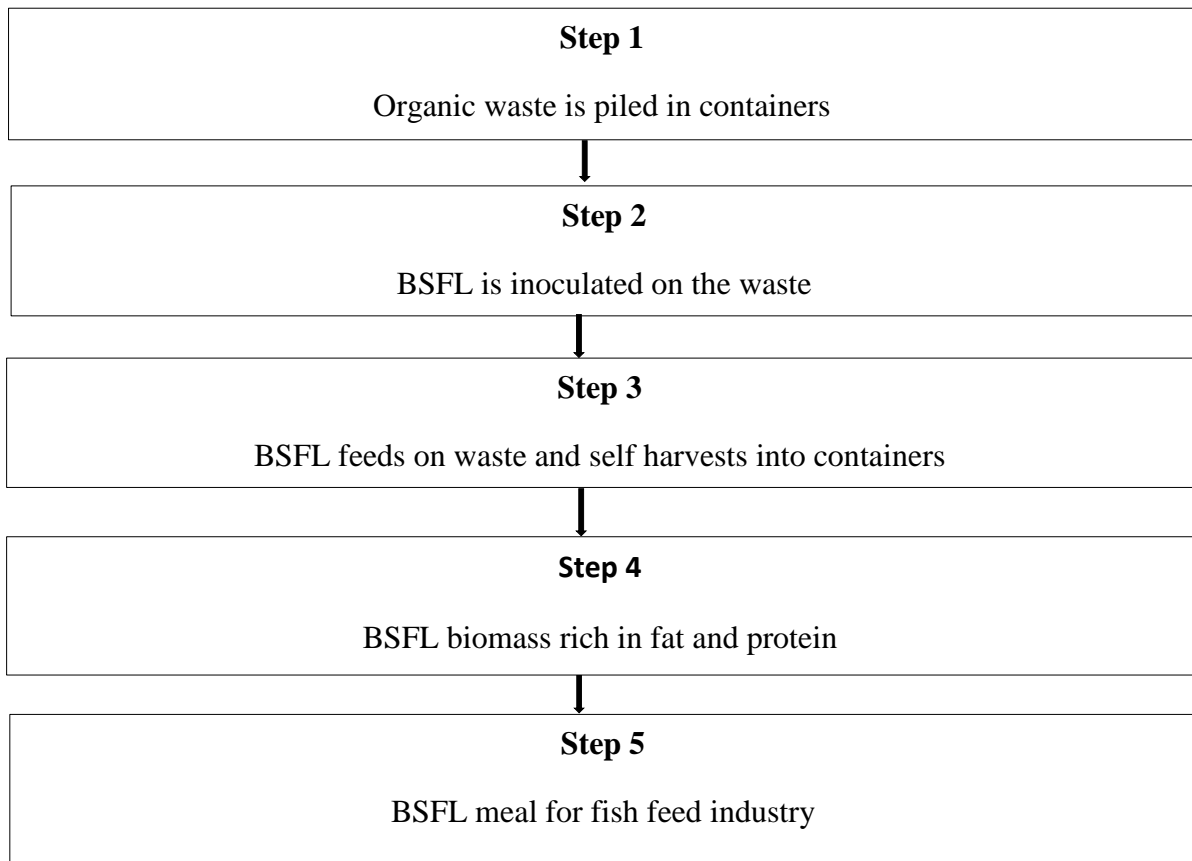


Figure 2.2: Steps in Black Soldier Fly Larvae production

Source: Adapted from Sheppard et al. (1994.)

2.4 Financial Analysis

2.4.1 Measures of project worth

One of the main ways of accessing the feasibility of any investment project is a profitability analysis. Profitability analysis is used to ascertain the viability of a project when cost is matched against cost in what is known as capital budgeting. Cash budgeting involves the detail mapping of net cash flow a project is expected to make over a period of time. According to Gittinger (1982) the usual method used under cost benefit analysis is NPV, BCR, IRR and payback period. However, NPV is the best indicator amongst the four since the IRR and payback period are subject to various constraints.

Net Present Value (NPV)

According to Gittinger (1982), the NPV is a major indicator of the financial feasibility of a project. A project's NPV is computed by discounting cash flow statement by taking time into consideration using an appropriate discount rate. This discount rate in general depends on the projects perceived risk as defined by financial institutions for their borrowing rate. The interpretation for NPV is that if it is positive then the project is viable however if it is negative then the project should be rejected. An advantage of using NPV is that it allows easy comparison of different projects.

Internal Rate of Return (IRR)

IRR is the discount rate at which NPV is zero. IRR analysis is used to ascertain whether investments returns will be enough to justify that investment (Gitman, 2006). It provides a clear indication of whether an investment will be greater than the cost of capital. IRR can be computed using the trial and error method where different discount rates are tried until NPV is equal to zero (Jolly & Clonts, 1993). In evaluating investment decisions the IRR can be used concurrently with NPV, however, for long term project NPV is the preferable method (Mbugua, 2007). This is because the IRR has some inherent weaknesses that make NPV a better option (Brigham et la., 1999; Gitman, 2006). For example, the IRR assumes that future cash flows are invested at the IRR though it may be above current rates.

Benefit Cost Ratio (BCR)

The benefit cost ratio is also an indicator of the profitability of an investment. BCR is computed by dividing the discounted net benefits over the project's projected lifespan over the discounted cost (Gittinger, 1982). A ratio above one indicates viability of the project and a positive NPV whereas a ratio below one shows negative NPV a venture which is not financially viable.

2.4.2 Empirical studies on profitability analysis

A myriad of literature has used cost benefit analysis to ascertain the profitability of an investment. These include:

Offei et al. (2014) used cost benefit analysis to ascertain the financial feasibility of producing urine based fertilizer for vegetable farming in Accra, Ghana. The results showed a positive NPV of 8,147.79, BCR of 1.03 and an IRR of 22.65%.

Rurangwa et al. (2015) on the development of aquaculture in Ghana: Analysis of the fish value chain and potential business cases. In a research conducted in Ghana, Rurangwa et al. (2015) looked at the production cost and benefits of a conventional feed production in Ghana at different levels of production. Investment made in fixed assets amounted to 4, 2 million USD. Gross margin used in the calculation was approximately 60% of the estimated actual margins of Raanan feed. At this gross margin, the calculations still yielded a large amount of profit before marketing, depreciation and interest cost. The results of the study is presented in the Table 2.1.

Diener et al. (2009) on the topic are larvae of the black soldier fly a financially viable option for organic waste management in Costa Rica conducted an experiment in Costa Rica on the financial viability of BSFL production as a waste management technique which showed promising results. In the results, it was shown that an investment of USD 85,000 in a treatment plant (annual operating cost of 35,700) processing three tonnes of waste a day can yield larvae (dry weight) of 150kg a day. This larvae, could be sold on the market (at prevailing fishmeal price of USD1000/ tonnes) for USD 55000. A summary of results is shown in Table 2.2.

Table 2.1: Summary of financial feasibility results for conventional feed production in Ghana (Amount in USD)

	Production tonnes	Sales	Total Gross margin	Total operational cost	Profit before marketing, depreciation & Interest
1 Shift	8,000	5,600,250	2,000,000	984,000	1,016,000
2 shift	16,000	11,200,000	4,000,000	1,566,000	2,434,000
3 shift	25,000	17,500,250	6,250,000	2,166,600	4,084,000
4 shifts	32,000	22,400,250	8,000,000	2,683,200	5,317,000

Source: Rurangwa et al. (2015)

Table 2.2: Summary of financial feasibility results for BSFL meal production in Costa Rica (Amount in USD)

Project worth measure	Value (USD)
Investment cost	85,000
Operating Cost	35,700
Revenue from sale of larvae	55,000

Source: Diener et al. (2009)

According to Agrawal et al. (2011) however, the results for BSFL meal production was less than satisfactory. The research was conducted on latrines as substrate for BSFL production (900 pit latrines emptied per year). The results of the research showed that, production of BSFL meal will yield a loss of USD 37,888 and a negative return on initial capital (IRR) of -227% . This was after an upfront investment cost of USD 16,680. A summary of results is shown in Table 2.3.

Table 2.3: Summary of financial feasibility results for BSFL meal production in USA (Amount in USD)

Project wealth measure	Value (USD)
Annual Profitability	(37,888)
Upfront Capital Investment	16,680
Return on capital investment	(227%)
Total time to break even	(no breakeven)

Source: Adopted from Agrawal et al. (2011)

2.4.3 Partial Budget Analysis

2.4.4 Overview of partial budgeting

Decisions on change in a farming system is very important since this may lead to increasing or declining profits. Partial budgeting is therefore needed to make these decisions (Alimi and Alofe, 1992). Partial budgeting is a technique that is employed to assess the costs and benefits resulting from changes on the farm system (Kay et al., 2008). This technique specifically focuses on the implications of the intended change in a business operation by comparing the benefits and costs resulting from implementing the alternative with respect to the current practice (Soha, 2014).

According to Kay et al. (2008), in partial budgeting, the main factors looked at are:

1. The new costs arising when insect based feed is used
2. The new revenue arising when insect based feed is used
3. The cost incurred from using conventional feed
4. The revenue gained from using conventional feed

The limitation of partial budget is that only two alternatives can be compared at a particular time that is the current situation and the new alternative.

2.4.5 Empirical studies on partial budget analysis

Various researchers have used partial budget analysis to estimate changes in enterprise. A few include:

Offei et al. (2014) using partial budget analysis ascertained that a cabbage farmer in Accra would make savings of GHS 24.59 when he uses sanitized urine as a substitute for chemical fertilizer.

Soha (2014) used partial budget analysis for his study to estimate the effect on net benefit of changing from one level of Nitrogen-fertilizer application to another on sorghum production, The experiments consist of three treatments of 100kg N per fedden (T1), 200kg N per fedden (T2) and 300 kg N per fedden (T3). It was found out that substituting treatment 1 with treatment 2 has a higher net benefit of 9.61 as compared to substituting T2 with T3 with a net benefit of 0.72 where it was concluded that treatment 2 was most preferred.

2.5 Perception Analysis

2.5.1 Likert scale

A consumer's decision to buy a product depends on the perceived risks and benefits associated with the product. To ascertain this perception on various issues, marketing researchers have used rating scales (Likert, 1932). Respondents are asked to rate their opinions or perceptions on scales which are all positive ranging from lowest to highest or on scales that range from negative to positive. A Likert type scale questionnaire is used to assess the degree to which respondents agree or disagree with statements on benefits and risks of using BSFL-based fish feed. Likert scale is preferred because it can be built into an index and there is little loss in accuracy when interpreting ordinal data is treated as interval (McGivern, 2006). To use the Likert scale, multiple statements are used in this type of questionnaire to solicit various answers from respondents. Multiple statements are used because it is easier to measure perception with multiple statements than with a single statement (McGivern, 2006).

2.5.2 Empirical studies on perception analysis

Researchers have successfully used Likert scale type questionnaires to determine perceptions and opinions. Some of these include:

Verbeke et al. (2015) used a five point Likert scale to ascertain the perceived benefits and risks of using BSFL in fish feed. In the experiment, 14 benefit and risk statements were scored by farmers using a Likert scale ranging from (1) strongly agree to (5) strongly disagree. The research revealed composite overall mean scores of 3.71 and 3.04 for benefit and risk statements respectively. A paired sample and t- test ($t=0.86$; $P<0.001$) revealed a significant difference between the two scores. Researchers therefore concluded that farmers have a significantly higher perception of the benefit of insects in feed than they do of the risk. A summary of results is shown in Table 2.4.

Table 2.4: Summary results of perception analysis

	Benefit statement	Risk Statement
Overall mean scores	3.71	3.04
T-test	0.36	
P-value	0.001	

Source: Adapted from verbeke et al. (2015)

In 3013, Ghosh and Hasan determined the attitude of Bangladesh farmers towards sustainable agriculture using 5-point Likert type scale for the analysis where 90 respondents were sampled in two villages. The result showed that majority of the respondents 'agreed' to the use of compost and green manure in their field as a substitute to chemical fertilizer.

According to Assis and Mohd Ismail (2011), used a 5-point likert scale to determine the attitude of farmers towards organic farming. The likert scale comprised of six positive

statements and six negative statements. The study concluded that majority of the respondents have positive attitudes towards organic farming.

2.6 Willingness to Pay Analysis

2.6.1 Overview

Estimation of a consumer's willingness to pay for a product is a technique used to determine the amount consumers would pay for a product without an existing market (non-market goods) or a good without a well-established retail outlet (Lawi, 2014). The notion of willingness to pay is the largest amount an individual is willing to pay for an improvement in product or service. There are many approaches employed to ascertain a consumer's willingness to pay for a product. This is classified into stated and revealed preferences. The revealed preference is determined by watching the individuals purchasing price and expenditure habits to gain particular goods and service. This means that the approach to employ to ascertain WTP is on the basis of consumer behaviour (Samuelson, 1948). Unlike the revealed preferences, the stated preference requires respondents to give values to various goods and services rather than observing their purchasing habits (King et al., 2000). To determine this, methods such as contingent valuation, travel cost, hedonic pricing, experimental auctions and conjoint analysis can be used. The revealed preference uses information from experiments and market data whereas the stated preference uses direct and indirect market surveys.

Contingent Valuation Method (CVM)

This is a method usually used by researchers for goods that are not currently on the market. This is a survey approach where market simulation is done for a non-market good. Prices are obtained for the good based on hypothetical description given during the survey. Generally,

Cummings et al. (1986) purported that when contingent valuation method is used for goods that respondents are at least familiar with it can yield fairly accurate results.

The CVM uses surveys to obtain what respondents will be willing to pay for a project. This is a way of determining consumer preference for the product. CVM circumvents the absence of a real market by providing respondents with a hypothetical one in which they can weigh the trade-offs of the product and make purchasing and pricing decisions. It involves asking individuals to value increments or decrements in a good or service by attaching WTP for the commodity. In the hypothetical market, these parameters are defined: the good under interest, the status quo, the level of provision and the increment or decrement there in, the institutional structure under which the good will be provided. To elicit highly accurate responses, CVM is structured in a well-defined way in order to solicit a choice of purchase contingent on the occurrence of the hypothesised situation (Cummings et al., 1986)

The Contingent valuations methods have been identified for soliciting responses from respondents. These include; open ended: In this method, respondents are not given a starting price to begin with. However, the disadvantage of this is that it leads to a lot of outliers (large amounts or very low amounts), bidding game: the bidding game offers respondents a series of bids to choose from. When acceptance is made or a respondent refuses to pay for a particular bid, the game closes and the WTP is elicited, payment card: the payment card presents respondents with a visual aid containing large numbers of monetary amounts. Respondents are tasked with ticking sums they are willing to pay and crossing out sums they are unwilling to pay, Dichotomous or referendum format: this format can either be single bounded, double bounded or multiply bounded.

Contingent valuation method is a method well used by researchers because there is little information on actual consumer behaviour, its popularity is not due to the accuracy of the method in determining willingness to pay. One problem with the demand is that demand and price can be overstated since the survey is hypothetical. Respondents may be unwilling to pay in real life situations of the product. This can lead to distortions in demand projections made by various enterprises. This arises when the method is not administered well thereby giving consumers a false idea of the product. According to Whittington (1998), contingent valuation method when used should include adjustments to fit the conditions and cultural differences of various regions.

2.6.2 Empirical studies on willingness to pay (WTP) analysis

There is a myriad of literatures on assessing consumer willingness to pay using the contingent valuation method.

Asenso-Okyere et al., (1999) discussed willingness to pay for health insurance in a developing economy. The pilot study of the informal sector of Ghana used contingent valuation (Asenso-Okyere et al., 1997). Using the bidding game, the research solicited the maximum amount farmers were willing to pay. The results showed that over 90% of the respondents agreed to participate in the scheme and up to 63.6% of the respondents were willing to pay a premium of $\text{¢}5000$ or $\$3.03$ a month for a household of five persons.

Campiche et al. (2004) used CVM in their research to examine the impact of consumer characteristics on willingness to pay for natural beef in the southern plains of United States of America. They used the Dichotomous Choice Contingent Valuation Method (DC-CVM) to solicit survey responses to choice between amount paid for regular and natural beef.

