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ASSESSMENT OF PESTICIDES RESIDUE LEVELS IN COCOA BEANS FROM THE SEFWI WIAWSO DISTRICT OF THE WESTERN REGION OF GHANA

BY

MAXWELL OSEI BOADU

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MAXWELL OSEI BOADU (BSc CHEMISTRY)

A THESIS SUBMITTED TO THE SCHOOL OF RESEARCH AND GRADUEATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF

MASTERS OF PHILOSOPHY

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DECLARATION

I do hereby declare that except for references and quotations which have been duly acknowledged, this is a research carried out by me under the supervision of Dr. Ben. K Banful and Mrs. H. V. Adzraku Senior Lecturers of the Department of Horticulture, Kwame Nkrumah University of Science and Technology. This work has not been submitted in whole or in part for a degree anywhere.

I am, therefore, solely responsible for any shortcomings, marginal or substantial which may be found in this work.

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ABSTRACT

Cocoa is the most important agricultural export crop in Ghana, and the country has an enviable reputation of producing high quality cocoa. The nymphs, adults of mirid species and the stink bugs are important insect pests of cocoa. The main method of their control is by the application of conventional insecticides. Consumer awareness on food safety and environmental concerns raise major issues on chemical pest control in cocoa. The research study aimed to determine the residue levels of pesticides and its effect on cocoa beans quality in the Sefwi Wiawso District. A multi-stage sampling procedure which included purposive and simple random sampling techniques was employed. The findings of the research study included the following: Insect pests and diseases particularly capsids, mirids and black pod disease were mentioned by the respondents as a major production constraint. Majority (98.8 %) of the farmers used chemicals to control pests on their cocoa farms and was knowledgeable about the dos and don't s with pesticide usage. About 10.0 % of them reported to have been combining different pesticides and higher doses of approved pesticides for spraying with the aim to boost efficacy. The pesticide residue analysis revealed that permethrin, a synthetic pyrethriod, which is unapproved to be used on cocoa, had a concentration of 0.07 mg/kg which exceeded Japan MRL of 0.05 mg/kg in bulked sample from all the selected communities in the district. No pesticides residue was detected in the roasted cocoa samples. A chi square test value at 5 % showed that there was a significant (p=.011) relationship between the farmers' pesticide usage patterns and the pesticide residue levels in cocoa bean samples from the Sefwi Wiawso cocoa district. The need for increased efficiency of the CODAPEC programme, education and training, and more governmental support in terms of incentives are recommended.

DEDICATION

I dedicate this work to my dear wife Mrs. Vida Osei Boadu and my children for their relentless and keen interest they have demonstrated throughout the course of study.

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COCOBOD	Ghana Cocoa Board
CODAPEC	Cocoa Disease and Pest Control Programme
CMC	Cocoa Marketing Company
CMB	Cocoa Marketing Board
CPC	Cocoa Processing Company
CSSVD	Cocoa Swollen Shoot Virus Disease
CSSVD-CU	Cocoa Swollen Shoot Virus Disease and Control Unit
CRIG	Cocoa Research Institute of Ghana
GCFS	Ghana Cocoa Farmers Survey
GAIN	Global Agricultural Information Network
GSA	Ghana Standard Authority
GOG	Government of Ghana
GDP	Gross Domestic Product
LBCs	Licensed Buying Companies
LDL	Low Density Lipoproteins
MRLs	Maximum Residue Levels
MHLW	Ministry of Health, Labour and Welfare
QCC	Quality Control Company

CHAPTER ONE

1.0 INTRODUCTION

Cocoa is the backbone of Ghana's economy and a major foreign exchange earner (Amoah, 1998). It is the most important agricultural export crop accounting for between 25-30 percent of total export earnings ($ 1.2 billion in 2007). Over the years, the export receipts have been on the increase from $ 682.5 million representing 48.8 % in 2010 to $ 859.4 million representing about 61 % of total export earnings in 2011 (COCOBOD Annual Report, 2011). Generally, it contributes about 10 percent to GDP (Cocoa Manual, 2010). The cocoa industry in Ghana employs over a million people with six million people earning their livelihoods from the crop and its products (Cocoa Manual, 2010). Currently, Ghana is the world's second largest producer of cocoa beans, after the Ivory Coast (Cocobod Annual Report, 2010). The cocoa tree starts bearing fruits 3-4 years after planting till about 30 years. In Ghana, they are collected most abundantly in the harvest seasons from the beginning of October to the end of June (Main crop season) and between July and end of September few pods are also collected (Light crop season) which together constitutes a crop year. The harvested cocoa pods are broken, the beans scooped out, fermented and dried to an acceptable moisture content of 7.5 % before they are packed in bags and exported (Amoah. 2000).

Previously, the average cocoa farmer had limited contact with the product market and made little use of insecticides in the control of pest and diseases which constituted a major production constraint. Consequently, the Cocoa Disease and Pest Control Programme (CODAPEC) popularly known as Mass Spraying, introduced in 2009, served to resolve the problem of pest and disease control for the smallholder farmers (Abankwah *et al*., 2010).

Ghana's cocoa has always enjoyed an unparalleled reputation for quality in international markets and it regularly exceeds international guidelines due to its effective farm management practices and quality control system (Sibun, 2008). Issues about maximum residue levels (MRLs) supported by various legislations in the EU, Japan and the USA have suggested that producers must comply with the codes of practice to minimize the threat of contamination of food from pesticides (Bateman, 2010). In September 2008, a European Union Legislation on Maximum Residue Levels (MRLs) on Pesticides (Regulation 149/2008/EEC) came into effect (QCC Annual Report, 2008). The Regulation set maximum levels on the amount of pesticides permitted on imported foods including cocoa beans. In the U.S.A, the Environmental Protection Agency (EPA) established the Food Quality Protection Act of 1996 which regulates the amount of pesticide residues permitted on food for consumption (QCC Annual Report, 2008). The EPA also required that all approved pesticides should clearly be labelled with instructions for proper use, handling, storage and disposal.

In Japan, the Ministry of Health, Labour and Welfare (MHLW) established a new legislation in May 2006, setting new MRLs for food products (QCC Annual Report, 2008). Aside the limited working and technical knowledge of pesticide by most smallholder farmers, users and retailers of pesticide products, implementation of pesticide regulations and their control in Ghana has had many challenges including illegal smuggling of unapproved products across the country's borders (Bateman, 2010).

In recent times, the indiscriminate use of pesticides, both approved and banned, in cocoa production has had adverse effect on the cocoa international trade due mainly to the residues found in the beans with a concomitant effect on human health (Adu-Acheampong *et al.*, 2010). For instance, pesticide residue analysis conducted by the Ghana Standard Authority on some cocoa bean samples for the two most popular pesticides used by farmers, showed high levels of their active ingredients (Imidacloprid for Confidor pesticide and pirimiphos methyl or Actara pesticide), above the permissible level of 0.05ppm (QCCL, 2011). Efforts should therefore be made by COCOBOD and other regulatory bodies to ensure that the pesticides residue levels in the county's cocoa beans are within the permissible levels to avoid the rejection of beans from Ghana with its attendant international sanctions and loss of substantial revenue. There is however a dearth of information on pesticide use in the cocoa industry in relation to the residue levels in the cocoa beans and their effects on bean quality after primary processing by roasting of the beans.

Using Sefwi Wiawso District as a case study the general objective of the study therefore was to determine the residue levels of pesticide in cocoa beans and their effects on bean quality after primary processing by roasting.

Specifically, the study objectives were to:

- examine farmer's pesticide use pattern and practices along the production chain;
- identify and catalogue the range of pesticides used by farmers in cocoa production; and
- determine the effect of roasting (primary processing) on the pesticide residue level and quality of beans for secondary processing.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Quality of Ghana's Cocoa

Ghana's cocoa has earned an excellent reputation in overseas markets. This is extremely valuable and must be protected in the short and long term. To maintain this reputation will require constant vigilance, as there have been some residue issues highlighted by importing countries, notably Japan. In some cases production systems will need to be updated to preserve the status of Ghanaian cocoa and to stay ahead of the changing regulations and standards demanded by international buyers. Systems will be needed to maintain (and in some cases improve) food safety controls. These proactive systems, which manage food safety and prove that safety is being adequately controlled, will be an increasingly important factor in supplying safety-conscious world markets such as Europe, the US and Japan (Cooper, and Cudjoe, 2012).

According to the International Cocoa Organization (ICCO, 2010), Ghana cocoa is richer in Theobromine and Flavonoids which have given the beans the unique, mild and rounded flavor. As such the quality of Ghana cocoa beans have become the world's standard against which all cocoa is measured. The International Cocoa Standards require cocoa of merchantable quality to be fermented, thoroughly dried, free from smoke, abnormal or foreign odor and free from any evidence of adulteration. It must be reasonably free from living insects, broken beans, fragments and pieces must be reasonably uniform in size. Manufacturers want beans that are fully fermented and not slaty or purple (Ntow, 2001).

Quality control of cocoa beans in Ghana is very rigorous and as such cocoa from Ghana continues to enjoy high premium on the World's Commodities Market because of its unsurpassable high quality (Ntow *et al*, 2006). The high quality of Ghana cocoa beans has been ensured and diligently maintained over the years, through the effective quality control practices, inspection and monitoring at the time of purchase by the Quality Control Company (QCC) of COCOBOD (Cocobod Annual Report, 2010).

As part of their responsibility the QCC undertakes disinfestation (Spraying, fogging and fumigation) of cocoa beans, during storage and prior to shipment to ensure that only insect free cocoa beans are exported. Rodent and other pests control is also carried out in all cocoa storage premises to prevent damage to the beans in storage; and inspection, grading and sealing of cocoa for the international and local markets. Ghana cocoa is subjected to a minimum of three stages of quality inspection prior to shipment. This gives added assurance and confidence to the customers for Ghana Cocoa at all times (Cocobod Annual Report, 2010).

2.2 Cocoa Processing in Ghana

Although serious attempts have been made to process cocoa locally, the bulk of cocoa beans produced in the country are still exported. Government's policy is to increase cocoa processing locally by at least 50 % by the end of the decade. The enabling conditions created in free zone enclaves, have led to the attraction of private foreign processing companies and the expansion of state-owned facilities. According to data from International Cocoa Organization, ICCO (2010) 200,000 metric tonnes of cocoa grindings were achieved in Ghana in the 2009/2010 season. This constituted about 32 % of the beans produced for the 2009/10 cocoa season indicating that the Government's target for grindings was not achieved (Adjinah and Opoku, 2010).

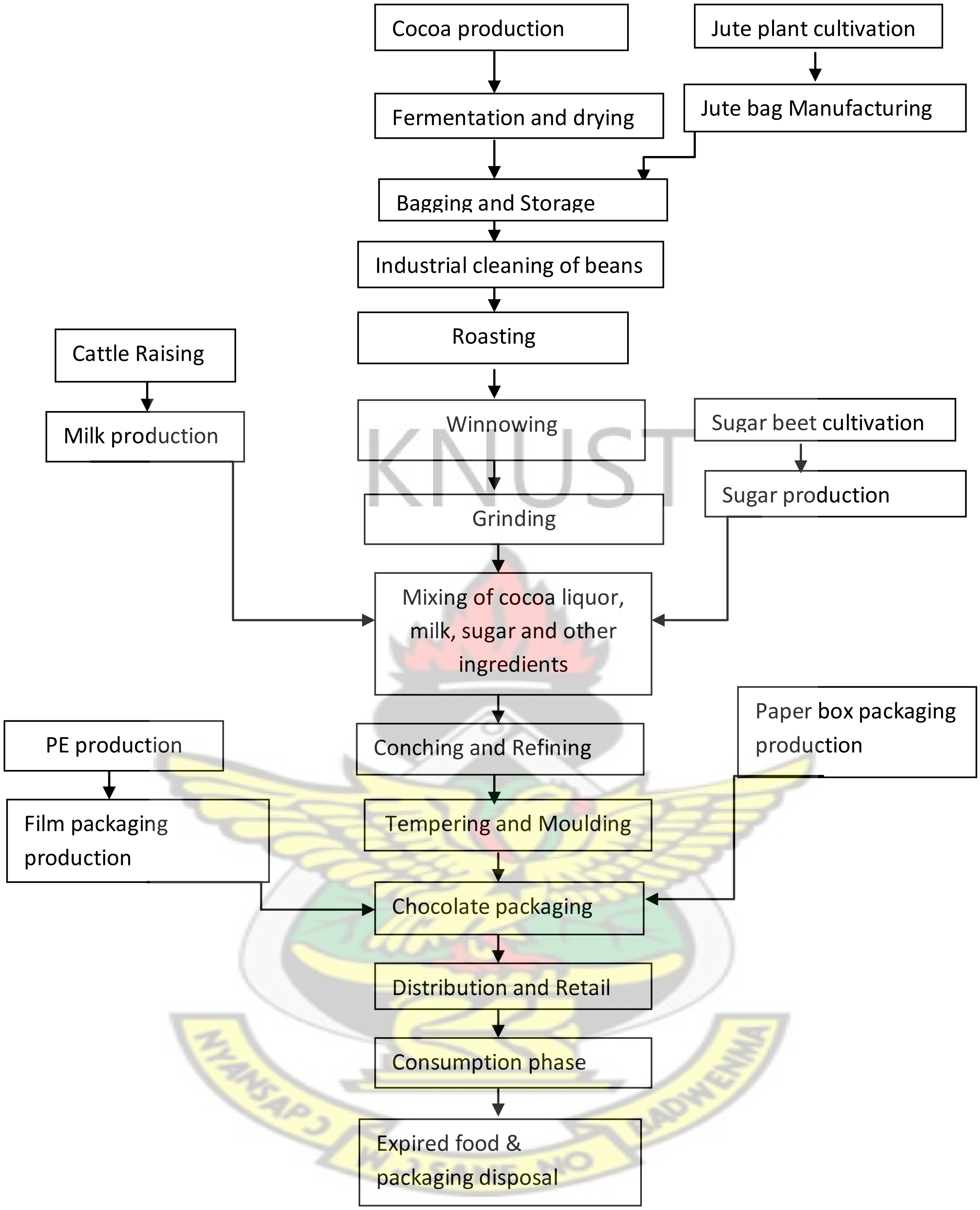
In spite of their peripheral role in the standard household menu - mainly as a dessert or snack, food products made from cocoa go through a long line of operations not normally found with other processed foods as shown Figure 2.1 (Awuah, 2002). Ripe cocoa pods are plucked from the trees and gathered together on clearings in the cocoa farms. After about ten days, all available hands, young and old, gather together to assist in the splitting of the pods and removal of the beans with their hands (Amoah, 1998).

According to Amoah (2000), this could be a critical stage in the contamination process, with pesticides getting transferred from the workers to the wet beans during handling. The wet beans are collected together in a heap and covered with plantain and/or banana leaves for fermentation After fermentation, the beans are dried in the sun on raised bamboo mats to desired moisture content of around 7.5 % or less (Amoah, 2000) (Figure 2.1).

After dried cocoa beans have been received at the processing plant, they are inspected and thoroughly cleaned of all extraneous matter, such as sticks, stones, metal fragments, dust, loose shells, small fragments and clumps of cocoa beans. The cleaning process consists of a series of operations involving sieves, brushes, airlifts and magnetic separators to remove the unwanted materials. The cleansed cocoa beans are roasted at temperatures between 90-170 °C, using a petroleum-based fuel or electricity. This process is needed to enhance the chocolate flavour, reduce the moisture content further, and loosen the shells for subsequent removal. The nibs (cotyledons) become friable and dark in colour in the process (Amoah, 2000).

At the next stage, the shells are separated from the nibs in a process known as winnowing. Winnowing machines use a multi-layered sieve frame with meshes of different sizes, one above the other, with the largest mesh on top. The roasted and crushed beans are ground into a paste or cocoa mass. The grinding process is achieved in two or three stages, using a combination of mills. The cocoa liquor obtained is heat-treated in storage tanks at temperatures of between 90-100 °C for aging and microbial destruction (Amoah, 2000).

The cocoa paste could be pressed in a hydraulic device to extract cocoa butter. The cake released after pressing is passed through kibbling machines, which break them into smaller pieces, and are packed into four-ply multi-walled paper sacks lined with polyethylene. These are ready for sale and shipment as kibbled cake. The cocoa butter, on the other hand, may be mixed with other ingredients of chocolate, namely, butter, sugar, milk and emulsifiers. The chocolate mix is subjected to additional processes known as conching and tempering. Conching removes residual moisture, while tempering transforms the thick semi-liquid mix into a solid product through heat treatment. After this process the chocolate is poured into moulds of different shapes and then packaged for the market (Amoah, 1998) (Figure 2.1).



Source: Awuah (2002).

Figure 2.1: Flowchart for chocolate production

2.3 Health Importance of Cocoa Consumption

While the soporific effect of cocoa drinks is widely known, recent research activities have unearthed additional more important health benefits which have enhanced further the attractiveness of cocoa products generally. There are three types of chocolate: dark, milk and white chocolates. Most of the benefits of chocolate consumption are associated with the dark brands.

In the last decade, studies have shown that chocolate consumption can play an important role in the reduction of risks or delaying the development of cardiovascular diseases, cancer and other age-related diseases (Adjinah and Opoku, 2010). It has also been linked positively to anti-carcinogenic activity in human cells, hypertension, diabetes and sexual weakness. It's newly found reputation as an aphrodisiac, stems from the ability of its sweet and fatty nature to simulate the hypothalamus, which induces pleasure sensation and affects the level of serotonin in the brain (Afoakwa, 2008).

Cocoa products contain flavonoids and amino acids, and these have been cited as the source of its beneficial effects, while carbohydrates, theobromine and lead have been mentioned as responsible for the negative effects. The flavonoids belong to a large and complex group of compounds called polyphenols and are found in plant products, mainly fruits and vegetables (Adjinah and Opoku, 2010). The phenols in cocoa products have been associated with antioxidant properties, reduction in migraine, and protection of arteries from plaque formation and prevention of Low Density Lipoproteins (LDL) formation two hours after consuming dark chocolate and perceptible lowering of blood pressure. Some studies have also linked chocolate consumption to muscle recovery and delayed brain function decline (Reuters, 2007).

Protein is broken down in the body to form twenty amino acids needed by the body. Eight of these are called essential, which means they are not made by the human body itself and must be supplied from outside. Fourteen of the twenty amino acids found in the body, including the eight essential ones, have been found in cocoa. In addition to building cells and repairing tissues, amino acids also have antioxidant properties, and they form antibodies to combat invading bacteria and viruses and taking care of free radicals (Awuah, 2002).

While international standards are such that the pesticides used in the field can hardly find their way into chocolate, a number of documented negative effects have been associated with some of the naturally and absorbed constituents of cocoa. Perhaps the major one is obesity. It is believed that the amounts of dark chocolate that needs to be consumed in order to experience the good benefits of the product could lead to obesity and its resultant negative effects. Although it is not supported by scientific studies, it is also believed that chocolate consumption can lead to acne (Appiah, 2004).

The heavy metal, lead, is known to maintain a high solubility in chocolate, and this may lead to lead poisoning (Rankin *et al*, 2005). Chocolate is also known to be toxic to some animals like horses, dogs, parrots, cats and small rodents (Awuah, 2002).

2.4 Pests and Diseases Associated with Cocoa Production

The increasing world population cannot be sustained without the use of pesticides in food production. Their usage therefore benefits not only farmers but also consumers. Pesticides are used to reduce food losses not only during production, but also during the post-harvest storage stage (Moy and Wessel, 2000). The general pest control strategy is for the intervention to destroy the pests feasting on the crops, but at the same time not to damage the produce so much as to render them unhealthy or unprofitable. Good agricultural practice (GAP) requires good timing and proper application (Awudzi *et al*., 2006). The crops are sprayed on the advice of specialists at an opportune time in the reproductive cycle of the pest, when the highest numbers could be eliminated. Also in order to maintain the activities of friendly insects the area of application of the insecticides should be clearly delineated (Offei *et al*., 2000).

The major diseases affecting cocoa in Ghana are shown in Table 2.1. The most important of these are *Phytophthora* pod rot, commonly called "blackpod", and locally known as '*akate*'; and the swollen shoot virus, also known locally as '*cocoa sasabro*'. The black pod rot, a fungal disease which appears as characteristic brown necrotic lesions on the pod's surface and as rotting of the beans, does the most damage to cocoa. An estimated 30% of annual cocoa production is lost to it, especially during years of high rainfall. In 2005 the cocoa bean price lost its forecasted productive market value by an estimated US$1.5 billion in lost revenue on the world commodity market (www.icco.org, 2010).

Most insects which attack cocoa are of the bug or *miridiae* family. This is a large family of insects of which capsids, the most well-known, have achieved their notoriety from the degree of havoc they can wreak on cash crops like cocoa. They feed on plants by piercing the tissue and sucking their juices. Capsids are small, terrestrial insects, usually oval-shaped or elongate and measuring less than 12 mm. They were identified as pests at the turn of the last century and are the main insects that feed on cocoa in Africa (Mahot *et al.*, 2005).

Table 2.1: Major Diseases affecting Cocoa in Ghana

Disease	Type of Infection (Causal agent)	Symptoms
Black pod	Fungus (*Phytophthora spp.*)	Pod rots, go brownish-black. Beans destroyed in immature pods. Could result in die-back
Brown root rot	Fungus (*Fomes noxius*)	Leaves fall prematurely and die-back of twigs occurs. Fungus fruit bodies on root and dead trunks. Soil is affected.
Cocoa Necrosis	Virus (Cocoa necrosis virus)	Leaves show bands of transparent lesions often with perforated centers
Collar crack	Fungus (*Armillaria mellea*)	Longitudinal cracking of trunk from ground level to about 1.2 m upwards, fills with cream-coloured mycelium
Collar rot	Fungus (*Ustulina zonata*)	Defoliation and death of plants. White fan shaped patches of mycelium are produced underneath bark and roots
Cushion gall	Fungus (*Calonectria rigidiuscula*)	Excessive production of buds at the nodes
Vascular streak Die – Back	Fungus (*Oncobasidium theobroma*)	Leaves turn yellow and fall prematurely. Smaller branches wither starting from the tips
Mealy pod	Fungus (*Trachysphaera fructigena*)	Pods turn brown, becomes encrusted with white to pinkish mealy growth of the fungus
Mistletoe	Flowering Plant (*Tapinanthus bangwensis*)	Parasitic flowering plant on host branches. Part of branch withers
Pod rot	Fungus (*Botryodiphlodia theobromae*)	Appears as brown necrotic areas with concentric rings of black spots. Pods are later covered with black sooty powder

Red rust	Alga (*Cephaleuros mycoidea*)	Reddish patches on leaves and twigs; leaves are shed prematurely
Swollen shoot	Virus (Cocoa swollen shoot virus)	Swelling of chupons and twigs; leaves develop yellow patterns, get crinkled and malformed
White rot	Fungus (*Fomes lignosus*)	Premature defoliation, death of twigs, pods are small
White thread blight	Fungus (*Marasmius scandens*)	Leaves are covered and killed in a network of white mycelial threads

Source: Offei *et al.* (2000).