Other recent applications of CVM to ascertain consumers' willingness to pay include: Research to investigate the willingness to pay for Farm Insurance by Smallholder Cocoa Farmers in Ghana (Abbeam et al., 2014). Owusu and Anifori (2013) used CVM to assess consumers' willingness to pay premium for organic fruits and vegetables in Ghana.

Factors affecting willingness to pay

Most of willingness to pay studies generally include socio-demographic characteristics such as gender, income level, age, household, marital status, access to extension, membership of FBO, awareness of the product, experience and education as factors influencing WTP. These socio-demographic characteristics were found to be significant in explaining the decision to buy organic foods, pay for health insurance amongst others.

For example, Asenso-Okyere et al. (1997) using an ordered probit model, the level of insurance premiums households were willing to pay were found to be influenced by dependency ratio, income or whether a household has difficulty in paying for health care or not, sex, health care expenditures and education.

Campiche et al. (2004) using the multinomial model revealed that household income and location were significant determinants of willingness to pay for natural beef, However, the research found age, education, gender, and educational level were not significant.

Engel (2008), Carried out a survey of the determinants of consumer willingness to pay for organic foods in South Africa, empirical results indicates that age, marital status, and level of education are the socio-demographic factors that significantly explain consumers' willingness to pay a premium for organic food.

A research conducted by Abbeam et al. (2014) on cocoa farmers' willingness to pay for farm insurance using independent double-hurdle model determined that awareness of insurance, marital status, number of years in cocoa farming, educational level, age of farmer and income level significantly affected WTP.

CHAPTER THREE

METHODOLOGY

Introduction

This chapter describes the various methods that were used to achieve the objectives of this study. It begins with the conceptual and theoretical framework underlying the study. The chapter further explains the various methods that were used to achieve the objectives of the study, the method of data collection, and provides a brief description of the study area.

3.1 Conceptual Framework

For every investment the main objective is profitability. The questions that the entrepreneur asks when introducing a novel product to the market is; if a product is manufactured will there be demand for it and at what price? If there is, will it be profitable to produce taking into account revenue and costs of inputs needed for production? This study as shown in Figure 3.1 seeks to review a complete business model for analysis to serve as a road map for entrepreneurs wanting to manufacture BSFL meal and BSFL feed. It looks at the production of BSFL meal and BSFL based fish feed as the main output, and the various factors that drive the production of these products.

To invest in a new venture, as suggested by the neoclassical theory the investor must consider both profitability and demand. Profitability entails considering market interest rates and price of capital, whereas demand looks at the market for the product. As shown in Figure 3.1, profitability is assessed by comparing revenue and cost of production to determine whether the difference is negative or positive. This will determine whether to invest or not to invest in a venture. On the other hand, profit cannot be looked at in isolation, to drive production of BSFL based fish feed, an entrepreneur must look at the demand for the feed by farmers. In

this case a consumer's decision to buy or willingness to pay for the BSFL based fish feed is assumed to be influenced by the price of the product, demographic, socio economic factors, perception and the gains and losses of its conventional substitute (Campiche et al., 2004). This is consistent with the factors affecting demand. Thus, an investment decision to produce BSFL is determined by profitability (taking into revenue and cost) and demand for the product. Figure 3.1, shows how these factors work together to drive the industrial scale production of BSFL meal and BSFL based fish feed.

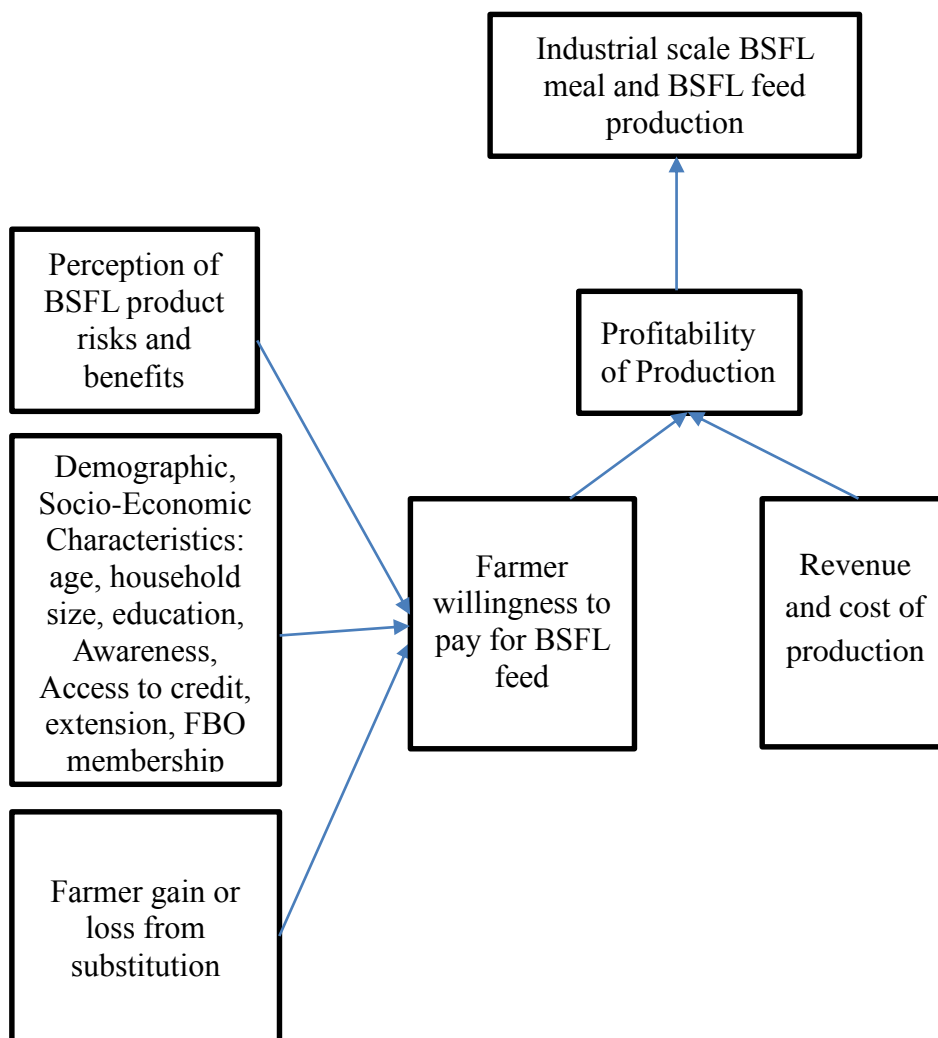


Figure 3.1: Conceptual framework illustrating investment decisions of feed entrepreneurs and fish farmers

Source: Adapted from Neupane et al. (2002)

3.2 Theories Underlying the Study

Investment theory

Investment decisions are important for micro economic and macro-economic growth of a country. An investment that pays off is able to ripple off to the entire economy in terms of job creation and GDP contribution. As a result investment decisions are taking after meticulous consideration of all factors and different theories have been propounded to explain investment decisions and behavior.

The neoclassical flexible accelerator model theory is the main theory underlying this study. It takes into consideration profitability, depreciation, and interest rate while also considering the changes in aggregate demand. This theory was propounded by Jorgenson (1967) and it stipulates that an investment behaviour is explained by profitability, interest rate on the market and the changes in aggregate demand for the product. This means that for an investment to be made in any venture all these factors put together must be considered.

In terms of profitability as an investment decision, costs and benefits must be identified and compared. Gittinger, (1982), stipulates that for costs and benefits to be compared for projects with varying costs and benefit streams, these costs and benefits must be discounted. This study uses four main discounted measures such as Net Present Value (NPV), Benefit Cost Ratio (BCR), Internal Rate of Return (IRR) and Payback period to ascertain the investment viability of the production of black soldier fly larvae meal production and black soldier fly larvae based fish feed production.

In assessing aggregate demand for a product, studies show that consumers make their own decisions to balance the marginal utility and marginal price of products. From the utility

theory, farmers derive satisfaction from the use of aquaculture inputs they use in fish farming to maximize output. This studies uses perception studies and willingness to pay studies to access the demand of BSFL based fish feed by fish farmers.

3.3 Method of Data Analysis

3.3.1 Determining the level of profitability of BSFL-based feed production

Scenario A: Production of BSFL meal

BSFL meal is the larvae of the black soldier fly that has been grounded into powdered form. This serves as animal protein ingredient in the production of formulated fish feed.

Costs and benefits analysis:

One way of evaluating the viability of an enterprise is the use of cost benefit analysis (Gittinger, 1992). This usually involves matching the Cost: start-up cost and other operational cost, against revenue streams that accrue over a period of time, usually assumed to be the end of the production period. Various researchers have used cost benefit analysis to ascertain profitability Sogbesan & Ekundayo (2014) and Offei et al (2014).

Preliminary results from experiment conducted by at BNARI sponsored by FiBL which started in 2014 and ended in 2016 helped to determine some of the cost of production. The experiment was conducted on the production of BSFL meal via the use of organic waste. Summary of logistics used for experiment was obtained from science researchers' station experiment and cost extrapolations were made from it. Also, a summary of experimental results and was obtained, from these results, large scale projections were made.\

The total cost for the production of the insect based feed was identified as follows:

Fixed costs: Fixed costs are the costs that are paid regardless of production and usually accrue during the start of the project (Jolly and Clonts, 1993). In the short run, fixed cost remains constant regardless of variations in production.

$$\text{TFC} = \text{FC}_1 + \text{CF}_2 + \dots + \text{CF}_{16} \quad (3.1)$$

Where

$\text{CF}_1 = \text{Land}$

$\text{CF}_2 = \text{Building}$

$\text{CF}_3 = \text{Adult Cage: For Reproduction amongst adult larvae}$

$\text{CF}_4 = \text{Larval Container: For housing larvae}$

$\text{CF}_5 = \text{Drums: For storing organic waste for inoculation of larvae}$

$\text{CF}_6 = \text{Drums stand: For holding drums elevated above ground}$

$\text{CF}_7 = \text{Collection bins: For collecting of self-harvested larvae.}$

$\text{CF}_8 = \text{PVC pipe: For connecting drums to collection bins}$

$\text{CF}_9 = \text{Industrial oven: For drying and killing of larvae}$

$\text{CF}_{10} = \text{Grinder: For milling the BSFL into powder (BSFL meal)}$

$\text{CF}_{11} = \text{Shovel: For turning organic waste}$

$\text{CF}_{12} = \text{Sieve, for sieving out waste from larvae after washing}$

$\text{CF}_{13} = \text{Weighing Scale: For measuring of the weight of organic waste}$

$\text{CF}_{14} = \text{Gloves: For protection of hands while handling waste}$

$\text{CF}_{15} = \text{Nose mask: For protection against bad odour from waste}$

$\text{CF}_{16} = \text{Trucks: For moving of waste to project site}$

Variable cost: Variable costs are the cost that change as the level of production changes

$$\text{TVCs} = \text{VC}_1 + \text{VC}_2 + \dots + \text{VC}_9 \quad (3.2)$$

Where

VC₁ = Layer feed (Larval Diet): For feeding larvae during the first 10 days after hatching

VC₂ = Organic Waste: Feed for larvae after 10 days

VC₃ = Electricity: For powering machinery and equipment and other general uses

VC₄ = Water: For washing of larvae after self-harvesting and other general uses

VC₅ = Sacks: Fish feed is usually packed into 50kg sacks. The hessian bag, made from woven jute, is much used in tropical and sub-tropical countries. The relatively open fabric enables water vapour and heat to escape readily from the meal.

VC₆ = Labour: Human resource needed for operations which changes according to production level. (Minimum wage will be used for computation)

VC₇ = Fuel: For moving of organic waste to manufacturing site

VC₈ = Water: For washing of larvae before processing and other general use

VC₉ = Repairs and maintenance

The assumptions for computations for cost and revenue were based on these premises:

1. An average fresh larvae weighs 2 grams
2. 300 larvae is fed on 10g of larvae meal daily for 10 days before inoculation on waste
3. When dried up the weight of the larvae reduces to one-third of its original fresh weight
4. The larvae has a mortality rate which is negligible and therefore not taken into account.
5. The larval container can store up to 10,000 number of larvae
6. The Pre-consumer waste is free
7. 25 tonnes of waste is needed to produce 3 tonnes of larvae meal a day
8. A single drum can store up to 30 kilos of waste
9. Production is started at full capacity of 1000 tonnes and therefore remains constant over the 20 year period (20 years based on asset with the longest lifespan)

10. The adult black soldier fly does not feed and therefore no funds will be spent on meal for adult.

11. Casual workers are paid at minimum wage GHS8.80 per day

Projections were made based on these premises and a cash flow statement was developed for 20 years based on the assets with the longest useful life. Assets with shorter life were replaced within the 20 years of projected cash flow and subtracted from that year's revenue.

Stages of profitability analysis:

BSFL meal is a relatively new product on the market. From Table 3.1, in computing the Revenue for the 1st price scenario, the market selling price of fishmeal was used. However, in order to encourage the adoption of the BSFL, and garner demand for the product, it should have an introductory price that is relatively lower than that of fishmeal (Agrawal et al, 2011). In addition, this study sought to provide a less costly option to fishmeal. As a result, from Table 3.1, a 2nd, 3rd and 4th price scenarios analysis was done on the profitability of the business by decreasing the market price by 20%, 15% and 10% respectively to ascertain the price below conventional fishmeal at which all the profitability indicators such as BCR, IRR and NPV are below

Table 3.1: Summary of profitability analysis performed on price scenarios

Analysis	Description
1	Using market prices of fishmeal(GHS117 per 20kg bag)
2	Using 20% below market price of fishmeal (GHS94 per 20kg bag)
3	Using 15% below market price of fishmeal(GHS100 per 20kg bag)
4	Using 10% below market price of fishmeal (GHS105 per 20kg bag)

Source: Authors own computation (2017)

Sensitivity analysis:

Sensitivity analysis was performed on analysis 4 (Using 10% below market price of fishmeal) since it was found to be the most viable projection below market price of fishmeal at which the investments profitability indicators such as BCR, NPV and IRR are still acceptable. The sensitivity analysis was performed by increasing cost by 10% and decreasing output by 10%. Since this is a new project, it is important to increase cost to make up for any contingencies that may arise. In addition, output was reduced because insects, like other animal production may not be able to meet the predicted output due to for example handling, diseases and mortality.

Scenario B: Production of BSFL-based fish feed

The BSFL-based fish feed is feed that has been formulated with BSFL meal as an animal protein ingredient. It is formulated by using BSFL meal and other ingredients such as wheat bran, soybean, fishmeal, common salt and maize. The research used BSFL meal as a 75% replacement of fishmeal as animal protein.

Costs and benefits analysis:

A research conducted at WRI provided some of the cost projected for the production of BSFL-based fish feed. This research converted the BSFL meal into BSFL-based fish feed by adding various ingredients such as fishmeal, wheat bran, soybean, maize, cassava flour and common salt. The experiment consisted of replacing fishmeal in fish feed with BSFL meal by 75%, 50% and 25%. This BSFL feed projection is however based on 75% replacement of fishmeal by BSFL meal since the research showed that it had the highest profit index.

Total fixed cost was defined as:

$$\text{TFC} = \text{FC}_1 + \text{FC}_2 + \dots + \text{FC}_{10} \quad (3.3)$$

Where:

$\text{FC}_1 = \text{Land}$

$\text{FC}_2 = \text{Building}$

$\text{FC}_3 = \text{Extruder: For turning the feed into a state that can float}$

$\text{FC}_5 = \text{Mixer: For mixing of various ingredients used for the meal}$

$\text{FC}_6 = \text{Grinder: For milling the various ingredients}$

$\text{FC}_7 = \text{Weighing Scale: For measuring of the weight of organic waste}$

$\text{FC}_8 = \text{Trucks: For moving of waste to project site}$

$\text{FC}_9 = \text{Conveyor belt}$

$\text{FC}_{10} = \text{Pelleter}$

The total variable cost is defined as:

$$\text{TVCs} = \text{VC}_1 + \text{VC}_2 + \dots + \text{VC}_9 \quad (3.4)$$

Where:

$\text{VC}_1 = \text{other ingredients for formulating the compound feed}$

$\text{VC}_2 = \text{BSFL meal}$

$\text{VC}_3 = \text{Electricity: For powering machinery and equipment and other general uses}$

$\text{VC}_4 = \text{Water: For washing of larvae after self-harvesting and other general uses}$

$\text{VC}_5 = \text{Sacks: Fish feed is usually packed into 50kg sacks. The hessian bag, made from woven jute, is much used in tropical and sub-tropical countries. The relatively open fabric enables water vapour and heat to escape readily from the meal.}$

$\text{VC}_6 = \text{Labour: Human resource needed for operations which changes according to production level. (Minimum wage will be used for computation)}$

VC₇ = Fuel: For moving of organic waste to manufacturing site

VC₈ = Water

VC₉ = Repairs and maintenance

The assumptions for computations for cost and revenue were based on these premises:

1. The feed is produced at 60% animal protein, 75% of this is BSFL meal and 25% is fishmeal.
2. Production is started at full capacity of 1000 tonnes and therefore remains constant over the 20 year period
3. Casual workers are paid at minimum wage GHS8.80 per day
4. The BSFL meal used for production is purchased by the entrepreneur

Stages of profitability analysis:

BSFL feed is a relatively new product on the market. In the 1st analysis, revenue was computed by using the market price of conventional starter fish feed. However, in 2nd analysis, the average amount farmers are willing to pay for BSFL-based fish feed was also used as selling price to compute revenue for the cost benefit analysis. A summary of analysis performed is shown in Table 3.2.