2.5 The National Cocoa Disease and Pest Control Programme (Codapec)

Throughout the 90's, the tonnage of cocoa produced annually rarely exceeded 400,000 metric tonnes. This situation was attributed to a variety of causes, although the prevalence of pests and cocoa diseases was seen as the main reason. Crop losses due to mirids alone were estimated at between 25-35 % per annum. To reverse this trend, the government of Ghana in the year 2000 introduced the national Cocoa Diseases and Pests Control Programme, CODAPEC, popularly known as "mass spraying", to combat the resurgence of mirids and black pod diseases on cocoa farms. This opportunity was also to be used to train farmers and technical personnel in the scientific methods of pests and diseases control (Adjinah and Opoku, 2010). Participants were trained in the dosage of the various pesticides, dangers of exposure to pesticides, importance of the use of protective clothing, observance of personal hygiene, environmental safety issues, and first-aid, techniques of application and handling and disposal of empty containers. Lessons were given through radio programmes, town meetings and 'training-of-trainers' workshops. Table 2.2 shows the brands of pesticides approved by the Cocoa Research Institute of Ghana (CRIG), which are currently in use on Ghanaian cocoa farms under the CODAPEC programme and their application frequency.

The black pod control programme covered all cocoa-growing districts in the Volta, Brong Ahafo and parts of Western, Ashanti and Eastern Regions. Spraying against mirids, on the other hand, covered the Central, Eastern and parts of Western and Ashanti Regions. Spraying gangs were established at each spraying centre. A gang of ten (for black pod control) and six (for mirids control) had a supervisor each responsible for the general execution of the programme at the unit level. One mechanic was attached to a group of 20 gangs to oversee the maintenance and repairs of the spraying machines. The farmers, who were direct beneficiaries of the exercise, were themselves responsible for the sanitation practices, i.e. brushing, pruning, shade management and removal of diseased pods from the farms. They also provided water for spraying and were expected to monitor the activities of the sprayers on the farm and learn from the gangs for future sustainability of the programme. The spraying is carefully done using a portable petrol-engine driven knapsack mist-blowers, which combines the idea of low-volume application of sprays with the principle of using fan-driven air to carry the spray up into the trees (Cocoa Manual, 2010).

As a result of this initiative, between the period 2002-2004, nearly 600,000 ha involving about 360,942 farms and 330,121 individual farmers, were sprayed three times each season against the black pod diseases, while an estimated 826,141 ha involving 470,801 and 446,593 farmers were sprayed twice each season in the mirids control exercise. From the 2001/2002 season when cocoa beans output of 380,000 metric tons was recorded, production jumped to about 500,000 metric tonnes in the 2002/2003 season and almost doubled in the 2003/2004 season to an all-time high of over 736,000 metric tonnes. Started ten years ago, the mass spraying exercise has now become a permanent fixture in all the 72 geographical districts in the cocoa-growing areas with the following breakdown:

21districts for black pod spraying only, 35 districts for mirids only, and 16 for both programmes. District Task Forces (DTF) and Local Task Forces (LTF), have been formed in each operational district and local area, respectively. The DTF manages the project at the district level and is in charge of gang recruitment, storage, distribution of inputs and logistics and general supervision. The LTF on the other hand, handles project management at the village level and is responsible for the planning and execution of the programmes at that level (Cocoa Manual, 2010).

Table 2.2: Pesticides approved for use in the control of mirids and black pod disease under the CODAPEC programme of Ghana

Pesticide used	Active ingredient	Method of spraying	Frequency of spraying
Fungicides			
Ridomil 72 plus WP	12% metalaxyl, 60% Cuprous oxide	Knapsack sprayer	3 times during each cocoa season
Nordox 75 WP	86% Cuprous oxide, 14% inert	Knapsack sprayer	3 times during each cocoa season
Funguran OH WP	Cuprous hydroxide	Knapsack sprayer	3 times during each cocoa season
Champion WP	77% cupric hydroxide	Knapsack sprayer	3 times during each cocoa season
Kocide 101 WP	Cupric hydroxide	Knapsack sprayer	3 times during each cocoa season
Fungikill WP	Cupric hydroxide + Metalaxyl	Knapsack sprayer	3 times during each cocoa season
Metalm 72 Plus WP	Cuprous oxide + metalaxyl	Knapsack sprayer	3 times during each cocoa season
Insecticides			
Akatemaster	Bifenthrin	Knapsack sprayer	Twice during each cocoa season
Actara	Thiamethoxam	Knapsack sprayer	Twice during each cocoa season
Cocostar 210 EC	Bifenthrin + Pirimiphosmethyl	Knapsack sprayer	Twice during each cocoa season
Confidor 200SL	Imidacloprid	Knapsack sprayer	Twice during each cocoa season
Carbamult	Promecarb	Knapsack sprayer	Twice during each cocoa season

Source: COCOBOD, 2010.

The seasonal cocoa production figures along with the amounts of fertilizers and pesticides which have been used in Ghana from 2004 to 2010 are summarized in Table 2.3. The table indicates clearly that cocoa production has increased significantly in the last decade, but it has been at the expense of more pesticides and fertilizers. Data obtained from COCOBOD indicate that fourteen different kinds of insecticides and fungicides have been used for spraying farms since the start of the mass spraying exercise. Even with the limited data provided, the increase in pesticide usage per unit weight of cocoa over the period is evident. The same trend applies to fertilizer usage. Serious attention must be paid to these trends beyond the normal concerns with maximum residue limits (MRLs) which international traders focus on. The impact of these prodigious amounts of chemicals used in cocoa production on the environment as a whole can be determined through life-cycle analyses (Ntiamoah and Afrane, 2012).

Table 2.3: Seasonal Cocoa Production, Fertilizer and Insecticide Usage in Ghana, 2004-2010

Crop Season	Cocoa Production (10^6kg)	Total fertilizer Used (10^6kg)	Pesticide usage		Fertilizer Used per MT	Fungicide Used per MT
			Insecticide (Litres)	Fungicide (MT)		
2004/05	601.9	-	1023.6	1120.0	-	1.86
2005/06	740.4	-	745.0	759.4	-	1.03
2006/07	614.5	70.1	590.0	1120.0	0.11	1.83
2007/08	729.0	85.8	102.0	1290.0	0.08	1.77
2008/09	662.0	105.0	1760.0	1800.0	0.16	2.72
2009/10	362.0	130.0	2300.0	1997.7	0.20	3.16

Sources: ICCO (2010)

While non-chemical means of managing cocoa pests and diseases are widely recommended, the need for agro-chemicals to manage cocoa pests and diseases is unavoidable and will continue for years to come. However, the effects of continued exposure of users of pesticides, environmental risks, issues of pest resistance and possible hazards for consumers require a re-examination of the benefits of pesticide application and the associated risks.

Hence the introduction of Good Agricultural Practices (GAP) to considerably mitigate, if not eliminate, the problems associated with the excessive and unnecessary application of pesticides. High residue levels and tainting of the beans could lead to their rejection on the international market. Testing for residues is carried out following internationally agreed and validated methods (Moy and Wessel, 2000). Though some insecticide residues are sometimes found in the shells, they are hardly found in the nib which is used in chocolate manufacture (Moy and Wessel, 2000).

2.6 Pesticide Use in Ghana

Ghana is a developing country experiencing high economic growth rate in the West African Sub-region (Sibun, 2008). As an agriculture-based nation, the use of pesticides contributes much to the national development and public health programmes. Ever since the inception of pesticides, its use to protect crops from pests has significantly reduced losses and improved the yield of crops such as cereals, vegetables, fruits and other crops. Ghana thus, has known a continuous growth of pesticide usage, both in number of chemicals and quantities because of the expansion of area under cultivation for food, vegetables and cash crops (MOFA, 2003).

Pesticide application in Ghana is more concentrated in cocoa, oil palm, cereals, vegetables and the fruits sectors (Bateman, 2008). Although purchased physical inputs (agrochemicals, seeds and tools) represent less than 30 % of the total cost of crop production, the use of pesticides is becoming more widespread. For instance, between 1995 and 2000, about 21 different kinds of pesticides were imported into the country for agricultural purposes (MOFA, 2003). Its use has been embraced by local communities that are making a living from sale of vegetables and other cash crops. There is ample evidence that these products especially tomatoes are always sprayed and sold immediately after maturity for consumption. This inevitably puts a high risk on consumers who always get their supply directly from the farmers. In Ghana, it is estimated that 87% of farmers who use pesticides, apply any of the following or a combination of pyrethroids, organophosphates, carbamates, organochlorines on vegetables (Ntow, 2001).

Among the different types of pesticides known, organochlorine pesticides are the most popular and extensively used by farmers due to their cost effectiveness and broad spectrum activity. Lindane is widely used in Ghana on cocoa plantations, vegetable farms, and for the control of stem borers in maize. Endosulfan is popularly applied in cotton growing areas, vegetable farms, and coffee plantations in some parts of Ghana. Pesticides, particularly DDT and lindane which are no longer registered and are banned substances for any use in the country were once employed to control ectoparasites of farm animals and pets in Ghana (Ntow *et al*, 2006).

Pesticides which are mostly used to control foliar pests of pineapple in Ghana include chlorpyrifos, dimethoate, diazinon, cymethoate and fenitrothion while the fungicides maneb, carbendazim, imazil, whiles copper hydroxide are used for post-harvest treatments (Fianko *et al*, 2011). Lambda cyhalothrin, cypermethrin, dimethoate and endosulfan are also used by vegetable growers in tomato, pepper, okra, eggplant, cabbage and lettuce farms. Glyphosate, fluazifop-butyl, ametryne, diuron or bromacil are normally employed in land clearing (Cudjoe *et al*., 2002). Nonetheless, the most extensively used pesticides in the pepper, tomato, groundnut and beans cultivation are karate, cymbush, thiodine, diathane, lubillite and kocide (Yeboah *et al.*, 2004).

Dinham (1993) estimates that 87% of farmers in Ghana use chemical pesticides to control pests and diseases on vegetables and fruits. Ntow *et al*. (2006) gave the proportions of pesticides used popularly on vegetable farms as herbicides (44%), fungicides (23%) and insecticides (33%). In a study encompassing 30 organized farms and 110 kraals distributed throughout the 10 regions of Ghana, Awumbila and Bokuma (1994) found that 20 different pesticides were in use with the organochlorine lindane being the most widely distributed and used pesticides, accounting for 35 % of those applied on farms. Of the 20 pesticides, 45 % were organophosphorous, 30% were pyrethroids, 15 % were carbamates and 10 % were organochlorines.