Table 3.2: Summary of analysis performed

Price scenario	Description
1	Using market price (GHS200 per 20kg bag)
2	Using MWTP amount (7%) below market price (GHS186 per 20kg bag)

Source: Authors secondary data (2017)

Sensitivity analysis:

Sensitivity analysis was performed on analysis 2 (Using MWTP amount, 7% below market price) since that is the price at which farmers are willing to pay for the BSFL-based feed. The sensitivity analysis was performed by increasing cost by 10% and decreasing output by 10%. Since this is a new project, it is important to increase cost to make up for any contingencies that may arise. In addition, output was reduced because input supply (for example BSFL meal) for the feed production may not meet expectations and production may fall.

The discounted measures of project worth for the two scenarios

To evaluate the profitability or “Net Benefit” for investments which are expected to last for more than a year, discounted measures of project worth such as Net Present Value (NPV), Benefit Cost Ratio (BCR) and Internal Rate Return (IRR) are used. This is particularly important because of the premise that the value of a cedi today is worth more than the value of a cedi tomorrow. Discounting essentially is the technique through which future benefits and costs of BSFL meal and BSFL-based fish feed are brought down to their present value (Gittinger, 1982). The cash flow generated from the benefits and costs were discounted to their present value. A discount rate of 31% which is the average of Ghana Commercial Bank (31%) and Agricultural Development bank (31%) was used. The following indicators were computed from the discounted value:

The Net Present Value (NPV)

In calculating the Net Present Value, the sum of the discounted future streams of benefit were matched against the sum of discounted future streams of cost. The NPV is the difference between the two discounted figures. A positive NPV shows viability and profitability of the

project whereas a negative NPV indicates that the project is not viable. However, it is important to note that these computations are only as reliable as the data that is used in computing them. The researcher must therefore ensure that the data worked with is accurate.

The NPV equation is specified as:

$$NPV = \sum_{t=1}^{t=n} \frac{(B_t - C_t)}{(1+r)^t} \quad (3.5)$$

Where NPV= Net present value, t= number of years, r= discount rate, B=benefits, C=Cost

The definitions for the alphabets is constant for the rest of the equations of the study. The decision rule for NPV is that the NPV should be greater than 1.

Benefit-Cost Ratio (BCR)

To compute the BCR, the discounted benefits were divided by the discounted cost in a period of time t. The benefit cost ratio is important because it shows the cedi made on every dollar invested in the venture. The decision rule for BCR is that the ratio of benefit to cost should be greater than 1.

The BCR equation is specified as:

$$BCR = \frac{\sum_{t=1}^{t=n} B_t / (1+r)^t}{\sum_{t=1}^{t=n} C_t / (1+r)^t} \quad (3.6)$$

Internal Rate of Return (IRR)

To compute the IRR, the rate was found at which NPV is equal to zero. The IRR of a project should be higher than the interest rate on loan or return on capital to make the project desirable for investment. This means that the greater the IRR the better it is for the investor. It

can be computed with the trial and Error method by finding the rate at which NPV is equal to zero (Jolly and Clonts, 1993).

The IRR model is specified as:

$$\text{IRR} = \sum_{t=1}^{t=n} \frac{(B_t - C_t)}{(1+r)^t} = 0 \quad (3.7)$$

3.3.2 Determining the perception of farmers toward BSFL-based feed

As shown in Table 3.3, a Likert scale was used to collect information from respondents on 10 different perception statements. The statements were grouped into five statements for perceived risk and five statement for perceived benefit. These perception statements were adapted from similar work done by Verbeke et al. (2015), on the perception of farmers on the use of insects in animal feed. The statements encompasses economic, health and environmental factors since these have been known to influence purchasing decisions. (Owen et al., 2000; Loureiro et al., 2001). The questionnaire had a scale ranging from disagree (1) to agree (3). Respondents were asked whether they agreed, were not sure or disagreed.

Various scores were attached to their answers. The various means of the statements were then found using a weighted mean index.

Table 3.3: Perception statements of perceived risk and benefit

Perception Statements	Disagree (1)	Not Sure (2) (Midpoint Scale)	Agree (3)
The use of BSFL in fish feed can:			
Risk Statements			
1. Decrease demand for fish			
2. Cause release of noxious gases during BSFL production			
3. Introduce BSF which will spread diseases to human beings			
4. Cause microbiological contamination to fish			
5. Be detrimental to the health of fish consumers			
Benefit statements			
1. Decrease the overexploitation of water bodies			
2. Lower the cost of Fish feed			
3. Lower our dependence on imported feed			
4. Improve organic waste management in the country			
5. Improve the sustainability of aquaculture production			

Source: Authors adaptation of Verbeke et al. (2015)

A weighted mean index is the weighted average response of various respondents. It is calculated to find the mean response to various perception statements.

The WMI model is specified as:

$$WMI = \frac{\sum f_i * w_i}{N} \quad (3.8)$$

Where: f_i = Frequency of response to the i^{th} scale, w_i = Weight of the i^{th} scale

N = Number of Respondents

The Cronbach's alpha was used to test the internal consistency of the scale. This is a test performed to confirm that the various statements under risks and benefit are related and can therefore be aggregated into a composite score. This means that, the overall mean for risk and the overall mean for benefit can be computed. To show a high degree of internal reliability, the Cronbach's alpha should be greater than 0.7.

The paired sample t-test was used to test for the significance of the difference between the overall means computed and the midpoint scale. It was also used to test the significance of the difference between the overall risk mean and overall benefit mean. The paired sample T-Test is usually used to compare two different means from the same sample. This was done to ascertain whether the difference between the two means is significant or not.

3.3.3 Determining farmers' willingness to pay (WTP) for BSFL-Based feed

Contingent Valuation Method was used to determine maximum amount respondents are willing to pay for BSFL-based fish feed. WTP for a product is the maximum amount of money that may be contributed by an individual to equalize a utility change (Lusk and Hudson, 2004).

The contingent valuation method was used because the product is not on the market yet in Ghana. Under the contingent valuation method, the bidding game was used to ascertain the maximum prices that farmers are willing to pay. Specifically, the dichotomous choice, double bounded contingent valuation method was used for the bidding game. This approach was used because it gives the farmer an easy choice of responding 'yes' or 'no' and it mimics a farmers purchasing decision in real life. In addition, it prevents outliers in the data since the responses are within a limited range. Before starting the bidding game, the product was described to respondents in detail, explaining the process of production and the components of the product, the current substitute of the product was also made known to the respondents. Each was then asked to choose whether they will be willing to pay for the product or not.

On the part of the bidding game, the various bids were set GHS220.00 maximum and GHS180.00 minimum. The bid began at GHS200, the price of conventional feed, if the respondent is not willing to pay, the price was reduced successfully by GHS10 until accepted or until it reached the minimum of GHS180. On the other hand, if the respondent is willing to pay, it is increased from GHS 200 by GHS10 upwards until the maximum of GHS 220 is reached. This is comparable to the bidding game conducted by Asenso-Okyere et al., (1997) on the willingness to pay for health insurance for health insurance in Ghana. The mean amount that farmers were willing to pay was computed from these responses.

The formula used was:

$$\text{Mean Willingness to Pay (MWTP)} = \frac{\sum EBV_i * f_i}{n} \quad (3.9)$$

Where EBV = Elicited Bid Value of respondents (final bid), F = Frequency of respondents, n = total number of respondents

Identifying the factors affecting the amount farmers are willing to pay: The Tobit regression model

The Tobit regression model was used to determine the factors that influence the maximum amount farmers are willing to pay. The Tobit was chosen because the dependent variable is continuous. The model was specified as:

$$Y^* = \beta_0 + \beta_1 \text{AGE} + \beta_2 \text{HSEH} + \beta_3 \text{MS} + \beta_4 \text{ANINC} + \beta_5 \text{EDUC} + \beta_6 \text{AWA} + \beta_7 \text{MFBO} + \beta_8 \text{AEX} + \beta_9 \text{RS} \beta \quad (3.10)$$

Where Y^* is the latent variable for the maximum amount farmers are willing to pay for the product.

Explanation of the dependent variable

The dependent variable represents the maximum amount each farmer was willing to pay (Y) during bidding.

Explanation of the independent variables

Annual income (ANINC): Income is measured in Ghana Cedi as a continuous variable. As a factor affecting demand, it is expected to have a positive relationship with MWTP which is in line with the economic theory of demand. Research conducted by Asenso-Okyere et al. (1997), showed that income is positively related to willingness to pay for health insurance.

Education (EDUC): Education is measured in number of years as a continuous variable. It is expected to have a positive relationship with MWTP since studies have shown that the higher an individual's educational level, the more the person is willing to pay for a product. This is because the individual is able to better understand benefits of the product and are willing to pay more. According to Owusu and Anifori (2013), education has a positive correlation with willingness to pay premium for organic fruits and vegetables.

Marital status (MS): Marital status measured as a discrete variable, married or unmarried. Marital status is expected to have a positive relationship with willingness to pay for BSFL feed. This is because, married people are more likely to adopt innovations in order to make gains and support the family. In a research done by Engel (2008), marital status was found to positively influence willingness to pay premium for organic food.

Age: Age is measured in actual number of years as a continuous variable. It is expected to have a positive or a negative effect on MWTP. It is expected that young people are more likely to buy an innovative product than older people.

Household size (HSEH): Household size is measured as a continuous variable. It is expected to have a positive or negative relationship. The rationale here is that either the farmer will be willing to pay less since money left over with a large family size may be small, or the farmer may be willing to pay more in order to increase productivity and take care of the large family size.

Membership with a farmer based organisation (MFBO): This was measured as a discrete variable with Yes as 1 and No as 0. The membership in an FBO is expected to have a positive relationship with MWTP. This is because members of an FBO are more likely to discuss the benefits and risks amongst themselves and gain better understanding to try the product (Asenso-Okyere et al., 1997).

Access to extension service (AEX): This is another complimentary factor of demand. Access to extension was measured as a discrete variable with Yes as 1 and No as 0. It is expected to have a positive relationship with willingness to pay. Farmers with access to credit are expected to have better knowledge about feed and therefore be more willing to pay higher prices for BSFL-based fish feed

Awareness (AWA): Awareness or knowledge of insects was measured as a discrete variable, with Yes as 1 and No as 0. Awareness of insects as feed is expected to affect and positively influence willingness to pay for BSFL-based fish feed. This is because people who are aware

of insects as feed will be more willing to pay for it since they are aware of its benefits. In a research conducted by Abbeam et al. (2014), awareness was found to be significant and positively related to the willingness of cocoa farmers to pay for farm insurance.

Residential status (RS): The residential status of farmers was measured as a dummy variable. Residents is measured as 1 and migrant as 0. It is expected that residents will have a positive relationship with willingness to pay. This is because they are more willing to invest in new products since they expect to be involved in the production of fish for a long time. Migrants may leave the area for a different occupation at any point in time. A summary of the dependent variables is shown in Table 3.4.

Table 3.4: Description of dependent and explanatory variables

Variable	Description	Measurement	Aprior Expectation
AGE	Age	Years	+ / -
MS	Marital Status	Dummy Married=1, Otherwise=0	-
EDUC	Education	Years	+
AEXT	Access to extension	Dummy Yes=1, No=0	+
ANINC	Annual income	Ghana Cedi	+
HSEH	Household size	Number	+ / -
MFBO	Membership in FBO	Dummy Member=1, Non-member=0	+
RS	Residential status	Dummy Resident=1 Migrant=0	-
AWA	Awareness	Dummy Yes=1, No=0	

Source: Authors adaptation from Campiche et al. (2004) & Abbeam et al. (2014)

3.3.4 Estimating the gains in substituting the conventional feed for BSFL-based feed

Partial budget analysis was used to estimate the gains of substituting the conventional feed with BSFL-based fish feed. The cost and income from the existing feed was matched against that of the new feed as shown in Table 3.5. Partial budget analysis was chosen as method of analysis because the new costs and income will not affect the whole enterprise but just a portion of it (Kay et al., 2008). With regard to introducing a new type of feed in production the two main cost that change are cost of feed and revenue from fish production.

Table 3.5: Standard layout for partial budget

Losses		Gains
Income Lost		New Income
New Cost		Old Cost
Net Gain	or	Net Loss
Source:	Kay et al. (2008)	

On the losses side, the average cost of existing feed was compared with the average cost of BSFL feed. On the revenue side, results were garnered from an experiment conducted by WRI with BSFL-based fish feed and conventional fish feed. The experiment was conducted to ascertain harvested biomass of fish after it is fed with BSFL-based fish feed and the harvested biomass when fish is fed with conventional feed. This was used to ascertain the revenue since the price of the fish is directly related to the size of the fish at the end of the production period (Cobbina, 2010). These were then matched against each other to ascertain the net gain or loss from substitution.

3.4 Method of Data Collection

Secondary data

Objective 1: To determine the profitability of BSFL meal and BSFL-based fish feed production, secondary data was collected from researchers at BNARI and Water Resources Institute who had cultivated the BSFL and turned it into meal and feed. The process was initiated under a three-year project that began in 2014 and ended in 2017.

Primary data

Objective 2: To determine the perception of farmers towards the use of BSFL in fish feed, survey data was collected from 150 fish farmers in two districts (Asuogyaman and Lower Manya Krobo) in the Eastern region. Structured questionnaires were employed in the data collection process.

Objective 3: To determine the MWTP of farmers and factors affecting the amount they are willing to pay. Out the 150 fish farmers, survey data was collected from 68 of the farmers who operated hatcheries on the amount they were willing to pay for BSFL-based fish feed. The WTP price of BSFL feed was for fingerlings so only farmers who operated hatcheries were selected.

Objective 4: To estimate the farmers' gains losses in substituting conventional feed with BSFL-based fish feed. Primary data was collected from researchers at WRI. The data collected was on research performed on the growth performance (Yield) of fish when fed with conventional feed and the growth performance (Yield) when fed with BSFL feed. The 2017 market price for fingerlings and fish feed ingredients were collected from input dealers in the region.

3.4.1 Questionnaire

A structured questionnaire was used to conduct the survey of farmers to ascertain their perception of the use of BSFL in fish feed and their willingness to pay for the BSFL feed. Firstly the questionnaire was pre-tested with 6 farmers to ascertain whether additional questions should be added or removed from the questionnaire, the average time for answering the questionnaire and the clarity of the questionnaire. Changes were made from the results and the final questionnaire was printed and administered to 150 farmers. This was done through a face to face interview with the assistance of two enumerators. Farmers were drawn from a farmer based organisation where as some others were also interviewed that did not join the farmer based organisation.

The questionnaire was divided into eight parts. The first and second part was on the demographic and socioeconomic factors such as age, sex and income. The third part was on the farm\culture characteristics to ascertain the economic standing of the farm.

The fourth part of the questionnaire was on the institutional characteristics, this is because for effective demand, institutions have to be in place. Questions such as access to credit and extension were asked.

The fifth part contained perception statements and respondents were asked to scale their responses using a 3 point Likert scale. The seventh part contained bidding prices where farmers were offered different prices to agree or disagree to buy.

Data was summarised using descriptive statistics.