Analysis of pesticide trade flow patterns, recorded by Ghana's Statistical Service, in 1993 indicated that a total of 3,854,126 kg of pesticides was imported with the following distribution: Insecticides (61 %), herbicides (24 %), Fungicides (9 %), Rodenticides (1 %) and others (5 %) (GSS, 1993). Besides, a survey conducted between 1992 and 1994 in the Ashanti, Brong Ahafo, Eastern and Western Regions of Ghana revealed that the most broadly used pesticides by farmers are: copper (II) hydroxide (29.0 %), mancozeb (11.0 %), fenitrothion (6.0 %), dimethoate (11.0 %), pirimiphos methyl (11.0 %), λ-cyhalothrin (22.0 %), and endosulfan (10.0 %) (Awumbila, 1996). Moreover, it was established that insecticides constituted about 67 % of pesticides employed by farmers while fungicides were about 30 % and herbicides and other pesticides types form 3 % of the total use (Awumbila, 1996).

On the other hand, it is on record that between 1995 and 2000, an average of 814 tons of pesticides was imported into the country annually, the greatest quantity being insecticides, 70%. The amount of pesticides imported into the country from 2002 to 2006 increased from 7763 metric tonnes to 27,886 metric tonnes (Table 2.4). Updated register of pesticides from the Environmental Protection Agency in Ghana in 2008 indicated that about 141 different types of pesticide products have been registered in the country under the Part II of the Environmental Protection Agency Act, 1994 (Act 490). These consist of insecticides (41.84%), fungicides (16.31%), herbicides (0.43%) and others (0.01%) (EPA, 2008).

Table 2.4: Annual imported pesticides into Ghana from 2002 to 2006

Class of Pesticides	Metric Tonnes				
	2002	2003	2004	2005	2006
Insecticides	4,130	5,974	8,418	10,006	12,728
Herbicides	2,186	2,939	4,578	8,566	10,718
Fungicides	1,079	1,249	2,402	2,205	3,195
Others	368	496	544	707	1,224
Total	7763	10,658	15,942	21,484	27,886

Source: Fianko *et al.* (2011)

2.7 Cocoa and Pesticide Residues

Pesticides have an important role in maintaining the yield and quality of cocoa during production, by controlling diseases, controlling insect pests and controlling unwanted weeds. However pesticides need to be applied in a safe and sustainable way that does not threaten the health of the operators using them, present risks to the environment, or result in illegal residues (Ntiamoah and Afrane, 2012).

All cocoa imported into the EU, Japan and elsewhere can be subject to analysis to detect the presence and quantity of chemical residues (and pathogenic microbiological organisms). Recent incidents in which the maximum permitted level (MRL) of certain pesticides has been exceeded have been the driving force in stimulating a re-assessment of food safety in Ghanaian cocoa. Beans can be rejected if it is found to contain: a) any banned active substances (the jargon for the active component of a pesticide) or b) chemicals that are not registered for use on cocoa, or c) residues of approved active substances that exceed the permitted maximum residue level (MRL). Rejected consignments may be destroyed, usually at the expense of the exporter. This has a financial cost that can be very significant to the individuals or companies concerned, but of much greater importance to Ghana is the potential damage to the reputation of the country's food exports (Ntiamoah and Afrane, 2012). For instance data from Japan on exceedance of MRLs has been collated in Ghana for the period 2008 to the first half of 2012. These data are summarized in Table 2.5.

During the 2008 crop season and the end of 2009 there were 85 exceedances reported. The majority were chlorpirifos, pirimiphos methy, endosulfan, fenvalerate, imidacloprid and permethrin, with 7, 22, 24, 15, 9 and 7 exceedances, respectively. In 2009, pirimiphos methyl and endosulfan were withdrawn from use and they disappeared from the figures reported by Japan. Permethrin use was actively discouraged in 2010, but 9 exceedances were reported that year, possibly as old stocks were used up. Since then only a single case has been reported. By the start of 2010, both fenvalerate and endosulfan had almost disappeared from the MRL exceedance data since 2009. This indicates the value of the cooperation between COCOBOD and EPA in withdrawing the registration for the two products. Since the start of 2010 the 67 MRL exceedances have mainly been fenvalerate (26), imidacloprid (29), thiamethoxan (2), permethrin (1), chlorprofam (1) and herbicide 2.4-D (1). Disturbingly, the values of the exceedances for imadacloprid have been as high as four times the Japanese MRL of 0.05 mg/kg. This is not a marginal problem, but a significantly excessive exceedance of the MRL. The 26 occurrences of fenvalerate are of particular concern as the pesticide is not registered for use on cocoa.

Examples of food safety problems that have occurred elsewhere have cost billions of dollars in lost trade. In very serious cases a problem can result in the loss of market access of an exporting country, as happened with milk from China after traces of melamine, an industrial chemical normally used to make plastics, were found in milk exported from the country. A second example, rather nearer to Ghana, occurred in 1997 when a ban was imposed on fish exports from Uganda to the European Union (EU) markets because the country's fish processors and exporters failed to meet the new EU Hygiene and processing quality standards for fish exports. Complete importation bans such as these are less common than more subtle effects that may only apply a sanction to a single production region if produce from that region is found by a buyer overseas to have an MRL exceedance (Ntiamoah and Afrane, 2012). Table 2.6 shows some of the health related effects of some chemical residues in chocolate when consumed (these are mainly based on animal studies).

Table 2.5: Japan MRL Exceedance data from Ghana MRL between 2008 and 2012

Year	Permethrin Chorpyrifos	Primihpos methyl	Endosulfan	Fevalerate	Imidacloprid	
MRL	0.05	0.05	0.1	0.01	0.05	0.05
2008	7	5	3	1	0	0
2009	0	17	21	14	9	7
2010	1	0	1	11	8	9
2011	0	0	0	13	15	1
2012*	0	0	0	2	6	0

(Ntiamoah and Afrane, 2012)

Table 2.6: Chemical residues in cocoa and their health effects

Chemical	Health effect on man
Methyl Bromide	Prostate cancer, kidney and liver effects, neurological effects
Pyrethrins	Carcinogenicity, reproductive and developmental toxicity, neurotoxicity
Hydrogen cyanide	acute toxicity, thyroid effects, nerve degeneration
Naled	Central nervous system disruption; headaches, nausea and diarrhea
Glyphosate	Effects on digestive system tissue, genetic damage, effects on reproduction, carcinogenicity.
Lindane	Irritation of nose and throat, lindane causes reproductive effects and also has effects on the liver, blood and cardiovascular system.

Source: Hamilton and Crossly (2004).

Regulation 396/2005/EC came into force on 1st September, 2008 and sets Maximum Residue Limits (MRLs) for pesticide residues in food and animal feed produced, or being imported into, the EU. MRLs were first published as Regulation 149/2008/EC in March 2008 in the form of Annexes to 396/2005/EC; these were updated before they came into force and continue to be subject to review. All cocoa beans imported into the EU must conform to the new Regulation, although temporary MRLs (tMRL) may apply to certain Active Ingredients (AIs) for a transitional period (QCC Annual Report, 2008).

Owusu – Ansah *et al.* (2010) identified that cocoa farmers use a wide range of pesticides to limit losses from pests and diseases in cocoa agriculture. Prominent among these are: Copper sulphate (a fungicide popular in the treatment of black pod infection; Benzene

Hexachloride (BHC) (an insecticide for the control of cocoa mirids); Aldrin/Dieldrin or Aldrex 40 (for the control of mealy bugs); Carbamate Unden, (an insecticide which is effective in controlling cocoa mirids in West African countries). Others are Kokotine, Apeco, Perenox, Arkotine, Didimac 25, Basudin and Brestan. Pesticide use is associated with risk and can be hazardous if not handled properly.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Field Survey

3.1.1 Profile of study area

The Sefwi Wiawso District is the seventh largest in the Western Region. It lies in the North eastern part of the region. The District cover an area of 2097 sq.km, South-East, representing 10 per cent of Land area of the Western Region with Sefwi Wiawso as the District Capital The District capital is 156km from Kumasi, the Ashanti Regional capital and 260km from Sekondi/ Takoradi, the Western Regional capital. The District is bordered to the west by Juabeso and Bia Districts and to the South by Aowin Suaman. It is also bordered by Bibiani – Ahwiaso – Bekwai to the coast and Wassa Amenfi West to the south – east. Its size is about 2,634 square kilometers (GhanaDistricts.com, 2011).

The District falls within the tropical rainforest zone with high temperatures throughout the year between 25^{o} C and 30^{o} C. Rainfall is between 1524mm – 1780mm per annum with double maxima peaks in June – July and September – October. Relative humidity is about 90 % at night and 75 % during the day. There are two long wet seasons separated by a short relatively dry season. The dry season is characterized by relatively low humidity. Agriculture is the major economic activity in the district in terms of employment and income generation, with about 80 % of the working population engaged in the cocoa sector which constitutes the main source of house hold income in the district.

3.1.2 Sampling methods, area and size

A multi stage sampling procedure which includes purposive and simple random sampling techniques were employed for the study. Sounders *et al*. (2009) asserted that purposive sampling technique is employed to enable the specific objectives of the study to be achieved. In this regard, purposive sampling method was use to select the Sefwi Wiawso district which produces about 10 % of cocoa in the western region as the study area. Subsequently, communities randomly selected in the District for the study were Amafie, Bosomoiso, Aseikrom and Apentanmadi. To avoid bias and improve the validity and reliability of the study, the simple random sampling method described by Cohen *et al*. (2000) was also used to select the 100 cocoa farmers and 12 agrochemical dealers.

3.1.3 Questionnaire design

The survey focused on examining farmer's pesticide use pattern and practices along the production chain as well as cataloguing the range of types of pesticides used in cocoa production in the District. For the farmers, the questionnaire covered areas that included bio-data, farming experience pesticide sources and types, pesticide knowledge, usage and application rates, pests and diseases of cocoa and food safety issues. For the agrochemical sellers emphasis was placed on bio-data, type of pesticide sold to farmers, registration status, training in pesticide handling, types of pesticides bought by farmers and level of farmers' knowledge in pesticide handling.

3.1.4 Questionnaire administration

The questionnaire was pre-tested on a small sample of respondents in three cocoa producing communities namely: Ntrentrenso, Nsawora and Futa in the district to help fine tune the questions and improve on the skills of the questionnaire administrators in order to ensure a reliable and efficient data collection. Personal interviews and administration of semi-structured questionnaires were used to obtain information from farmers. For the agrochemical sellers, however, they were given the questions to answer because they could read and understand them.

3.2 Laboratory Experiment

3.2.1 Experimental sites

The laboratory experiments were carried out at the laboratories of the Ghana Atomic Energy Commission and the Pesticide Residue Laboratory of the Ghana Standard Authority, in Accra.

3.2.2 Source of cocoa beans

Dried cocoa beans of merchandize quality were obtained from LBCs operating in the four study areas; Bosomoiso, Asiekrom, Apentemadi and Amafie in the Sefwi Wiawso District.

3.2.3 Cocoa sample preparations

The cocoa beans were divided into two lots. One lot was roasted in an oven at 120-150 ^{o}C for 30 min while the other lot was left unroasted. Each lot was milled separately, packed into zip bags, labeled and sent to Ghana Atomic Energy Commission laboratory for analysis.

3.2.4 Extraction of pesticide residue from cocoa beans

The Quick, Easy, Cheap, Effective, Rugged and Safe (QUECHERS) Mini-Multi residue method (Anastassiades *et al.*, 2003) used for analyzing pesticide residue in low–fat products was employed. About 10 g of homogenous and representative sample was weighed into a conical flask. About10 ml of distilled water was added to make into a paste. The paste was then allowed to stand for 10 min before 5 g of Na_2SO_4 was added and shaken. 20 ml of acetonitrile was added to homogenize it for 2 min. To improve extraction efficiency and recoveries the samples with the solvent were placed in a sonicator for 30 min and thereafter filtered with a Buckner funnel.

The procedure was repeated for both roasted and unroasted beans and all filtrate (organic layers) were pulled or added together. The non-roasted beans filtrate (organic layers) was concentrated to near dryness using rotary evaporator at 60 ^{o}C to get rid of any acetonitrile.

3.2.5 Clean-up steps

In order to improve and optimize the extraction process there was the need for a clean-up step to ensure the removal of matrix compounds that could be present in the cocoa beans which may interfere in the GC-MS analysis. Using an extraction vessel, the column was packed with 3g of silica gel and topped up with 3 g of alumina. In order to remove water and induce phase separation, 0.5 g of Na_2SO_4 was added into the column. The whole column set up was conditioned with 10 ml of Hexane to moist the adsorbent so that it will not absorb the solvents in the sample.

For the purpose of Quality Assurance, 20 ml of hexane was added to the concentrate (sample) in the conical flask but in 2 steps of 10 ml each to dissolve well. It was then eluted onto the column. Subsequently, 10 ml of hexane was poured into the round Bottom flask **(**RBF**)** to rinse it and also to take care of any residue that could be left in the RBF and eluted onto the column again. Elute was collected into a round bottom flask.

The elute was concentrated at 60 ^{0}C using a rotary evaporator to get rid of all the hexane. The concentrates were picked in 2 Ml of ethyl acetate into GC vials. The weights of the vials were taken for quality assurance purposes before loading onto the GC for Chromatographic separation.

3.3 Parameters Studied

Multi-pesticides chemical constituents such as synthetic pyrethroids, oganochlorines and organophosphates were measured.

3.4 Data Analysis

The data collected was subjected to descriptive analysis with the use of bar charts and frequency distribution tables. Statistical software's including SPSS version 16 and excel sheets were used to produce graphs and frequency distribution tables with all the data pre-coded before the analysis. Statistical tests such as mode; mean; t-tests and chi-square as well as an analysis of variance (ANOVA with means separation of Lsd at 5 % probability level); were also employed to analyze the questionnaires.

CHAPTER FOUR

4.0 RESULTS

4.1 Socio – Demographic Characteristics of Farmers

A total of 100 respondents were selected out of which 84 of the questionnaires were analyzed. This was as a result of errors and inconsistencies identified during editing and entry of data.

4.1.1 Gender dynamics of farmers

The results showed that about 68 % of the farmers were males whiles 32 % were females (Figure 4.1). When the gender dynamics were determined in relation to the farming communities surveyed, it was observed that all, except Asiekrom, had a male dominance (Table 4.1). At Asiekrom, the female farmers dominated with 57.1 %. In the three other communities, the male dominance was generally above 60 % (Apentemadu - 77.3 %, Mafie -75.9 % and Bosomioso - 63.2 %).

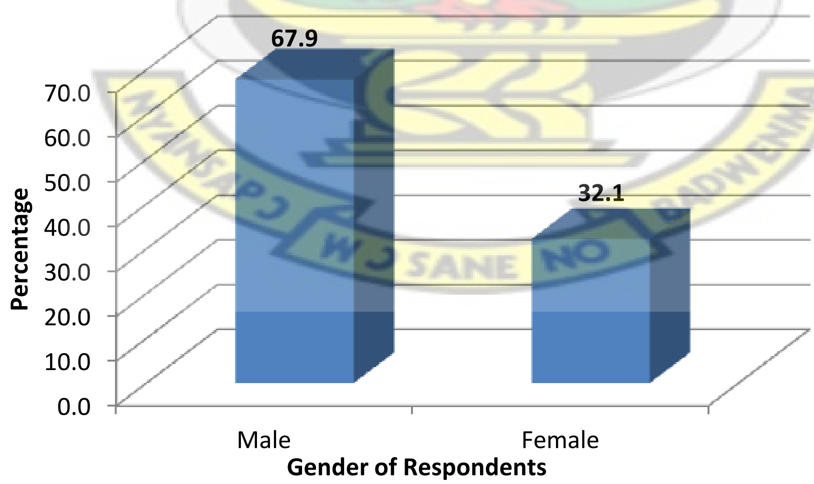


Figure 4.1: Gender of farmers

Table 4.1 Cross tabulation between gender of farmers and farming communities

		Area				Total
		Amafie	Apentemadu	Asiekrom	Bosomioso	
Gender of respondents	Male Count	22	17	6	12	57
	% within Gender of Respondents	38.6%	29.8%	10.5%	21.1%	100.0%
	%within Area	75.9%	77.3%	42.9%	63.2%	67.9%
	% of Total	26.2%	20.2%	7.1%	14.3%	67.9%
	Female Count	7	5	8	7	27
	% within Gender of Respondents	25.9%	18.5%	29.6%	25.9%	100.0%
	%within Area	24.1%	22.7%	57.1%	36.8%	32.1%
	% of Total	8.3%	6.0%	9.5%	8.3%	32.1%
Total	Count	29	22	14	19	84
	% within Gender of Respondents	34.5%	26.2%	16.7%	22.6%	100.0%
	%within Area	100.0%	100.0%	100.0%	100.0%	100.0%
	% of Total	34.5%	26.2%	16.7%	22.6%	100.0%

4.1.2 Age of farmers

The average age of the farmers was 47 years. The age distribution of the farmers is as follows: 1.2% of the farmers were between 15 and 20 years; 7.1% of the farmers were 21 to 30 years; 36.9% of farmers were 31 to 40 years; 4.8% of the farmers were 41 to 50 years and 50% of the farmers were over 60 years (Table 4.2).

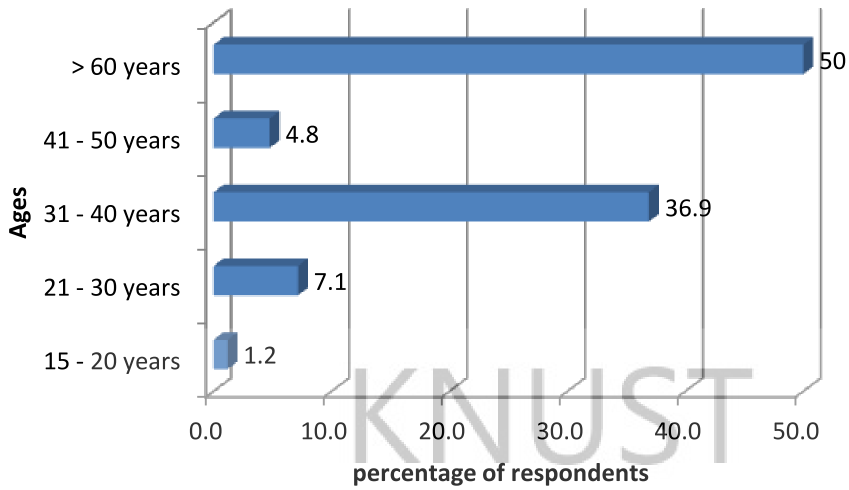


Figure 4.2: Age of farmers

4.1.3 Educational background of farmers

About 17.9 % of the farmers have not obtained any form of formal education. About 19 % of the farmers have primary education. A majority of 58.3 % have obtained JHS/MSLC. About 1.2 % of the farmers have completed SHS or Vocational or Technical school and 3.6 % of the farmers have completed Tertiary education.

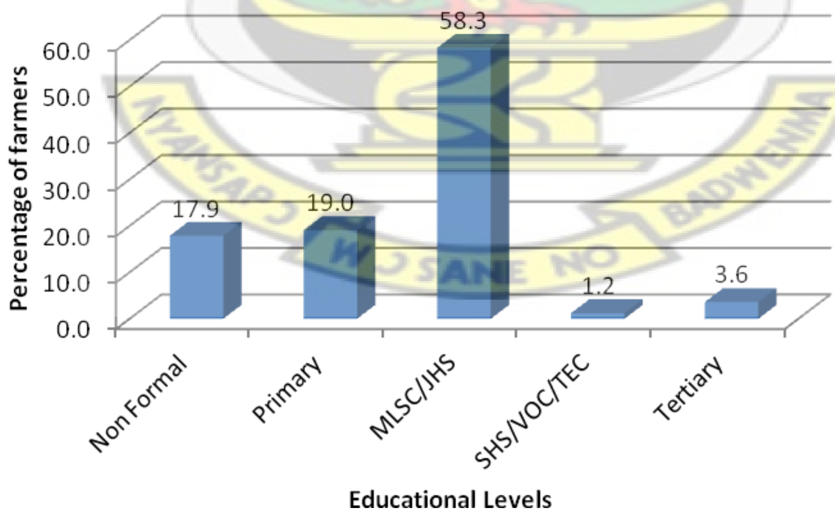


Figure 4.3: Educational background of farmers

4.1.4 Number of years of farming

About 11 % of the farmers of the farmers interviewed responded that they have farmed for about 20 years. Whilst about 10 % of them also said they have farmed for 30 years. About 91.7 % of the farmers indicated that they cultivated the farms themselves and the remaining 8.3 % of the farmers inherited the farm. No respondent was identified to have purchased or leased the farm.

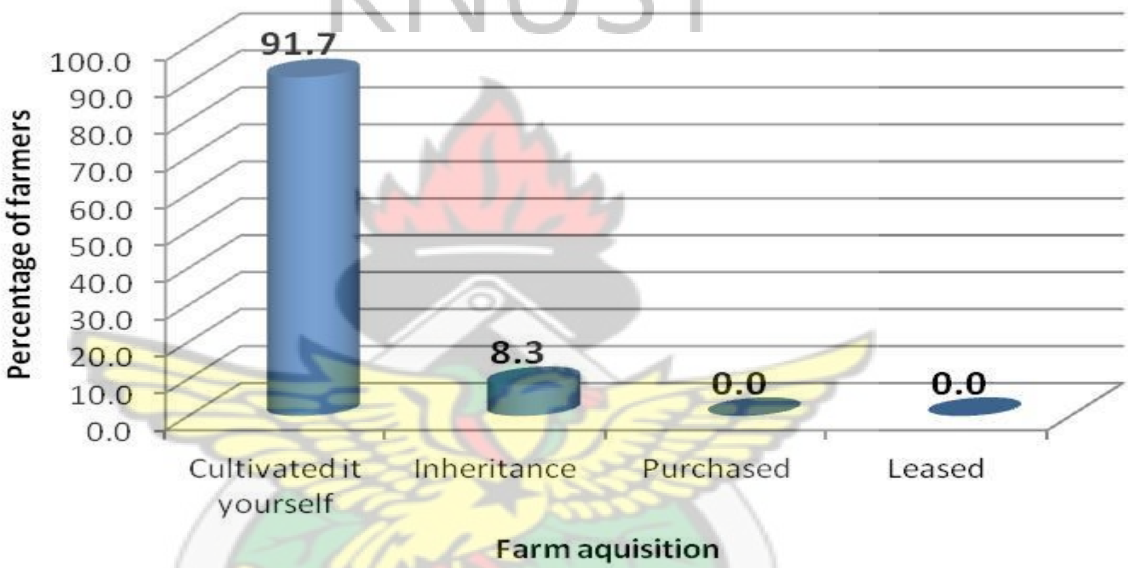


Figure 4.4: Acquisition of cocoa farms by respondents

4.2 Farmers' Spraying Regime, Practices and Pesticide Use Patterns

4.2.1 Farmers pest control practices

All the farmers indicated that they encounted pests on their farms and about 99 % of them used of chemicals to control the pests (Figure 4.5). The remaining 1 % of farmers used traps to control the pests.