3.4.2 Sampling procedure

The sampling was done in two stages (multistage sampling method), Firstly, the Asuogyaman district and Lower Manya Krobo districts were purposively selected from the Eastern Region because of the proliferation of fishing activities along the Volta River and government interventions in the districts in terms of aquaculture (Cobbina, 2010). An online calculator estimated a sample size of 230 for 5% confidence level, however, due to convenience, time constraint and availability, a sample of 150 fish farmers was used for the study. The farmers were selected proportionally from Asuogyaman district and Lower Manya Krobo district. Ninety of the respondents were selected from Asuogyaman district and 60 from Lower Manya Krobo district. The Asuogyaman fish farmers association provided a list of 38 farmers and all of them were interviewed. The rest were marked and selected through snowballing after identification by interviewed farmers. In Asuogyaman the communities visited were Atimpoku, Akosombo Marine, Senchi Ferry, and Old Akrade. In Lower Manya, the communities selected were Kpong and Akuse. These communities were selected due to their proximity to the Volta Lake and the proliferation of fish farmers in the area.

3.5 Profile of Study Area

The study was conducted in Asuogyaman and Lower Manya Krobo districts in the Eastern Region.

3.5.1 Asuogyaman district

According to GSS (2014a), the Asuogyaman district was created under government instrument LI 1431 of 1988. It has a population of 98,046, representing 3.7% of population of Eastern Region. Out of the total population there are more females (52.0%) than males (48.0%), the district is essentially a rural one with (70.6%) of the people living in rural areas

compared to urban areas (29.4%). The population of the district is largely youthful with more than half (64%) of the population below 30 years and children (0-14 years) constitute 37.4% of the total population.

Asuogyaman is located approximately between latitudes $6^{\circ} 34' N$ and $6^{\circ} 10' N$ and longitudes $0^{\circ} 1' W$ and $0^{\circ} 14' E$. It is about 120m above Mean Sea Level (MSL) and covers a total estimated surface area of 1,507 sq. km, constituting 5.7% of the total area of the Eastern Region. It is bordered to the north by Afram Plains South District borders and the Upper and Lower Manya districts to the south and west (Figure 3.1). The Volta River cuts through such ridges to create a gorge ideal for the construction of the Volta Dam at Akosombo. The existence of the Volta Lake accounts for the proliferation of fish farms in the district.

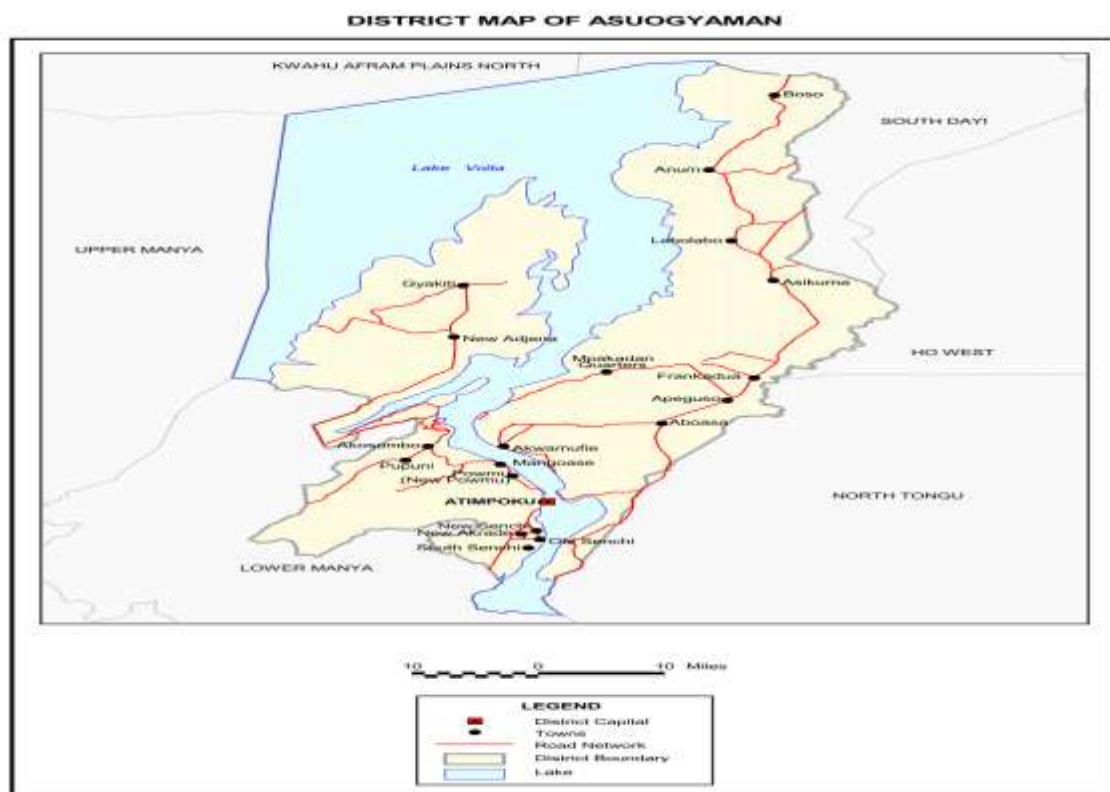


Figure 3.2: Map of Asuogyaman district

Source: GSS, 2014

The Asuogyaman District lies within the Dry Equatorial Climate Zone, which experiences substantial amount of precipitation. It is characterized by a double maxima rainfall, which reaches its peak period in May - July, and the minor season occurs in the period of September - November. Annual rainfall usually starts in April with the peak month in June and ends in November (GSS, 2014a).

Majority of the people in the district are engaged in agriculture and related trades. There are three (3) prominent types of agricultural activities in the district. These are livestock rearing, food cropping and cash cropping. However, most of the farming activities in the district are focused on the production of food crops. The major food crops produced are maize, cassava, plantain, yam and vegetable. A large number of these farmers have smallholdings. Most of the farmers engaged in crop farming are also involved in livestock rearing (GSS, 2014a).

Fishing in the Volta Lake also constitutes an important segment of the agriculture sector. Fishing is done mainly in some communities along the 141km shoreline including parts of the Kpong headwaters. These communities include Dzidzokope, Atimpoku, Abume, Akosombo, Surveyline, Adomi, Dodi Asantekrom, Asikuma, Mpakadan and Senchi Ferry and old Akrade (GSS, 2014a)..

3.5.2 Lower Manya Krobo district

According to GSS (2014b), the Lower Manya Krobo district was elevated to a Municipality status in July 2012 by a Legislative Instrument (L.I.) 4026 with Odumase- Krobo as the capital. It has a total population of about 89,246 comprising of 46.5% male and 53.5%

female. This is mainly comprised of the young people with 35.1% of the population falling below 15 years. Only 8.3% of the population fall within 60 years and above.

The Municipality is strategically located at the Eastern corner of the Eastern Region of Ghana and it lies between latitude 6.05N and 6.30N and longitude 0o08W and 0.20W with an altitude of 457.5m above sea level. The Municipality is bounded on the North-west by Upper Manya Krobo District, on the North-east by Asuogyaman district, on the South-east by North Tongu District and on the South by Yilo and Dangme West District (Figure 3.2). The LMKM covers an area of 304.4 square kilometres, with a population density of 293.2 persons per square kilometre (GSS, 2014b).

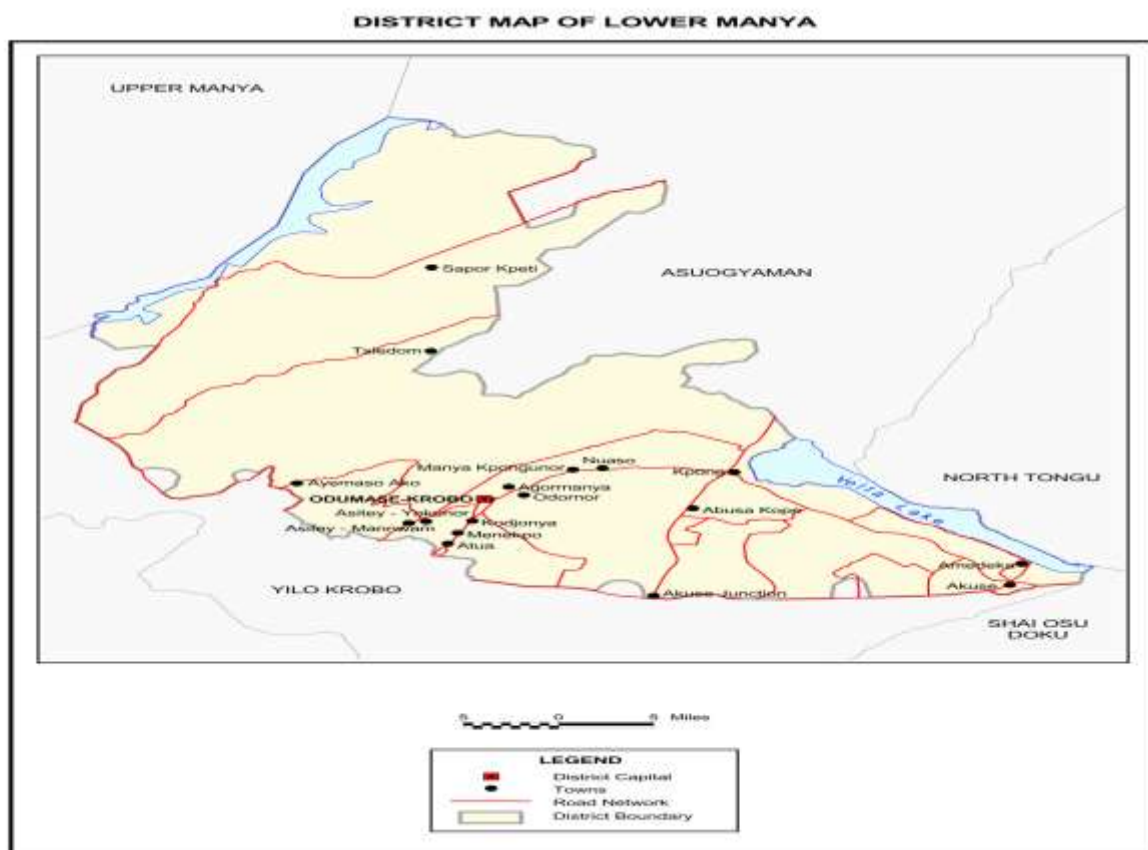


Figure 3.3: Map of Lower Manya Krobo District

Source: GSS (2014)

The topography of the Lower Manya Krobo Municipality is relatively flat with isolated hills partitioning the Municipality from the north-western point to the east. The Landscape of the northern part is generally undulating with several streams, most of which drain into the Volta Lake. Much of the eastern boundaries of the District constitute the shores of the Volta Lake. This has created proliferation of fish farming in the area. A section of the population especially the men folk earn their living through fishing on the Volta Lake which lies at the North-Eastern part of the Municipality (GSS, 2014b).

The people of Lower Manya Krobo Municipal are mainly farmers with some of the population engaged in trading. Cereal (Maize) is the most common agricultural product found in the Municipality together with, cassava, pepper, pineapple, watermelon, sweet potatoes, plantain, yam, cocoyam, okra, tomatoes and others (GSS, 2014b). Some communities in the region are: Akuse, Agorman, Kpong and AsiteyMannwan.

3.6 Scope and Limitations of the Study

The study focuses on the profitability of production and farmers willingness to buy given certain factors. It does not cover the marketing and sales part of the product and it also assumes away the existence of inputs for production.

Another limitation of the study is the fact that the actual feed was not available at the time of the research and farmers had to base their WTP on descriptions made to them. The WTP suggested may therefore not be a fair representative of what they are actually willing to pay. This is however a consistent limitation of most WTP studies since the product is usually not on the market. Finally, time and resource constraints limited the number of farmers that were

interviewed to 150, though the scientific online calculator suggested a number of 230 to get a confidence level of 5%.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

Introduction

This chapter deals with the presentation and discussion of results obtained from the study. First, the socio-economic characteristics of respondents are described and discussed. Then the results from the financial feasibility analysis, perception of farmers towards the use of BSFL in fish feed, the MWTP and the factors influencing the decision. Finally, results from the savings farmers will make from switching from conventional feed to BSFL feed is discussed

4.1 Socio Economic Characteristics of Respondents

The following profile was ascertained from the fish farmers surveyed in the district:

Gender:

The respondents interviewed were made up of 3% (4) female and 97 % (146) male. Very few women were involved in fish farming. This is in agreement with FAO (2012), which asserts that men are involved in the main fishing activities whereas women are involved in the post-harvest activities like processing of the fish and trading.

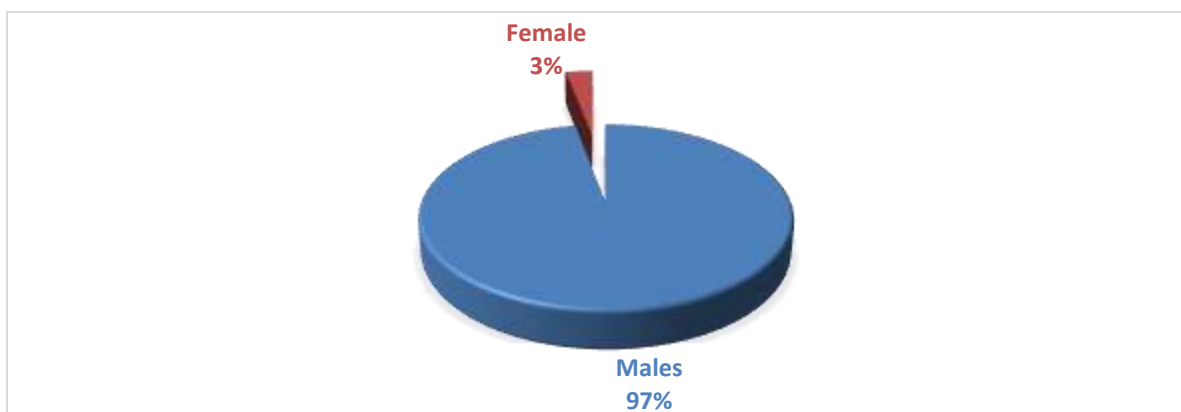


Figure 4.1: Gender profile of respondents

Source: Survey data (2017)

Age:

Out of a total of 150 respondents interviewed, 24% (36) fell within the age range of 26-30 and 24% (36) within 36- 40 years. This was followed by 21% (32) falling within the range of 31- 35 years, ages 20-25 was represented by 14% (21) of respondents. Age group 41-45 and 46-50 contributed 7 % (11) and 4 % (6) respectively. Finally, age 51-55 and age 56-61 contributed 4% (6) and 1% (2) respectively. This shows that majority of the respondents fell within the ages of 26- 40 years and only a few were above 55. This contradicts the research that reported that majority of fish farmers in the country are aging but agrees with GSS (2014) survey report of the districts that says that majority of the citizens in both districts are youthful.

Education:

Out of the respondents, JHS education was the highest at 39% (58) followed closely by SHS at 27% (41). Respondents that had no Education made up 13% (19) of the sample and those with tertiary education 14% (21). Respondents with primary education were lowest 7% (9). Most of the respondents fell within the level of JHS and Secondary school which means that most fish farmers in the region have some form of education.

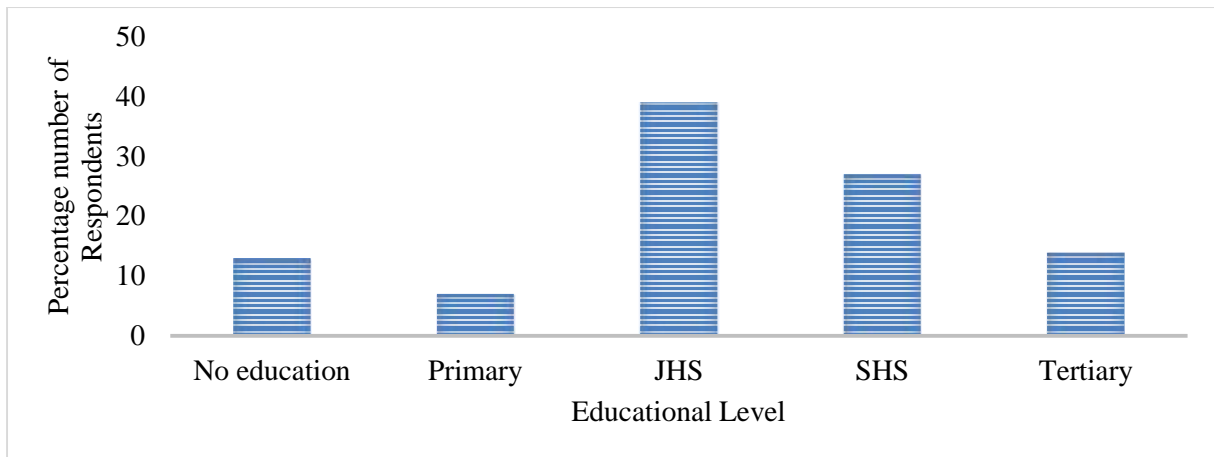


Figure 4.2: Educational profile of respondents

Source: Survey data (2017)

Marital status:

About 86% of the respondents were married whereas 14% indicated that they were single. This represents 129 and 21 of the respondents respectively. This to be expected since most of the population fell between 30-45 years.