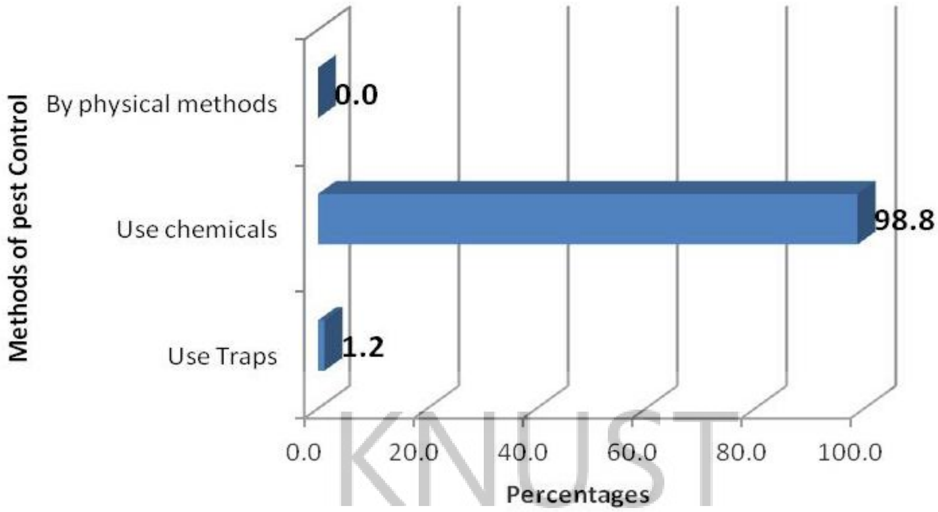


Figure 4.5: Farmers practices for the control of cocoa farm pests

4.2.2 Farmers Knowledge and Use of Pesticides

Almost all the farmers (98.8 %) indicated that they had some knowledge about pesticides and had themselves used these pesticides to control the cocoa pests (Table 4.2). On the contrary, 1.2 % of the farmers had no knowledge of pests and therefore had never used pesticides to control these pests.

Table 4.2: Farmers' knowledge and use of pesticides

	Frequency	Percentage (%)
Yes	83	98.8
No	1	1.2
Total	84	100

4.2.3 Farmers knowledge of active ingredients in relation to acquisition of pesticides

About 29.8 % of the farmers stated that they know the active ingredients in the pesticides they apply and use whilst majority of 70.2 % of them admitted that they had no knowledge of the active ingredients in the pesticides they used (Figure 4.6). However, regarding the toxicity of pesticides they used, about 98 % of the farmers indicated that they have some knowledge about pesticides toxicity whilst the remaining 2.4 % of them were unaware.

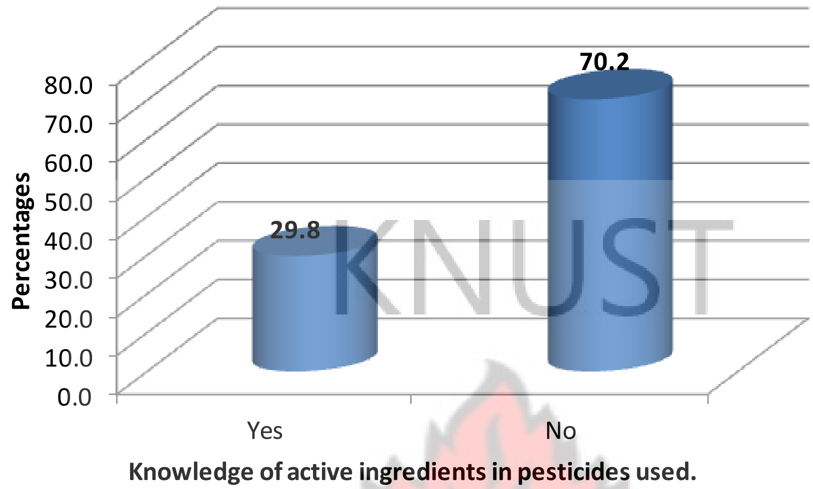


Figure 4.6: Knowledge of active ingredients in the pesticides used

As regards the purchase of the pesticides, majority of the farmers (91.7 %) indicated that they acquired their pesticides from certified agrochemical sellers. A few of the farmers (4.8 %) reported that they acquired their pesticides from vehicles that came on market days (Figure 4.7). Only 2.4 % of the farmers stated that they purchased their pesticides from roadside sellers. The remaining 1.2 % of the farmers stated that they had their pesticides from families, friends and agricultural extension officers. Some of the pesticides commonly used by farmers were Akate master (Bifenthrin), Sidalco(Dimethomorph + Chloro), Wuxal Ascofol, Confidor 200SL (Imidacloprid), Actara 25 WG (Thiamethoxam), and Defender (Glyphosate 360 g/L).

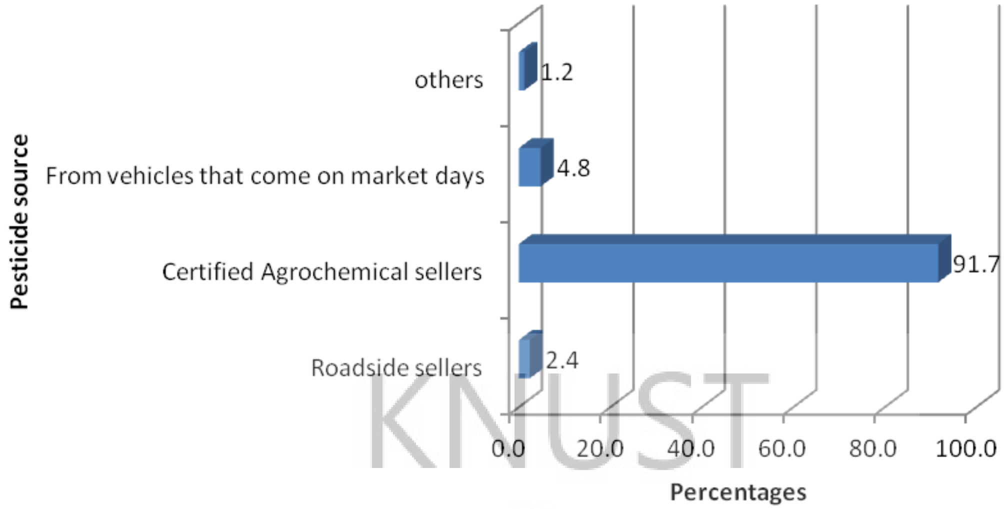


Figure 4.7: Source of acquisition of pesticides

4.2.4 Farmers pesticides application strategies

Majority of the farmers (90 %) indicated that they used only one pesticide at a time to spray against pests and diseases on their cocoa farms. However, about 10 % of the farmers stated that they used a combination of two pesticides to spray against insects and diseases on their cocoa farms (Figure 4.8). None of the farmers used a combination of three pesticides due to a reduction in the potency of the formulated pesticide and high cost of purchase.

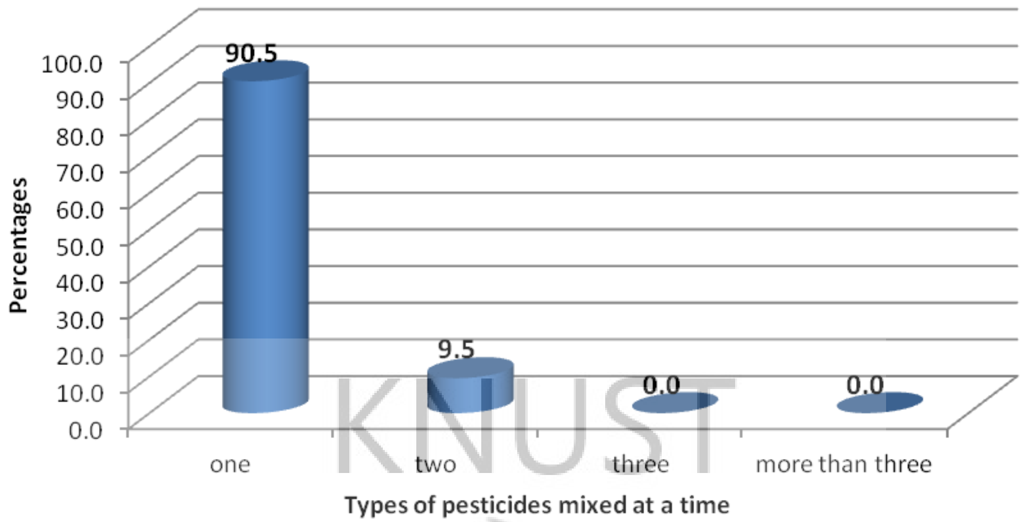


Figure 4.8: Number of pesticides used at a time for spraying

4.2.5 Farmers knowledge of measurements, calibration and sprayer types

Majority of the farmers (72.6 %) used the lid of the pesticide container to measure the quantity of pesticides required for spraying (Table 4.3). An appreciable proportion of farmers (26.2 %) used the lid of the spraying equipment whilst only 1.2 % of the farmers used the pesticide measuring cups recommended for use by the manufacturers.

Table 4.3: Instruments used for the measurement of required quantity of pesticides

	Frequency	Percentage (%)
Lid of pesticide container	61	72.6
Lid of spraying equipment	22	26.2
Pesticide Measuring cup	1	1.2
Total	84	100

The tables below show the type of insecticides and fungicides used by framers and their application rates. About 25 % of the respondents used more than the recommended rate of Akati Master, 6 % of farmer used over doses of Confidor and 5 % used over dose of

Actara. Reasons given for the quantity used included the extent of disease infection of cocoa trees and pest attack.

Table 4.4: Quantity of insecticides used per tank

Insecticide	Recommended rate/11L Knapsack by CRIG	Parentage of farmers		
		% Below	% Recommended rate	% Above
Confodor(*Imidacloprid)*	30	3	91	6
Akate Master(*Bifenthrin)*	100	3	72	25
Actara(*Thiomethoxam)*	17	2	93	5

With regards to fungicides used by farmers in the district, the research revealed that none of the farmers interviewed used Kocide 2000 and Metalm 75 WP even though they are approved by CRIG to be used on cocoa. For all the fungicides few farmers used dosages above the recommended rates.

Table 4.5: Fungicides Used per tank

Fungicides	Recommended rate/11L Knapsack by CRIG	Parentage of farmers.		
		% Below	% Recommended rate	% Above
Ridomil Gold (Cuprous Oxide and Mefonoxam)	50g	3	96	1
Funguran-OH (Cupric Hydroxide)	100g	8	89	3
Metalm 75 WP	50g	0	0	0
Fungikill 50 WP	75g	2	97	1
Kocide 2000(Cupric Hydroxide)	100g	0	0	0
Nordox 75 WG(Cuprous Oxide)	75g	4	91	5
Champion(Cupric Hydroxide)	100g	0	98	2

About 47.6 % of the farmers said that they acquired the knowledge of measuring the rate of pesticides from extension officers. About 38.1 % did self-learning. About 10.7% depended on information from labourers, media (radio), the chief farmers and through co-operative societies. Only about 3.6 % of the farmers acquired the knowledge through training by CSSVD – CU staff (Figure 4.9). The farmers reported that the appropriate times to apply pesticides were when pests had been detected and cocoa trees were affected. All the farmers reported that spraying in the morning gave the best results.

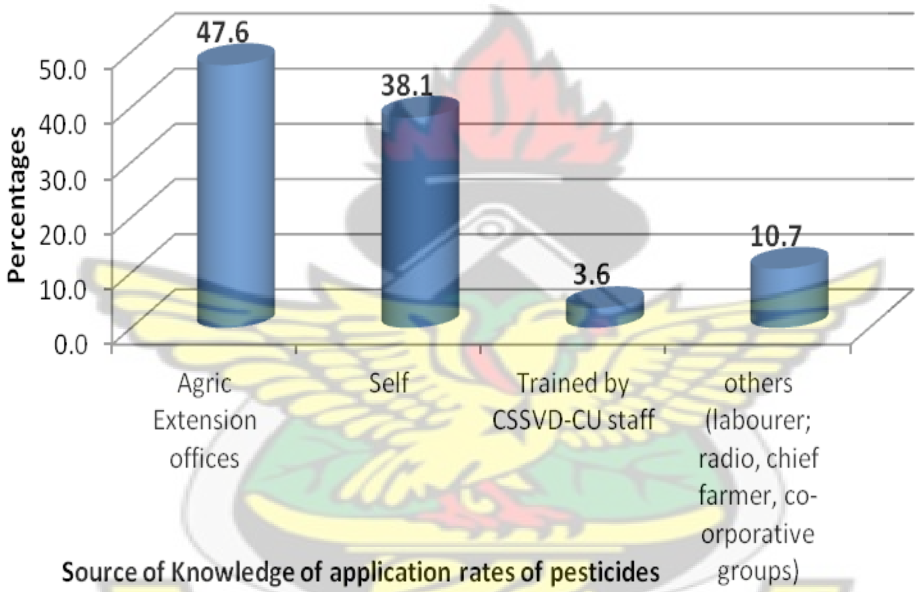


Figure 4.9: Farmers' knowledge acquisition on measuring rate of pesticides

On spraying equipment, majority of the farmers (98.8 %) reported that they used the motorized sprayer for spraying their crops whilst 1.2 % of the farmers used the Knapsack sprayer).

Table 4.6: Sprayer types used by cocoa farmers

	Frequency	Percentage (%)
Motorized/motor blow	83	98.8
Knapsack sprayer	1	1.2
Total	84	100

4.2.6 Pesticides selection by farmers

More than half (53.6 %) of the farmers indicated that effective control was their reason for selecting a particular type of pesticide although 29.8 % of the farmers reported that the availability of the pesticides as the main consideration factor for choosing a pesticide (Figure 4.10). The remaining 15.5 % of the farmers indicated that improving the yield of cocoa as the reason for selecting a particular pesticide. Only 1.2 % of the farmers indicated the price as their reason for choosing a particular type of pesticide.

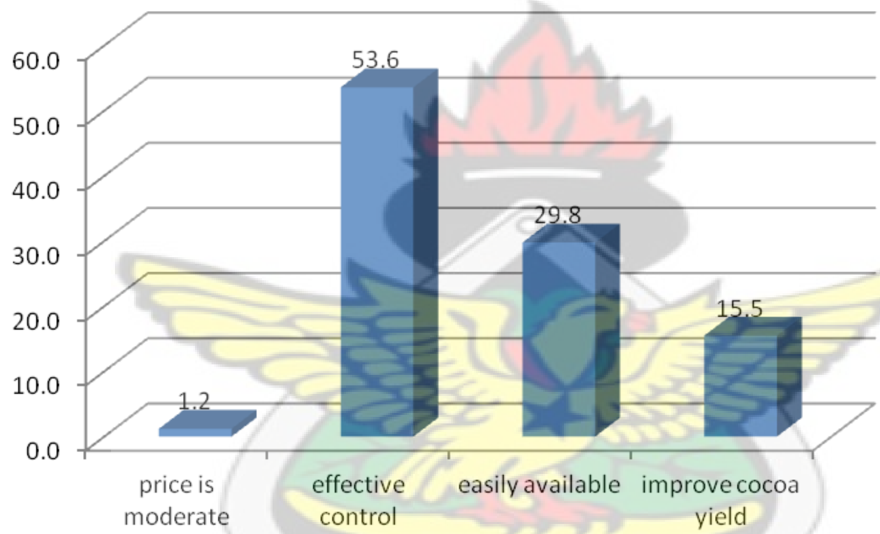


Figure 4.10: Reasons for selecting type of pesticide

4.2.7 Pesticides effectiveness and pesticide pre-harvest interval

Majority of farmers indicated that the pesticides they used were very effective whiles about 14 % said they were moderately effective with a few (2 %) of the farmers stating that the pesticides were not effective (Figure 4.11).

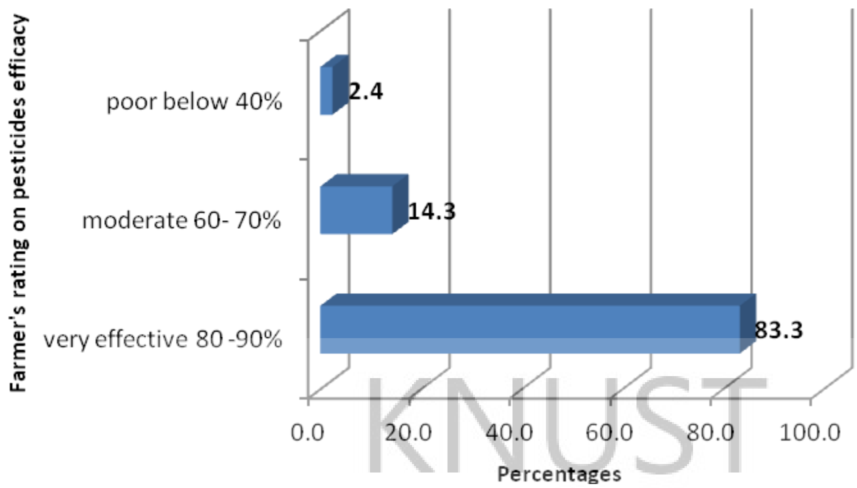


Figure 4.11: Effectiveness of pesticides used by farmers

In terms of pre-harvest waiting period of the pesticides, only a small number of farmers (2.4 %) waited for more than 4 weeks. Majority of the farmers (63.1 %) waited for an average of 2 weeks (range of 1- 3 weeks) whiles about 29 % waited for 3 to 4 weeks. On the other hand, about 6 % of the farmers do not wait for even 1 week after spraying to start harvesting (Figure 4.12).

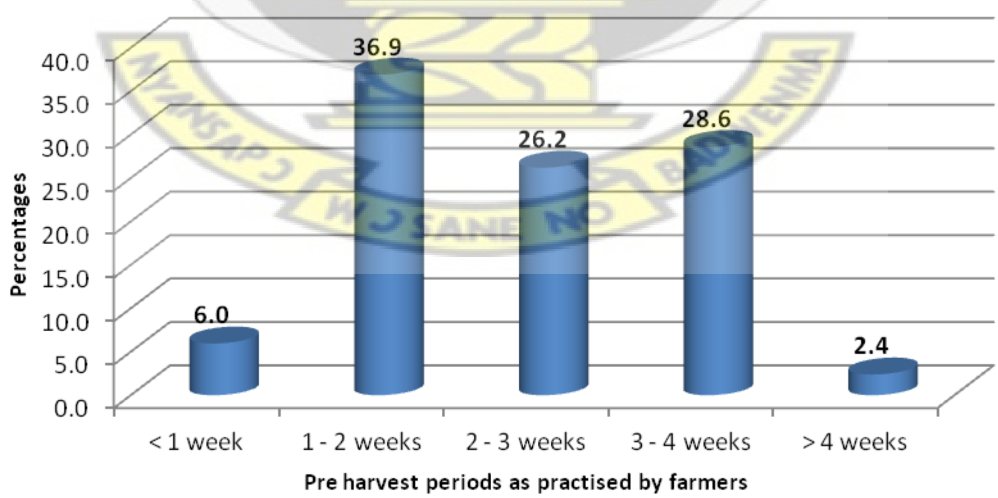


Figure 4.12: Pesticide Pre harvest intervals experienced by farmers

4.2.8 Farmers' pesticide residue awareness and source of information

About 85.7 % of the farmers responded that they knew that pesticide residue had become a food safety issue whilst 14.3 % of the farmers reported that they were not aware.

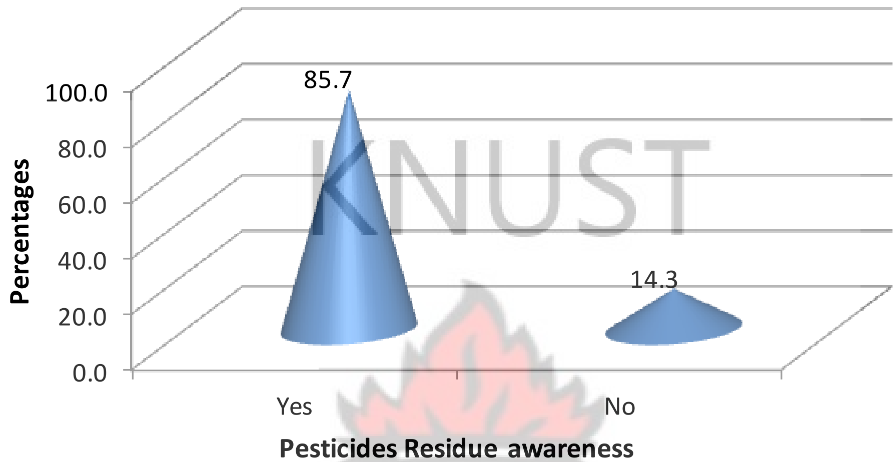


Figure 4.13: Pesticide residue as a food safety issue

For the farmers who were aware, 87.5 % of them stated that they learnt it from the media such as, the radio and television, whiles 9.7 % got to know from extension officers. Only about 3 % were informed by the chief farmers and co-operative societies (Figure 4.14).