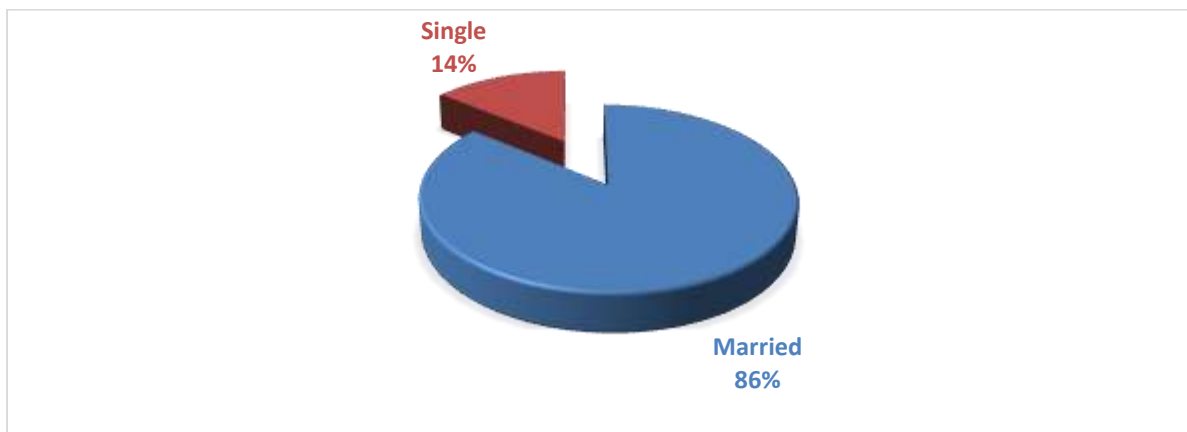


Figure 4.3: Marital profile of respondents

Source: Survey data (2017)

Residential status:

When farmers were asked about their residential status, out of the respondents, the highest was 74% (111) which represented migrants and 26% (39) which represents natives. Most of the respondents had migrated from the Volta region, Accra and other regions to farm in Eastern Region.

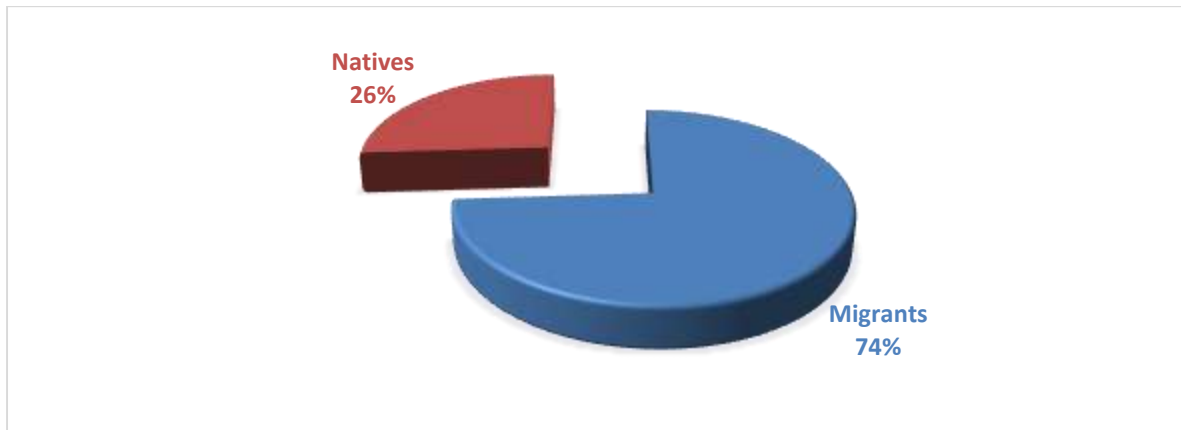


Figure 4.4: Residential profile of respondents

Source: Survey data (2017)

Religion:

All 150 of the respondents interviewed were Christians. This shows that the whole community is predominantly Christian. Religion was therefore not used in the determinants of WTP since there were no variations amongst farmers

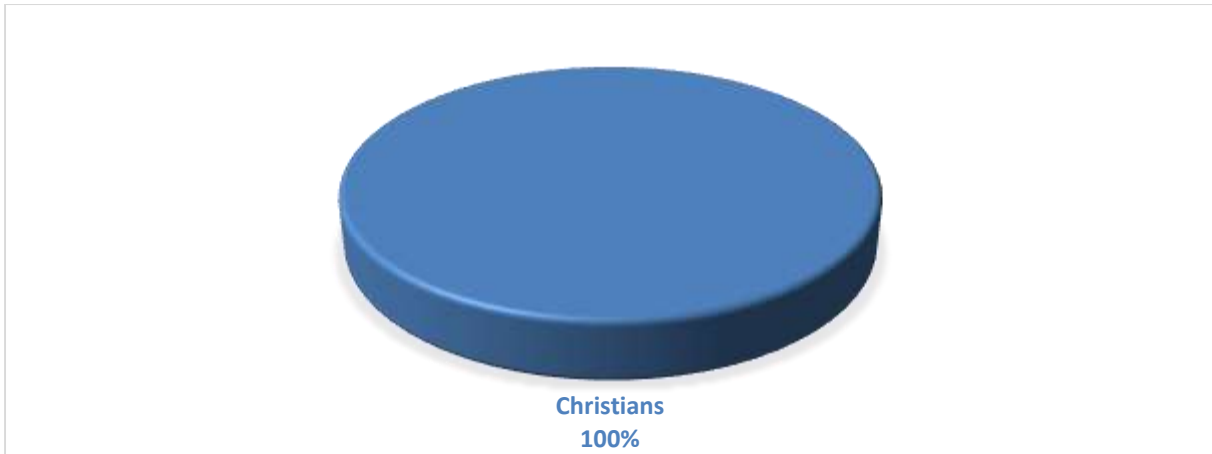


Figure 4.5: Distribution of respondents by religion

Source: Survey data (2017)

Occupation:

Out of the respondents interviewed, 87% (131) were full time farmers. A small percentage of 13% (19) had jobs outside fish farming. Out of the 18 respondents who had other Jobs, (9) were into fish processing (turning fish into salted fish), (5) were maize farmers and (4) cultivated various vegetables.

Business type:

The field research showed that 45% representing 68 of the farmers interviewed owned hatcheries where as 55% representing 82 of the farmers operated grow-outs. Some of the hatcheries did not sell to the market but rather produced for the grow-outs as an integrated business enterprise.

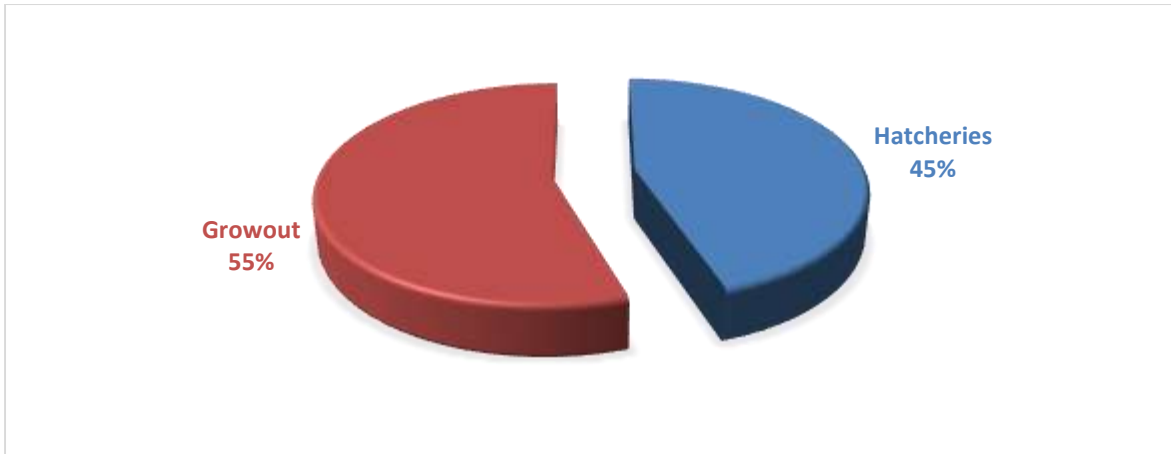


Figure 4.6: Profile of type of business operated by respondents

Source: Survey data (2017)

Annual revenue:

Respondents have an average annual income of GHS 97,623.33. The highest respondent had an annual income of GHS330,000.00 and the lowest an annual income of GHS8,000.00. The revenue was higher for farmers depending on the number of cages owned by the respondents. Farmers asserted that each cage produces an average of 4000 fish and generates income of GHS10,000.00

Land ownership:

In fish farming, some of the farmers operate ponds and cages in dug outs on land whereas some put the cages out in the water. Land ownership refers to both types since ownership of the land automatically entitles the farmer to water rights. Out of the 150 farmers interviewed, 34% representing 52 farmers owned the land they were fishing on and 66% representing 98 farmers were renting the land. This is to be expected since ponds and cages which are kept on land need dug outs into the land at huge investment cost which will not be feasible for rented land.

Culture practice:

All the farmers interviewed representing 100% of the sample practiced intensive fishing. All of the farmers fed their fish with feed at regular intervals and used hormones to make the sex of the tilapia homogenous so as to prevent proliferation of population growth. This reveals that, fish farmers are shifting from the semi intensive and extensive form of fish farming.

Fish farming structure:

Fish farmers that practice intensive farming do so in either a cage or a pond. Majority of the farmers at 56% representing 84 respondents farmed in Cage structures (average 5*5m) whereas 44% representing 66 of respondents farmed in ponds structures (average of 9m*9m). Most of the farmers owned cages which had been put in the Volta River for farming activity purposes, this makes it easier to farm the tilapia. This contradicts FD (2013), which purports that in terms of numbers, cages come after ponds.

Tilapia monoculture:

When farmers were asked if tilapia was the only fish farmed, 91% representing 137 of the sample responded yes, whereas 9% (13) responded no. The respondents that responded no to the question cultivated catfish on the side with the tilapia cultivation. This may be for economic purpose of catfish cultivation or to use the catfish to control tilapia prolific population growth. This confirms Cobbina (2010) statistics that 80% of the fish farmers in Ghana cultivate tilapia where as 20% cultivate catfish.

Direct market sales:

Fish farmers were asked whether they sold directly of the market to consumers. 90% of the respondents representing 135 farmers responded no. These people explained that middle men

buy from them and sell it to the market women. 10% of the respondents however mentioned that, they have workers who sell on their behalf directly on the market.

Membership of FBO:

35% (53) of the respondents interviewed were members of FBO. This figure may not be a true representation of the total population since farmers who join FBO's were specifically targeted for the study. 65% (97) of the study did not join FBO's however. These people were mainly the small scale uneducated farmers, the very large scale farmers and farms operated by foreigners.

Access to extension:

To ascertain respondent's access to credit, farmers were asked if they had received extension services at any point. 22% representing 33 of the respondents had no access to extension, however 78% of the respondents had access to extension. These respondents claimed that they when a problem arises on the farm, they call in extension officers and they come in to investigate.

Credit from financial institution:

96% representing 144 of the population had never borrowed from any financial institution, however, around 4% representing 6 of the respondents had taken some form of loan from a financial institution.

Cost of existing feed:

Respondents were asked if they thought the existing feed on the market were expensive. 100% of the respondents agreed that the existing feed is expensive. Researchers were shown

empty cages where farmers had abandoned farming due to high cost of feed. These farmers were unable to cover feed cost and had therefore closed shop.

Use of farm made feed:

Farmers were asked if they make their own feed. Out of the respondents interviewed, none of the farmers made their own feed although some have experimented with for example insects in the past. This contradicts Obirikorang et al. (2015), which asserts that most farmers in Ghana produce supplementary fish feed at farm level. However, this shows that farmers are shifting to intensive farming and commercial formulated feed as a result.

Knowledge of ingredients of existing feed:

Respondents were asked if they knew the components of existing feed and was marked “yes” if the respondent was able to list at least one ingredient. 91% of the population did not know any of the ingredients used in making the current feed on the market. This is comparable to research done by 9% representing 13 respondents however, were able to mention at least one of the ingredients used to make current feed on the market. The ingredient that most of the respondents were able to mention was fishmeal.

Deciding factor when purchasing feed:

Respondents were asked what the deciding factor was when purchasing fish feed giving a choice between cost, brand and ingredient. Out of the 150 respondents, 92% (138) chose cost as the deciding factor when buying feed. 6% (9) of the respondents mentioned brand as the deciding factor. Only 2% (3) of the respondents mentioned ingredients as the deciding factor and this may be because most of the respondents did not know the ingredients of existing fish feed.

Knowledge on BSFL and insects as feed ingredient

When asked if they knew about BSFL or the use of insects as feed 49% (73) of the respondents responded yes whereas 51%(77) responded no. The respondents that knew of insects as feed were relatively large because most of the farmers mentioned that insects are food for fish in their natural habitat. Also, FiBL and WRI had already organised workshops to educate the farmers in Asuogyaman district. In addition, a French company had also sensitized farmers in the region on BSFL since they wanted to start sale of a BSFL-based fish feed in the region. Some of the foreign owned fish farms, primarily the ones owned by Chinese farmers were also aware of the existence of BSFL as feed.

Willingness to buy the BSFL-based fish feed

All the respondents were willing to buy the BSFL-based fish feed. Farmers expressed their interest in the new feed and asserted that they were willing to pay for the BSFL-based fish feed. This was mainly due to the fact that farmers perceive the existing feed cost to be very high and are therefore looking for new alternatives.

4.2 The Profitability of BSFL-based Feed Production

4.2.1 Scenario A: Production of BSFL meal

This scenario is under the assumption of an entrepreneur that invests in the manufacture of BSFL meal.

The results from the financial analysis showed that, for a production of 1000 metric tonnes a land size of 3,078 metres square is needed (Appendix 2). For BSFL meal production, a start-up cost of GHS4,230,192.98 with an initial investment in fixed asset of GHS2,061,896.69 and an annual operating cost of GHS 2,168,296.30 (Appendix 3) was identified. The main

cost driver was the cost of layer meal used to feed the BSFL larvae which made up 60% of total cost of operations (Appendix 4). The cost of producing a kilo of BSFL larvae meal was GHS 2.2 (Appendix 5).

The results from analysis 4, was the most favourable since the price used to compute revenue was below the market price of existing feed but all the profitability indicators such as NPV, IRR and BCR were still acceptable. This analysis revealed a positive NPV of GHS5,735,340.08, a BCR of 2.4 an IRR 32% and a PBP of 1 year, 4 months. This is in tandem with Kaliba et al. (2010), where research revealed that, at 1145 m.t. (15% discount rate) production an NPV of USD3,084,341 and an IRR of 33% will be realised from producing fishmeal from the waste of channel catfish. The other analysis (1, 2, & 3) had favourable NPV, BCR and Payback period, but the IRR was lower than the 31% discount rate. The payback period for all the analysis were favourable, within the acceptable range (payback back period less than 5 years) for a risky agricultural investment. The summary results of the discounted measures of the worth of the project with the various analysis given these costs and benefits is shown in table 4.1 and complete work is shown in Appendix 6, 7, 8 & 9.

Table 4.1: Summary results for discounted measures

Indicator	Amount(GHS)
Analysis 1: Using market price (GHS117 per 20kg bag)	
NPV (31%)	7, 617,450.63
BCR (31%)	2.7
IRR	43%
Payback Period	1 year, 2 months
Analysis 2: Using 20% below market price (GHS94 per 20kg bag)	
Therefore NPV	3,853,229.54
IRR	22%
BCR	2.2
Payback	1 year, 9 months
Analysis 3: using 15% below market price (GHS100 per 20kg bag)	
NPV	4,794,284.81
IRR	27%

BCR	2.3
Payback	1 year, 6 months
Analysis 4: Using 10% below market price (GHS105 per 20kg bag)	
NPV	5,735,340.08
IRR	32%
BCR	2.4
Payback	1 year, 4 months

Source: Cash flow projections in Appendix 6, 7, 8 & 9

Analysis 1: Using market price (GHS 117 per 20kg bag)

From table 4.1 the NPV of GHS7, 617,450.63 implies that the present value of all the future benefits exceeds the present value of the future costs projected over the 20 years of the project. The BCR of 2.7 shows that for every GHS1 invested in the production of BSFL, an earnings of GHS 2.7 is made on it. The IRR of 43% shows that the project has a high earning capacity and ability to cover the interest rate of 31%. This means that if the entrepreneur goes for a loan at a rate of 31% it can be paid back. Finally, upon investing in the project, it will take the Entrepreneur 1 year and 2 months to pay back. This means that the project is financially viable at market price. (See table 4.1 and appendix 6)

Analysis 2: Using 20% below the market price (GHS 94 per 20kg bag)

From Table 4.1 and Appendix 7, at the 20% reduction in the market price, the project is still viable at a positive NPV of GHS 3,853,229.54 and a BCR of 2.2. However, the IRR is 21% which is less than the 31% average interest rate charged by banks (used as discount rate). In conclusion, though it is financially viable with a positive NPV, payment of loan at existing rate may be difficult since the projects' internal rate of return (IRR) is lower than the interest rate (discount rate)

Analysis 3: Using 15% below the market price (GHS100 per 20kg bag)

When the market price is reduced by 15%, the project is still viable at a positive NPV of GHS4,794,284.81, BCR of 2.3 and payback period of 1 year, 6 months. However, the IRR is 27% which is less than the interest rate for borrowing loans at 31%. In conclusion, though it is financially viable with a positive NPV, covering at existing rate may be difficult since the projects' internal rate of return (IRR) is lower than the banks' lending interest rate (discount rate)

Analysis 4: Using 10% below the market price (GHS105 per 20kg bag)

From table 4.1, at a reduction in market price by 10%, the project is viable with a positive NPV of GHS 5,735,340, BCR of GHS 2.5 and payback period of 1 year, 4 months. The IRR of 31% is very acceptable since it is higher than the discount rate that is the commercial banks average lending rate of 31%. The lending rates in Ghana is very high, therefore projects must make enough returns to cover and pay back the high rates in the country.

In conclusion, since BSFL is a relatively new product, and the study seeks to provide a less costly option to market price of conventional fish meal, the BSFL meal can be priced 10% below the price of fishmeal and still maintain acceptable rates in all the profitability indicators.

Sensitivity analysis (10% cost overrun and 10% decrease in production)

Sensitivity analysis was therefore performed on analysis 4 (using 10% below market price GHS107) since it is the price below market price at which all the profitability indicators is acceptable. It was done by increasing cost by 10% and reducing production by 10%. The results as shown in table 4.2 revealed that, at 10% reduction in cost and output, the

entrepreneur still makes a positive NPV and BCR. However, the IRR is below that of the discount rate which means that the internal rate of return may not be enough to cover the borrowing rate of 31%. This means that at a lower cost of capital (discount rate), the production of BSFL meal is still viable.

Table 4.2: Summary of results for the sensitivity analysis

Indicator	Amount
NPV	3,398,740.46
IRR	19%
BCR	1.9
Payback period	1 year, 11 months

Source: Cash flow projections in Appendix 10

4.2.2 Scenario B: Production of BSFL-based fish feed

This scenario assumes Purchase of BSFL meal and the use of it as partial (75%) replacement of fishmeal to make fish feed. It is under the assumption of an entrepreneur that invests in use of BSFL in the production of fish feed. The results from the financial analysis showed that, for a production of 1000 metric tonnes an initial investment in fixed asset of GHS1,746,000.00 and an annual operating cost of GHS4,743,280 was identified. (See appendix 11 for breakdown of costs and benefits). The analysis 2, which used the WTP amount of fish farmers revealed favourable results of the discounted measures. This analysis, revealed a positive NPV of GHS8,130,254, a BCR of 1.95 and an IRR of 30%. The results form analysis 1 (Using market price) also produced similar results. The payback period for all the analysis were favourable, within the acceptable range (payback back period less than 5 years) for a risky agricultural investment. These figures are especially promising because the fish feed industry is a high earning sector as shown by research. In a research conducted by Ruwangwa et al. (2015), at 60% margin of current feed prices, there was a profit (before

interest and tax) of USD 1,016,000 at 8000metric tonnes production. This shows a high degree of profit and earning in the feed industry. The summary of the discounted worth of the project is shown in table 4.3 and appendix 12 & 13.

Table 4.3: Summary of results for discount measures

Indicator	Amount (GHS)
Analysis 1: Using market price (GHS200 per 20kg bag)	
NPV	10,378,126
BCR	2.1
IRR	38%
Payback	1 years, 2 months
Analysis 2: Using MWTP amount, 7% below market price (GHS186 per 20kg bag)	
NPV	8,130,254
BCR	1.95
IRR	30%
Payback	1 years, 5 months

Source: Cash flow projections in Appendix 12 & 13

The results from the MWTP show that the farmers are willing to pay GHS186 (7%) less the price of existing feeds on the market. A financial analysis was therefore performed by reducing the selling price of BSFL-based feed by 7% to ascertain whether the project will be viable at that level. From table 4.3, when the Selling price is reduced by 7%, the project is still viable at a positive NPV of GHS8,130,254.00, a BCR of 1.95 and an IRR of 30%. GHS1.95 and payback period of 1 year, 5 months. However, the IRR is 30% which is slightly less than the interest rate for borrowing loans at 31%. In conclusion, production at the MWTP amount is financially viable.

Sensitivity Analysis (10% cost overrun and 10% production decrease)

Sensitivity analysis was performed by increasing cost by 10% and decreasing production by 10% simultaneously. The results for the analysis as shown in Table 4.4 and Appendix 14 revealed a positive NPV of GHS3,633,822.23, a BCR of 1.60, an IRR of 13% and a payback

of 2 years, 1 month. The NPV and BCR is favourable, however, the IRR is less than the cost of capital. The payback period is within the 5 year range of risky agricultural projects.

Table 4.4 Results from sensitivity analysis

Indicator	Amount (GHS)
NPV	3,633,822.23
BCR	1.60
IRR	13%
Payback Period	2 years, 1 month

Source: Cash flow projections in Appendix 14

4.3 The Perception of Farmers towards the use of BSFL in Fish Feed

Table 4.5 shows a summary of results of the means of various statements showing farmers' perceived benefit and risk towards the use of BSFL in fish feed. A Likert scale was used to solicit response from farmers with a scale ranging from (1) disagree, (2) do not know to (3) agree.

Table 4.5: Perception statements and various means

Perception Statements	Mean	Average Response
Risk statements		
The use of BSFL in fish feed can:		
1. Decrease demand for fish	1.053	Disagree
2. Cause release of noxious gases during BSFL production	1.593	Not sure
3. Introduce BSF which will spread diseases to human beings	1.513	Not sure
4. Cause microbiological contamination to fish	1.400	Disagree
5. Be detrimental to the health of fish consumers	1.406	Disagree
Benefit statements		
The use of BSFL in fish feed can:		
1. Decrease the overexploitation of water bodies	2.840	Agree
2. Lower the cost of Fish feed	2.753	Agree
3. Lower our dependence on imported feed	2.886	Agree
4. Improve organic waste management in the country	2.880	Agree
5. Improve the sustainability of aquaculture production	2.666	Agree

Source: Survey data (2017)

From Table 4.5, on the side of the risk statements, results show that farmers disagree with most of the risk statements. For example, the 1st statement on the decrease in the demand for fish has a mean of 1.05, this means that most of the farmers disagreed with the statement that demand for fish will decrease if customers know that fish is currently being fed with BSFL-based feed. This is not surprising since most of the farmers purported that consumers do not care and do not know the current feed that is used to feed the fish. A change to BSFL feed in their opinion will not affect demand. Also, according to TIU (2012), demand for fish may increase as environmentally conscious people may demand more of it.

However the 2nd and 3rd statements that is on the production of noxious gases and the BSF spreading diseases, the farmers' means were closer to the midpoint scale at 1.6 and 1.5 respectively. This means that on those issues most of the farmers did not know either way. Farmers mentioned that since they have not seen the production of BSFL they could not tell the smell and were not sure whether the BSFL will carry diseases. These risk statements are quite unfounded since BSFL is known to restrain bacterial growth and therefore reduce odour of waste (van Huis et al., 2013). In addition, BSFL do not spread diseases, on the contrary they reduce the oviposition of disease carrying houseflies (Graczyk et al., 2001)

The 4th and 5th risk statements on the fact that BSFL may contaminate the fish and when eaten by consumers may be detrimental to the health of consumers also had means below the midpoint of the scale at 1.4. This means that most of the farmers disagreed with these statements. This may be because some of the farmers had experimented with feeding the fish with various insects before and had received varying successful results. They mentioned that no adverse effect had been noticed. Also, the farmers mentioned that insects are the diet of

fish in the wild so it is not harmful to fish or human beings. Since BSFL is an insect then they assumed the Black soldier fly larvae will also be the same

The Cronbach's alpha for risk statements was 0.800 showing that the scores for the various statements can be summed up into an overall score. The overall mean risk score computed was 1.4 and significantly lower than the average point of the scale ($t=-6.576$, $p<0.003$) (See Table 4.5). This means that overall it can be concluded that farmers do not perceive the production of BSFL for fish feed will be harmful to demand, the environment or the health of the fish and consumers.

From Table 4.5, on the side of the benefit statement, the farmers on average agreed with all the perceived benefit statements. This means that farmers vocally agreed with the benefit statements. After explaining BSFL technology used for turning it into feed, most of the farmers agreed with the various benefit statements. This may also be because some of the farmers interviewed joined FBO's and had already been sensitized by workshops held by Water Research Institute (WRI) on the benefits of the BSFL.

The Cronbach's alpha for benefit statements was 0.719 showing that the scores for the various benefit statements can be summed up into an overall score. The overall mean benefit score computed was 2.8 and significantly higher than the average point of the scale ($t=19.163$, $p<0.000$). This means that overall it can be concluded that farmers perceive the production of BSFL for fish feed as beneficial to demand, the environment or the health of the fish and consumers.

Finally, a t-test performed showed that the overall mean benefit score of 2.8 was significantly higher than the overall mean risk score of 1.4 (($t=13.137$, $p\leq 0.000$). In conclusion, the results show that farmers perceive the benefits of using BSFL in fish feed production to be significantly higher than they perceive the risk of using BSFL in fish feed. This means that the use of BSFL in fish feed is perceived as highly beneficial in terms of economic significance, environmental, and social benefits.

4.4 The Mean Amount Farmers are Willing to Pay for BSFL and the Factors Influencing the Decision

4.4.1 The mean amount farmers are willing to pay for BSFL-based fish feed

As shown in Figure 4.7, the mean amount farmers were willing to pay for a 20kg bag of BSFL-based fish feed was GHS186.00, 7% less than the price of current feed prices. Only few (15%) of the respondents (hatcheries) were willing to pay the market value of GHS200.00. None of the respondents were willing to pay GHS 220.00 that is a premium of GHS 20(10%) above current feed prices. About 3% (2) were willing to pay GHS 210.00 that is a premium of GHS10 (5%) premium above the existing feed price. These were the only farmers that were convinced that the benefits of the BSFL feed warranted premium to be paid on it. 12% (8) were willing to pay the GHS 200.00, existing feed price. Of the respondents who were not willing to pay the GHS200.00/20kg bag, 26% (18) were willing to pay GHS190.00 and 59% (40) were willing to pay GHS180.00.

In conclusion, farmers are not willing to pay premium for BSFL-based fish feed; farmers are willing to pay a price 7% lower than the current feed price.

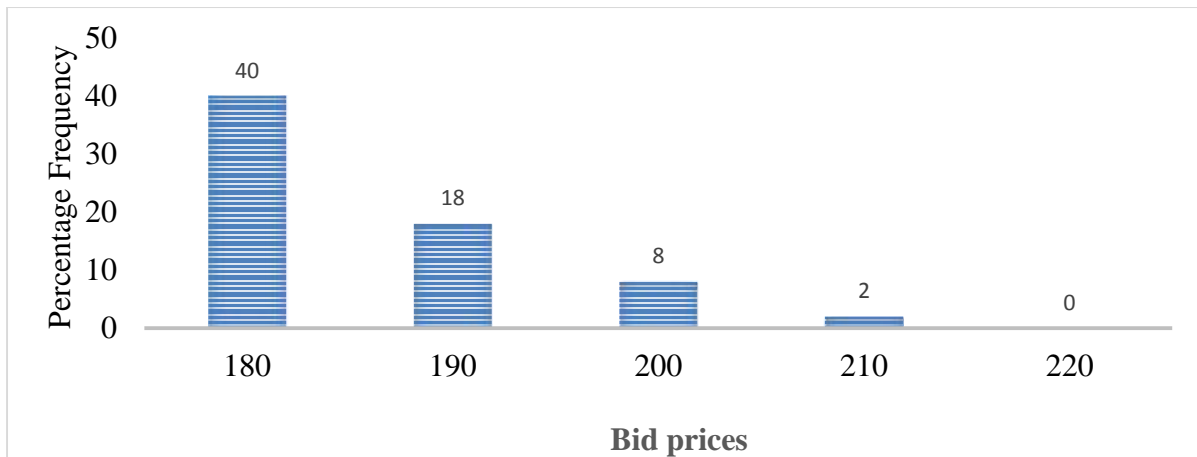


Figure 4.7: Frequencies and bidding amounts for willingness to pay survey

Source: Author's survey data (May 2017)

4.4.2 Factors influencing the amount farmers are willing to pay for BSFL-based fish feed

The results in table 4.6 show the Tobit regression results for ascertaining the significant factors influencing the amount farmers are willing to pay. The marginal changes and the direction of change in MWTP as the various variables change are shown in the table. Significant level is measured at 1% (***), 5% (**) and 10% (*)

From table 4.6, the F value of 8.64 means the overall significance of the model that has been specified is significant at 1%. A significant level of 1% suggests that the defined variables affecting MWTP fits the model for the study. A Pseudo R² of 0.249 signifies that variations in the dependent variable can be explained up to 24.9% by changes in the dependent variable.

Table 4.6: Tobit regression results on factors of willingness to pay

Variables	Coefficient	P-value	<i>Aprior</i> Expectation
Age	0.255	0.104	+-
Marital status	-6.959*	0.060	+
Household Size	-0.069	0.917	+-
Education	2.928	0.188	+
Residential status	0.601	0.892	+
Annual revenue	6.15E5***	0.006	+
Awareness	10.637***	0.004	+
Extension	6.138	0.392	+
FBO	0.701	0.918	+
Constant	142	0.000	

Number of obs = 68
F(9,59) = 8.64
Probs>F=0.000

Pseudo R2 = 0.2490
Log likelihood = -108.053

Source: Survey data (May, 2017)

Age, marital status, household size, education, access to extension, membership of FBO, residential status, were expected to influence WTP, the Tobit regression (Table 4.6) revealed however that, only three of the nine variables defined were insignificant. These were marital Status, annual revenue and awareness of insects as feed.

Annual revenue

Annual Revenue met aprior expectation and had a positive relationship with MWTP. Annual revenue was significant at 5%. This means that annual income of people in the regions is able to influence MWTP. Income as mentioned had a positive relationship with MWTP, this

means that people of higher revenues are more willing to pay higher prices for BSFL-based fish feed than people with lower revenue. This is in tandem with research that revealed that income positively influenced WTP (Asenso-Okyere et al., 1996; Campiche et al., 2004)

Awareness

Awareness was measured as awareness of the use of insects as a source of feed. This was expected to have a positive relationship with WTP. The regression results revealed that awareness is significant at 1% and is positively related to WTP. This means that fish farmers that are aware of the use of insects as feed for fish are more willing to pay higher prices for BSFL-based feed than otherwise. This is in tandem with Abbeam et al. (2014), where awareness was found to be statistically significant in influencing farmers' willingness to pay for farm insurance.

Marital status

Marital status had a negative relationship, which means that married fish farmers are more willing to pay lower amounts for BSFL-based fish feed than single fish farmers. This did not meet aprior expectation. In a research done by Engel (2008), marital status was found to positively influence willingness to pay premium for organic food. This research is in direct contrast with this findings.

4.5 The Gains Made from Substituting Conventional Feed with BSFL-Based Feed

The results revealed that, a fish farmer can make a gain of GHS6.30 by substituting 14.6kg of conventional feed with 14.6kg of BSFL-based fish feed. The stocked cages for the conventional feed and the BSFL-based fish feed yielded biomass of 7.73 and 7.67 respectively. This means that the biomass (yield) from BSFL-based feed was approximately

0.8% less than that of conventional feed. Therefore the revenue gained from BSFL-based fish feed was less than that of the existing conventional feed using the market price of a kilogram of fish (GHS12.00). Revenue from BSFL-based feed was GHS 92.04 whereas that of existing conventional feed was 92.76. However, on the cost side, the existing conventional feed is more expensive than that of BSFL-based fish feed (when BSFL is priced at 7% less the cost of existing fish feed). When these costs and revenues were matched against each other a net gain of GHS 6.53 is realised (See Table 4.7 and Appendix 15).

Table 4.7: Partial Budget analysis

LOSSES	GHS	GAINS	GHS
Loss in yield (conventional feed)	92.76	Gain in Yield(BSFL-based feed)	92.04
Cost of new feed	59.86	Cost of old feed	67.11
Net Gain	6.53		
Total	159.15	Total	159.15

Source: Survey data (May, 2017)

In conclusion, when the fish farmer uses 14.6kg of BSFL-based fish feed in place of 14.6kg of conventional feed, there is a net gain in production of GHS6.53. Consequently, this means that per every kilogram of BSFL based fish feed substituted for conventional feed, the farmer makes a net gain of GHS 0.44.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

Introduction

This chapter summarises the study and concludes on the various objectives set for the study. Based on these conclusions, recommendations are made to facilitate the production of BSFL meal and BSFL-based fish feed on an industrial scale.

5.1 Summary

The research sought to ascertain the feasibility of BSFL meal and BSFL-based feed production and to identify farmer's acceptance of the product. The study revealed that the BSFL meal production is feasible at 10% below the Selling price of conventional fishmeal at NPV of GHS5,735,340.00 an IRR of 32% and a BCR of 2.4. The production of BSFL-based fish feed was also feasible at MWTP amount with NPV of GHS8,130,254.76, an IRR of 30% and a BCR of 1.95. However the production of BSFL meal and BSFL-based fish feed is capital intensive with an initial start-up cost (Fixed asset and operational cost) of GHS4,230,193.00 and GHS6,489,280.00 respectively.

In ascertaining the perception and willingness to pay of farmers, 150 farmers were sampled from Asuogyaman and lower Manya krobo districts. Majority of the farmers were men and had some form of education. Under the perception analysis, the farmers overall mean score was 2.8 and 1.4 for benefit and risk statements respectively. When compared to the midpoint scale, the mean score for risk was significantly lower ($t=-6.576$, $p<0.003$) and for benefit score significantly higher ($t=19.163$, $p<0.000$) than the midpoint scale. Comparison of the overall mean benefit score with the overall mean score for risk showed that the score for benefit is significantly higher than that for risk ($t=13.137$, $p<0.000$).

The willingness to pay analysis revealed that farmers are willing to pay an average of GH186.00 for the BSFL-based feed. The factors that significantly affected WTP were annual income, marital status and awareness of insects as feed. Annual income and awareness affected WTP positively which means that higher income earners and people who are already aware that insects can be used as feed are more willing to pay higher amounts for the BSFL-based fish feed. On the other, marital status affected WTP negatively, this means that married people are less willing to pay higher prices for BSFL-based fish feed. Finally the partial budget analysis showed that, fish farmers will have a net gain of GHS6.53 for every 14.6kg of BSFL- based feed used in place of 14.6kg of conventional fish feed.

5.2 Conclusions

Based on the discussed results the following conclusions arise: The production of BSFL meal and BSFL-based fish feed is financially feasible giving 1000 metric tonnes production level and a discount rate of 31%. The amount of capital outlay needed to begin operations is high. There is a high degree of acceptance of the BSFL-based fish feed amongst fish farmers; they have favourable perception towards the use of BSFL in fish feed and are willing to pay for it. They do not perceive the use of BSFL in fish feed to be harmful in terms of socioeconomic, health and environmental factors. The perceived benefit of the use of BSFL in fish feed is significantly higher than the perceived risk of the use of BSFL in fish feed.

The farmers are willing to pay for and use the BSFL-based fish feed at price lower than the conventional feed. Being married and aware of insects as feed ingredient, as well as having higher annual income enhanced the amounts farmers were willing to pay for a unit of BSFL-based feed. Finally, replacement of existing feed with BSFL-based fish feed, all other factors held constant, will bring about a net gain for the farmer.

5.3 Recommendations

The use of BSFL to produce fish feed is a technique that will solve socio economic, health and sanitation issues. However, the initial cost of investment is quite high. The following are suggested:

- i. Entrepreneurs should form cooperatives and partnerships to produce the BSFL-fish due to the high initial investment required
- ii. Scientist-Entrepreneurs fora should be organised to share the results on the viability of BSFL production in order to encourage investments.
- iii. Potential *BSFL meal* manufacturers should be prepared to charge a price below that of the existing fishmeal to feed manufacturers. *BSFL-based fish feed* manufacturers should recognise the MWTP amount of farmers. This should be done in order to penetrate the market and to convince fish farmers to adopt the new product.
- iv. In making marketing and promotional decisions, the factors that significantly influence MWTP should be considered. Hence, higher income farmers and those with knowledge of insect as feed ingredient should be targeted by entrepreneurs. Ahead of introducing the product to the market, the entrepreneur should launch awareness of BSFL campaign to increase the number of people who get sensitised about the BSFL-based feed.
- v. Farmers should be educated of the gains of switching to BSFL-based fish feed with the results attained from the study through workshops and seminars in order for them to make informed decisions on what feed to use for fish farming.

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APPENDICES

Appendix 1: Questionnaire for fish farmers

Black Soldier Fly Larvae (BSFL) Based feed production: Profitability and Acceptability

Analysis.

This questionnaire is for academic purpose and will be treated as strictly confidential

Thank you for granting me the opportunity to speak to you, I am a research student from the Department of Agricultural Economics and Agribusiness, College of Basic and Applied Sciences, University of Ghana, Legon. In partial fulfilment of my programme, I am collecting data to support my Thesis. The major objective is to determine the feasibility of black soldier fly larvae (BSFL) meal and feed production and its acceptance amongst fish farmers. The specific objectives are to: 1. Determine the viability of BSFL meal and feed production, 2. Ascertain fish farmers' perception towards the technique used for BSFL-based fish feed production 3. Determine the amount and factors that influence willingness of farmers to pay for BSFL meal and 4. Estimate the gains in substituting conventional feed with BSFL-based fish feed. Your assistance and input would be very much appreciated.

Enumerator Questionnaire No

Field Worker's Code/No..... Date.....

District..... Mobile phone:

A. Demographic Characteristics

1. Name of respondent:

2. Age of respondent (Years):

3. Gender: 1= Male [] 0= Female []

4. Religion: 1= Christian [] 2= Muslim 3= Traditionalist [] 4= Others (specify).....

5. Marital Status: 1= Single [] 2= Married [] 3= Divorced [] 4= Widowed []

5= Never Married []

6. Household Size:

7. Residential Status: 1= Native [] 2= Migrant []

B. Socioeconomic Characteristics

8. Highest level of Education reached: 1= No Education [] 2= Primary [] 3= JHS []

4= SHS [] 5= Tertiary

9. Are you a full time fish farmer? 1= Yes [] 0= No []

10. If no what other activity do you undertake besides fish farming?.....

11. What type of business do you operate? 1= Hatchery [] 2= Grow out []

12. Land Ownership: 1= Land Owner [] 2= Tenant []

13. What is your annual income? GHS.....

C. Culture Characteristics

14. Which culture practice are you engaged in? 1= Intensive [] 2= Extensive [] 3= Semi intensive []

15. What do you farm the fish in? 1= Cage [] 2= Pond [] 3= Tank []

15. How many cages/fishponds/fish tanks do you own?

16. Total size of cages/fishponds/fish tanks

17. How many years have you farmed on current land?years

18. Do you farm tilapia only? 1= Yes [] 0= No []

i. If “No” what else do you farm?.....

20. How many times do you produce the tilapia in a given year?

D. Institutional Characteristics

21. Do you sell directly on the market? 1= Yes [] 2= No []

22. Do you sell through middlemen? 1= Yes [] 2= No []

23. If “No” who do you sell through?

25. Are you under any contract or agreement to produce? 1= Yes [] 0= No []

26. If “Yes”, with whom do you have such an agreement? 1= Individual(s) []

2= Restaurant/Hotel [] 3= School/Institution [] 4= Other(s).....

24. Are you a member of any farmer based organization? 1= Yes [] 0= No []

27. Do you have access to extension service? 1= Yes [] 2= No []

27. How many visits per month?

28. Have you borrowed from a financial institution before? 1= Yes [] 2= No []

E. Fish feed

29. Do you make your own fish feed? 1= Yes [] 2= No []

30. If no then where do you get your feed?

31. Do you think the existing fish feed is expensive? 1= Yes [] 2= No []

32. Do you know the components of the existing feed? 1= Yes [] 2=No []

33. Which of these factors do you consider when buying commercial fish feeds?

1= Ingredient [] 2= Cost [] 3= brand [] 4= Others []

F. Perception and awareness of BSFL-based fish feed

Product Description

This feed is an insect based feed that is made from the black soldier fly larvae (BSFL) meal and other ingredients. Unlike the conventional feeds where the main protein ingredient is fishmeal, the BSFL meal has replaced the fishmeal in this feed. This is due to high cost of fishmeal and its limited future supply. The BSFL is the larvae of the black soldier fly that can be found in tropical areas. It is easy to rear and it feeds on organic waste reducing the volume of the waste by up to 50% and producing a biomass that is rich in protein and fat. In formulating this feed, the BSFL is reared, harvested, dried and milled. Other ingredients such as fish oil, vitamins etc. are finally added to formulate the feed.

Based on this description, and already existing knowledge on insect based feed (if any), please provide answers to these questions and statements.

34. Have you fed the tilapia with insect before? 1= Yes [] 0=No []

i. What was the result of the trial? 1= poor [] 2= Somewhat good [] 3= Good []

35. Have you heard of insect (Black soldier fly) based feed? 1= Yes [] 2= No []

36. If “yes” How did you get to know? 1= institution/organization [] 2= workshop [] 3= Friends and family [] 4= Media [] 5= other Specify.....

37. Please indicate the degree to which you agree or disagree with the following statements.

Perception Statements	Disagree	Not Sure	Agree
	(1)	(2)	(3)
	(Midpoint Scale)		
The use of BSFL in fish feed can:			
Risk Statements			
1. Decrease demand for fish			
2. Cause release of noxious gases during BSFL production			
3. Introduce BSF which will spread diseases to human beings			
4. Cause microbiological contamination to fish			
5. Be detrimental to the health of fish consumers			
Benefit statements			
1. Decrease the overexploitation of water bodies			
2. Lower the cost of Fish feed			
3. Lower our dependence on imported feed			
4. Improve organic waste management in the country			
5. Improve the sustainability of aquaculture production			

G. Farmers willingness to pay for the BSFL-based fish feed

Based on the product description given above, please answer the following questions.

39. Would you be willing to pay for BSFL-based fish feed? a) Yes.... b) No....

40. If “No” what is your reason(s)?

.....

41. How much would you be willing to pay per KG?

Elicited bidding Price (GHC)	Yes	No
------------------------------	-----	----

a. 180		
b. 190		If No (go to "1")
c. 200 (starting bid)	If Yes (go to "4")	If No (go to "2")
d. 210	If Yes (go to "5")	
e. 220		

H. Production Cost

- 42. What is the average weight of the fingerlings harvested?kg
- 43. How many weeks does it take to grow fingerlings to harvest time? Weeks
- 44. How many tonnes of fingerlings do you produce per production cycle? tonnes
- 45. How much is the fingerlings produced sold for?kgGHS..... kgGHS
- 46. What is your total revenue per production cycle? GHS.....
- 47. How many kilograms of feed do you use per production cycle?

Please provide information on the following operational cost items per production cycle

Cost item	Quantity/Number	Cost per unit	Total Cost
Feed @ 1.1mm			
1.4mm			
1.9mm			
2.0mm			
2.5mm			
4.5mm			
Labour: Regular			
Casual			
Fertilizer			
Lime			
Transportation: Feed			
Others			
Harvesting cost			

Others? (a)Yes..... (b)No.....

If yes, please specify.....

.....

Enumerator Comments

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Appendix 2: Land size required for BSFL production and cost of land

Land size needed	(metres square)
Main Building	
office area	18
Processing unit(oven, and mill)	100
Room for housing of larvae up to 10 day old before inoculation	1000
Room for larvae inoculated in waste stored in barrels	1500
Storage room @ 85tonnes a month capacity	100
room for housing adult larvae	50
Sanitary facilities	10
External Building	
tools and other equipment shed	10
Vehicle parking	80
Sorting and cutting of waste area @ 25 metric tonnes of waste a day	210
Total area size	3078
Average size of one plot in Ghana	900
total area size in plot	3.5
Cost of one plot of land at prampram (township where existing feed company Raanan feed is located).	16,000
Cost of Three and a half plot (GHS)	56000

Appendix 3: Break down of initial start-up cost (Scenario A)

Fixed Cost	Cost per unit(GHS)	Total cost (GHS)
Land acquisition	16,000	56,000
EPA and other survey charges	20,000	20,000
Building construction	500,000	500,000
Building permit and other contingencies	10,000	10,000
Machinery and equipment		
Oven @ 5 mt per day capacity	40,000	40,000
mill @ 5 mt per day capacity	50,000	50,000
Truck (8*4) 3 mt capacity (2)	93,333	186,667
Conveyor system	30,000	30,000
Larval containers (0.3m *0.3m)	10	208,000
Drums	160	624,900
Drum stand	83	291,620
Adult cages (3m *3m)	70	2,100
Overall	78	2,000
Wellington boots	40	1,200
Shovels	20	1,000
Sieves	12	13,788
Wheelbarrows	186	2,000
Measuring scale	500	2,000
Sharp knives	5	1,000
Cutlass	20	1,000
PVC pipes @ 0.7m per drum	18	6,124
Collection bins for BSFL	4	12,498
Total fixed cost		2,061,897
Operational cost		
Cardboard	10	12,000
Masking tape	10	12,000
Labour	8.8/day	145,200
Transportation of waste (Fuel)	500 (1 truck)/day	312,000
Electricity	8	84,000
Water	4	48,000
Sacks	2	50,000
Maintenance and repairs	5400	5,400
Layer meal	70/45kg	1,296,296.30
Nose mask (Rubber)	20	2,400
Gloves	5	1,000
Contingencies		200,000
Total Operational Cost		2,168,296
Total start-up cost		4,230,193

Appendix 4: Breakdown of layer meal for feeding BSFL

Months	Larvae needed for 1000metric tonnes BSFL meal	Cost of meal/45kg	Quantity of meal needed (Kg)/day	Number of days larvae is fed	Total amount
January	208,333,333	70	6,944	10	108,025
February	208,333,333	70	6,944	10	108,025
March	208,333,333	70	6,944	10	108,025
April	208,333,333	70	6,944	10	108,025
May	208,333,333	70	6,944	10	108,025
June	208,333,333	70	6,944	10	108,025
July	208,333,333	70	6,944	10	108,025
August	208,333,333	70	6,944	10	108,025
September	208,333,333	70	6,944	10	108,025
October	208,333,333	70	6,944	10	108,025
November	208,333,333	70	6,944	10	108,025
December	208,333,333	70	6,944	10	108,025
Total	2,500,000,000	70	83,333	10	1,296,296

Appendix 5: Breakdown of cost of producing a kilo of BSFL larvae meal

Operational Cost	GHS
Cardboard	12,000
Masking tape	12,000
Labour	145,200
Transportation of waste (Fuel)	312,000
Electricity	84,000
Water	48,000
Sacks	50,000
Maintenance and repairs @2% of cost	5,400
Layer meal	1,296,296
Nose mask (Rubber)	2,400
Gloves	1,000
Contingencies	200,000
Total Operational Cost	2,168,296
Costing by just operational cost (Per kilo)	2.2
Costing including fixed cost 'Depreciation of fixed assets'	2,269,181
Cost of producing one kilo of BSFL meal	2.3

**Appendix 6: Scenario A (Breakdown of discounted costs and benefits)
Production at market price**

Production year	Discounted Cost	Discounted Benefit	Present value of net benefit	Cumulative Present value
			(4,230,192.98)	(4,230,192.98)
1	1,655,188.01	4,474,045.80	2,818,857.79	(1,411,335.19)
2	1,263,502.30	3,415,302.14	2,151,799.84	740,464.65
3	964,505.57	2,607,100.87	1,642,595.30	2,383,059.94
4	736,263.80	1,990,153.34	1,253,889.54	3,636,949.48
5	562,033.43	1,519,201.02	957,167.59	4,594,117.07
6	429,033.15	1,159,695.43	722,231.19	5,316,348.26
7	327,506.22	885,263.69	557,757.47	5,874,105.72
8	250,004.75	675,773.81	425,769.06	6,299,874.78
9	190,843.32	515,857.87	325,014.55	6,624,889.33
10	145,681.92	393,784.63	248,102.71	6,872,992.04
11	111,207.58	300,598.96	189,391.38	7,062,383.42
12	84,891.28	229,464.85	142,905.34	7,205,288.76
13	64,802.50	175,164.01	110,361.51	7,315,650.26
14	49,467.56	133,712.98	84,245.42	7,399,895.69
15	37,761.50	102,070.98	64,309.48	7,464,205.17
16	28,825.57	77,916.78	49,091.21	7,513,296.38
17	22,004.25	59,478.46	37,041.79	7,550,338.17
18	16,797.14	45,403.40	28,606.26	7,578,944.44
19	12,822.24	34,659.09	21,836.84	7,600,781.28
20	9,787.97	26,457.32	16,669.35	7,617,450.63
NPV			7,617,450.63	
IRR			43%	
BCR			2.70	

Appendix 7: Production at 20% below market price (Breakdown of discounted costs and benefits)

Production year	Discounted Cost	Discounted Benefit	Present value of net benefit	Cumulative Present value
			(4,230,192.98)	(4,230,192.98)
1	1,655,188.01	3,579,236.64	1,924,048.63	(2,306,144.35)
2	1,263,502.30	2,732,241.71	1,468,739.41	(837,404.94)
3	964,505.57	2,085,680.70	1,121,175.12	283,770.18
4	736,263.80	1,592,122.67	855,858.87	1,139,629.05
5	562,033.43	1,215,360.82	653,327.38	1,792,956.44
6	429,033.15	927,756.35	490,292.10	2,283,248.54
7	327,506.22	708,210.95	380,704.73	2,663,953.26
8	250,004.75	540,619.05	290,614.30	2,954,567.56
9	190,843.32	412,686.30	221,842.97	3,176,410.53
10	145,681.92	315,027.71	169,345.78	3,345,756.32
11	111,207.58	240,479.17	129,271.59	3,475,027.90
12	84,891.28	183,571.88	97,012.37	3,572,040.28
13	64,802.50	140,131.21	75,328.70	3,647,368.98
14	49,467.56	106,970.39	57,502.83	3,704,871.81
15	37,761.50	81,656.78	43,895.29	3,748,767.10
16	28,825.57	62,333.42	33,507.85	3,782,274.95
17	22,004.25	47,582.77	25,146.10	3,807,421.05
18	16,797.14	36,322.72	19,525.58	3,826,946.63
19	12,822.24	27,727.27	14,905.03	3,841,851.66
20	9,787.97	21,165.85	11,377.88	3,853,229.54
NPV			3,853,229.54	
IRR			22%	
BCR			2.16	

Appendix 8: Production at 15% below the market price (Breakdown of discounted cost and benefit)

Production year	Discounted Cost	Discounted Benefit	Present value of net benefit	Cumulative Present value
			(4,230,192.98)	(4,230,192.98)
1	1,655,188.01	3,802,938.93	2,147,750.92	(2,082,442.06)
2	1,263,502.30	2,903,006.82	1,639,504.52	(442,937.55)
3	964,505.57	2,216,035.74	1,251,530.17	808,592.62
4	736,263.80	1,691,630.33	955,366.54	1,763,959.16
5	562,033.43	1,291,320.87	729,287.43	2,493,246.59
6	429,033.15	985,741.12	548,276.87	3,041,523.47
7	327,506.22	752,474.14	424,967.91	3,466,491.38
8	250,004.75	574,407.74	324,402.99	3,790,894.36
9	190,843.32	438,479.19	247,635.87	4,038,530.23
10	145,681.92	334,716.94	189,035.01	4,227,565.25
11	111,207.58	255,509.11	144,301.54	4,371,866.78
12	84,891.28	195,045.12	108,485.61	4,480,352.40
13	64,802.50	148,889.41	84,086.90	4,564,439.30
14	49,467.56	113,656.04	64,188.48	4,628,627.78
15	37,761.50	86,760.33	48,998.84	4,677,626.62
16	28,825.57	66,229.26	37,403.69	4,715,030.31
17	22,004.25	50,556.69	28,120.02	4,743,150.33
18	16,797.14	38,592.89	21,795.75	4,764,946.08
19	12,822.24	29,460.22	16,637.98	4,781,584.06
20	9,787.97	22,488.72	12,700.75	4,794,284.81
Therefore NPV			4,794,284.81	
IRR			27%	
BCR			2.30	

Appendix 9: Production at 10% below market price (Breakdown of discounted costs and benefits)

Production year	Discounted Cost	Discounted Benefit	Present value of net benefit	Cumulative Present value
			(4,230,192.98)	(4,230,192.98)
1	1,655,188.01	4,026,641.22	2,371,453.21	(1,858,739.77)
2	1,263,502.30	3,073,771.92	1,810,269.63	(48,470.15)
3	964,505.57	2,346,390.78	1,381,885.21	1,333,415.06
4	736,263.80	1,791,138.00	1,054,874.21	2,388,289.27
5	562,033.43	1,367,280.92	805,247.49	3,193,536.75
6	429,033.15	1,043,725.89	606,261.64	3,799,798.40
7	327,506.22	796,737.32	469,231.10	4,269,029.49
8	250,004.75	608,196.43	358,191.68	4,627,221.17
9	190,843.32	464,272.08	273,428.76	4,900,649.93
10	145,681.92	354,406.17	208,724.25	5,109,374.18
11	111,207.58	270,539.06	159,331.48	5,268,705.66
12	84,891.28	206,518.37	119,958.86	5,388,664.52
13	64,802.50	157,647.61	92,845.11	5,481,509.62
14	49,467.56	120,341.69	70,874.13	5,552,383.75
15	37,761.50	91,863.88	54,102.39	5,606,486.13
16	28,825.57	70,125.10	41,299.53	5,647,785.67
17	22,004.25	53,530.61	31,093.95	5,678,879.61
18	16,797.14	40,863.06	24,065.92	5,702,945.54
19	12,822.24	31,193.18	18,370.93	5,721,316.47
20	9,787.97	23,811.59	14,023.61	5,735,340.08
NPV			5,735,340.08	
IRR			32%	
BCR			2.43	

Appendix 10: Sensitivity analysis at 10% cost overrun and 10% production decrease (Breakdown of discounted costs and benefits)
Production at market price

Production year	Discounted Cost	Discounted Benefit	Present value of net benefit	Cumulative Present value
			(4,230,192.98)	(4,230,192.98)
1	1,820,706.81	3,623,977.10	1,803,270.29	(2,426,922.70)
2	1,389,852.53	2,766,394.73	1,376,542.20	(1,050,380.49)
3	1,060,956.13	2,111,751.70	1,050,795.57	415.08
4	809,890.18	1,612,024.20	802,134.03	802,549.11
5	618,236.77	1,230,552.83	612,316.05	1,414,865.16
6	471,936.47	939,353.30	501,889.05	1,916,754.21
7	360,256.85	717,063.59	356,806.74	2,273,560.95
8	275,005.23	547,376.79	272,371.56	2,545,932.51
9	209,927.65	417,844.87	207,917.22	2,753,849.73
10	160,250.12	318,965.55	158,715.44	2,912,565.17
11	122,328.33	243,485.16	121,156.82	3,033,721.99
12	93,380.41	185,866.53	99,307.02	3,133,029.01
13	71,282.75	141,882.85	70,600.09	3,203,629.10
14	54,414.32	108,307.52	53,893.20	3,257,522.30
15	41,537.65	82,677.49	41,139.85	3,298,662.15
16	31,708.13	63,112.59	31,404.46	3,330,066.62
17	24,204.68	48,177.55	25,740.88	3,355,807.50
18	18,476.85	36,776.76	18,299.90	3,374,107.41
19	14,104.47	28,073.86	13,969.39	3,388,076.80
20	10,766.77	21,430.43	10,663.66	3,398,740.46
NPV			3,398,740.46	
IRR			19%	
BCR			1.99	

Appendix 11: Break down of initial start-up cost (Scenario B)

Cost	Amount (GHS)
Fixed assets (fixed cost)	
Land	56,000
EPA, surveyor fees and other charges	20,000
Building	500,000
Building permit and other charges	40,000
Grinder @ 5 tonnes per day capacity	50,000
Conveyer system	30,000
Feed Containers	50,000
Mixer	100,000
Scale	5,000
Trucks (2) at 3 tonnes capacity	300,000
Extruder @ 5 tonnes per day capacity	400,000
Pelleter	195,000
Total fixed assets	1,746,000
Operating expenses	
Electricity	252,000
Water	144,000
Cost of ingredients	
Fishmeal	870,000
BSFL Meal	2,340,000
Soybean	594,000
Wheat bran	63,600
Maize(white)	12,000
Cassava flour	12,680
Common Salt	20,000
Maintenance	30,000
Permanent skilled	90,000
Transportation	90,000
Sacks	125,000
Contingencies	100,000
Operating cost	4,743,280
Total Start-up cost	6,489,280

**Appendix 12: Scenario B (Breakdown of discounted costs and benefit)
Production at market price**

Production year	Discounted benefit	Discounted cost	Present value	Cumulative Present value
0			-6489280	-6489280
1	7,633,587.79	3,620,824.43	4,012,763.36	(2,476,516.64)
2	5,827,166.25	2,763,988.11	3,063,178.14	586,661.50
3	4,448,218.51	2,109,914.59	2,338,303.92	2,924,965.42
4	3,395,586.65	1,610,621.82	1,784,964.83	4,709,930.24
5	2,592,050.88	1,230,228.82	1,361,822.06	6,071,752.30
6	1,978,664.79	939,687.22	1,038,977.57	7,110,729.87
7	1,510,431.14	717,771.07	792,660.07	7,903,389.94
8	1,153,000.87	548,269.24	604,731.63	8,508,121.58
9	880,153.34	418,800.51	461,352.82	8,969,474.40
10	671,872.78	319,908.69	351,964.09	9,321,438.49
11	512,879.98	244,371.45	268,508.53	9,589,947.02
12	391,511.44	186,672.61	204,838.82	9,794,785.84
13	298,863.69	142,599.02	156,264.67	9,951,050.51
14	228,140.22	108,932.74	119,207.48	10,070,257.99
15	174,152.84	83,215.90	90,936.94	10,161,194.93
16	132,941.10	63,571.20	69,369.90	10,230,564.83
17	101,481.76	48,564.70	52,917.06	10,283,481.89
18	77,466.99	37,101.15	40,365.84	10,323,847.73
19	59,135.11	28,343.96	30,791.15	10,354,638.88
20	45,141.30	21,654.11	23,487.20	10,378,126.08
NPV			10,378,126.08	
BCR			2.1	
IRR			38%	

Appendix 13: Scenario B (Breakdown of discounted costs and benefits at MWTP amount-7% less the market price)

Production year	Discounted benefit	Discounted cost	Present value	Cumulative Present value
0			-6489280	-6489280
1	7,099,236.641	3,620,824.427	3,478,412.21	(3,010,867.79)
2	5,419,264.612	2,763,988.113	2,655,276.50	(355,591.29)
3	4,136,843.215	2,109,914.59	2,026,928.63	1,671,337.34
4	3,157,895.584	1,610,621.824	1,547,273.76	3,218,611.10
5	2,410,607.316	1,230,228.819	1,180,378.50	4,398,989.59
6	1,840,158.256	939,687.2215	900,471.04	5,299,460.63
7	1,404,700.959	717,771.068	686,929.89	5,986,390.52
8	1,072,290.809	548,269.235	524,021.57	6,510,412.09
9	818,542.6019	418,800.513	399,742.09	6,910,154.18
10	624,841.6809	319,908.687	304,932.99	7,215,087.18
11	476,978.3823	244,371.4494	232,606.93	7,447,694.11
12	364,105.6354	186,672.6116	177,433.02	7,625,127.13
13	277,943.2331	142,599.0247	135,344.21	7,760,471.34
14	212,170.4069	108,932.7401	103,237.67	7,863,709.01
15	161,962.1427	83215.90338	78,746.24	7,942,455.25
16	123,635.2234	63,571.19548	60,064.03	8,002,519.28
17	94,378.03316	48,564.69672	45,813.34	8,048,332.61
18	72,044.30012	37,101.14857	34,943.15	8,083,275.76
19	54,995.64895	28,343.95939	26,651.69	8,109,927.45
20	41,981.41141	21,654.10744	20,327.30	8,130,254.76
NPV			8,130,254.76	
BCR			1.958969834	
IRR			30%	

Appendix 14: Scenario B: Sensitivity analysis at 10% reduction in cost and production

Production year	Discounted benefit	Discounted cost	Present value	Cumulative Present value
-			(6,489,280.00)	(6,489,280.00)
1	6,389,312.98	3,982,906.87	2,406,406.11	(4,082,873.89)
2	4,877,338.15	3,040,386.92	1,836,951.23	(2,245,922.67)
3	3,723,158.89	2,320,906.05	1,402,252.84	(843,669.82)
4	2,842,106.03	1,771,684.01	1,070,422.02	226,752.20
5	2,169,546.58	1,352,430.54	817,116.04	1,043,868.24
6	1,656,142.43	1,032,389.72	623,752.71	1,667,620.95
7	1,264,230.86	788,083.76	476,147.10	2,143,768.05
8	965,061.73	601,590.66	363,471.07	2,507,239.12
9	736,688.34	459,229.51	277,458.83	2,784,697.96
10	562,357.51	350,556.88	211,800.64	2,996,498.59
11	429,280.54	267,600.67	161,679.87	3,158,178.47
12	327,695.07	204,275.32	123,419.75	3,281,598.22
13	250,148.91	155,935.36	94,213.55	3,375,811.77
14	190,953.37	119,034.63	71,918.74	3,447,730.51
15	145,765.93	90,866.13	54,899.80	3,502,630.31
16	111,271.70	69,363.45	41,908.25	3,544,538.56
17	84,940.23	52,949.20	31,991.03	3,576,529.59
18	64,839.87	40,419.24	24,420.63	3,600,950.22
19	49,496.08	30,854.38	18,641.70	3,619,591.92
20	37,783.27	23,552.96	14,230.31	3,633,822.23
NPV			3,633,822.23	
BCR			1.60	
IRR			13%	

Appendix 15: Breakdown of partial budget analysis

Diet	Feed input (kg)	Cost of feed (GHS)	Harvested biomass (kg)	Cost of fish/kg	Estimated value of biomass (GHS)	Profit
Conventional feed	14.6	67.11	7.73	12	92.76	25.65
BSFL feed @75% replacement of fishmeal	14.6	59.86	7.67	12	92.04	32.18
Difference		7.25			0.72	6.53