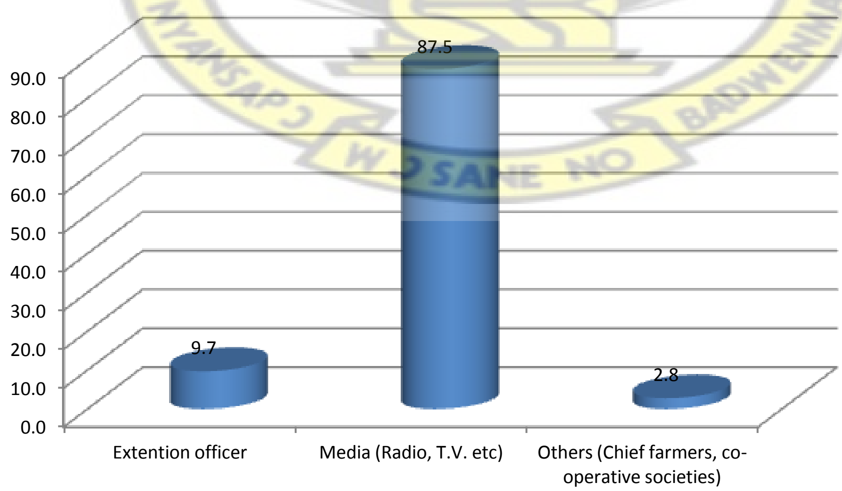


Figure 4.14: Sources of farmers' information on pesticide residue awareness

4.3 Relationship between Farmer's Pesticides Usage Patterns and the Pesticides Residue Analysis of Cocoa Samples

The Table 4.7 shows the results of a Chi square test carried out to find out whether farmers' pesticides use patterns and spraying regimes had any influence on the pesticide residue levels in the analyzed cocoa beans samples from the Sefwi Wiawso district.

Table 4.7: Chi square test

	Value	Df	Asymptotic Significance
Pearson Chi-Square	13.2145[a]	8	.011
Likelihood Ratio	16.896	8	.011
Number of Valid Cases	84		

a. 32 cells (100.0%) have expected count less than 5. The minimum expected count is .78.

The Chi square test of 13.2145 (p=.011) at 5 % level of significance showed that there is a significant relationship between the farmers' pesticides use patterns and the pesticide residue level in cocoa beans from the Sefwi Wiawso cocoa district.

Table 4.8: Symmetric measures of farmers' spraying regime; practices and pesticide use patterns

		Value	Approx. Significance
Nominal by Nominal	Phi	.592	.005
	Cramer's V	.592	.005
Number of Valid cases	84		

The symmetric measures of Phi and Cramer's V were used to measure the strength of association between the farmers' spraying regime practices and pesticide use patterns and the pesticide residue level in cocoa beans from the Sefwi Wiawso cocoa district. Both Phi and Cramer's V value of .592, p=0.005 shows that there is a strong association between the farmers' spraying regime practices and pesticide use patterns and the pesticide residue level in cocoa beans from the Sefwi Wiawso cocoa district and they are also statistically significant at 1 %. This strong association is estimated to about 59.2 %.

4.4 Organochlorines

Active ingredients of organochlorines detected in cocoa samples were p,p'-DDE, Gaamma chlordane and Alpha-endosulfan which are all unapproved to be used on cocoa.

Table 4.9: Organochlorines detected in cocoa samples

Society name	Society ID	Active Ingredient	Concnetration mg/kg	MRL EU	MRL Japan
Amafie	AMRT	p,p'-DDE	Less than 0.01	No MRL Set	No MRL Set
All Societies	ALRW	Gamma Chlordane	Less than0.01	No MRL Set	No MRL Set
Bosomois	BORW	Gamma Chlordane	0.02	No MRL Set	No MRL Set
Bosomois	BORW	Alpha-endosulfan	0.2	0.1	0.1
Bosomoiso	BORT	Alpha-endosulfan	0.0	0.1	0.1

4.5 Synthetic Pyrethroids

From the pesticides residue analysis, synthetic pyrethriods that were present in the cocoa samples were all ethrin, Bifenthrin, Fenpropathrin, Lamba-cyhalothrin, Permethrin, Cyfluthrin, Cypermethrin and Deltamethrin. Out of these only Bifenthrin has been approved to be used on cocoa.

Table 4.10: Synthetic pyrethroids Decteted in cocoa samples

Society Name	Society ID	Active Ingredient	Concenetration mg/kg	MRL EU	MRL Japan
All Societies	ALRT	Allethrin	Less than 0.1	No MRL Set	No MRL Set
Amafie (Roasted Beans)	AMRT	Allethrin	Less than 0.1	No MRL Set	No MRL Set
Amafie (Raw Beans)	AMRW	Allethrin	Less than 0.1	No MRL Set	No MRL Set
Bosomoiso	BORT	Allethrin	Less than 0.1	No MRL Set	No MRL Set
Apenemadi	APRW	Allethrin	Less than 0.1	No MRL Set	No MRL Set
All Societies	ALRT	Bifenthrin	Less than 0.1	0.1	0.1
Amafie	AMRT	Bifenthrin	0.14	0.1	0.1
Bosomoiso	BORT	Bifenthrin	Less than 0.1	0.1	0.1
Bosomoiso	BORW	Bifenthrin	Less than 0.1	0.1	0.1
Amafie	AMRT	Fenpropathrin	Less than 0.1	No MRL Set	No MRL Set
Bosomoiso	BORT	Fenpropathrin	Less than 0.1	No MRL Set	No MRL Set
Bosomoiso	BORW	Fenpropathrin	Less than 0.1	No MRL Set	No MRL Set
Amafie	AMRT	Lambda-Cyhalothrin	Less than 0.1	No MRL Set	No MRL Set
Bosomoiso	BORT	Lambda-Cyhalothrin	Less than 0.1	No MRL Set	No MRL Set
All Societies	ALRT	Permethrin	0.07	0.1	0.05
Amafie	AMRT	Permethrin	0.06	0.1	0.05
Bosomoiso	BORT	Permethrin	0.06	0.1	0.05
Amafie	AMRT	Cyfluthrin	Less than 0.1	No MRL Set	No MRL Set
Bosomoiso	BORT	Cyfluthrin	Less than 0.1	No MRL Set	No MRL Set
Amafie	AMRT	Cypermethrin	Less than 0.1	No MRL Set	No MRL Set
Amafie	AMRT	Deltamethrin	Less than 0.1	No MRL Set	No MRL Set
Asiekrom	ASRW	Deltamethrin	Less than 0.1	No MRL Set	No MRL Set

4.6 Organophosphates

Out of the thirteen (13) Organophosphates that were tested for, only Methamidophos was not detected in the cocoa samples. The detected ones are as follows; Chlorfenvinphos, Paeathion, Chlorpyrifos, Malathion, Fenitrothion, Pirimiphos-methyl, Fenofos, Diazion, Dimethoate, Phorate, Ethoporaphos and Profenofos. Apart from Diazion, all the remaining 11 detected were active ingredients of unapproved pesticides to be used on cocoa.

Table 4.11: Organophosphates detected in cocoa samples

Society Name	Society ID	Active Ingredient	Concentration mg/kg	MRL EU	MRL Japan
Amafie	AMRT	Profenofos	0.01	0.1	0.01
Amafie	AMRT	Ethoprophos	0.01	No MRL Set	No MRL Set
Bosomoiso	BORT	Ethoprophos	0.01	No MRL Set	No MRL Set
All Societies	ALRT	Phorate	0.01	No MRL Set	No MRL Set
Bosomoiso	BORT	Phorate	0.01	No MRL Set	No MRL Set
Apenemadi	APRT	Dimethoate	0.01	No MRL Set	No MRL Set
All Societies	ALRW	Dimethoate	0.01	No MRL Set	No MRL Set
Amafie	AMRT	Diazinon	0.01	No MRL Set	No MRL Set
Bosomoiso	BORT	Diazinon	0.01	No MRL Set	No MRL Set
Amafie	AMRT	Fenofos	0.01	0.1	0.01
Amafie	AMRT	Pirimiphos-methyl	0.01	No MRL Set	No MRL Set
Bosomoiso	BORT	Pirimiphos-methyl	0.01	No MRL Set	No MRL Set
Bosomoiso	BORT	Fenitrothion	0.01	0.2	0.1
Amafie	AMRT	Fenitrothion	0.01	-	-
All Societies	ALRW	Fenitrothion	0.06	0.2	0.1
Amafie	AMRT	Malathion	0.01	No MRL Set	No MRL Set
Bosomoiso	BORT	Malathion	0.01	No MRL Set	No MRL Set
All Societies	ALRT	Chlorpyrifos	0.015	0.1	0.05
Amafie	AMRT	Chlorpyrifos	0.045	0.1	0.05
Apenemadi	APRT	Chlorpyrifos	0.01	0.1	0.05
Aseikrom	ASRT	Chlorpyrifos	0.01	0.1	0.05
Bosomoiso	BORT	Chlorpyrifos	0.01	0.1	0.05
All Societies	ALRW	Chlorpyrifos	0.27	0.1	0.05
Amafie (Raw)	AMRW	Chlorpyrifos	0.01	0.1	0.05
Apenemadi(Raw)	APRW	Chlorpyrifos	0.02	0.1	0.05
Aseikrom(Raw)	ASRW	Chlorpyrifos	0.01	0.1	0.05
Bosomoiso(Raw)	BORW	Chlorpyrifos	0.14	0.1	0.05
Amafie	AMRT	Parathion	0.01	No MRL Set	No MRL Set
Amafie	AMRT	Chlorfenvinphos	0.01	No MRL Set	No MRL Set
Bosomois	BORT	Chlorfenvinphos	0.01	No MRL Set	No MRL Set

CHAPTER FIVE

5.0 DISCUSSION

5.1 Socio – Demographic Characteristics of Farmers

About 67.9 % of the farmers were males and the remaining 32.1 % were females. The following communities had male-dominated farmers: Amafie, Apentemadu and Bosomioso. Only Asiekrom had female-dominated farmers. This finding clearly indicates that cocoa farming is dominated by males. The finding is consistent with studies by Appiah (2004) and Abankwah *et al.* (2010) that cocoa farming in Ghana is male-dominated. The estimated average age of the farmers was 47 years which implies that more middle-aged farmers are into cocoa farming and this situation connotes a good future for the industry. The greater population of farmers with formal education (85 %) as revealed in this study suggests that the farming community could read and understand production information given them especially their ability to understand labels and instructions on pesticides.

With regards to the experience in cocoa farming, majority of the farmers have been farming cocoa for over 10 years, an indication that they were knowledgeable in the farming business. Their long experience was also related to the fact that most of them (92 %) owned their lands and therefore had the privilege of continuous farming.

5.2 Farmers' Spraying Regime and Practices and Pesticide Use Patterns

Insect pests and diseases particularly capsids, mirids and black pod disease were mentioned by the respondents as a major production constraint. The majority (98.8 %) of the farmers used chemical control means to control pests on their farms. This was an indication that farmers used pesticides intensively in the controlling of pests on their cocoa farms and this is in agreement with Bateman (2008) that pesticide application in Ghana is more concentrated in cocoa, oil palm, cereals, vegetables and the fruits sectors. The remaining 1.2 % of the farmers said they used traps. The physical methods were not used as a result of the tiring nature of the activity and also because they were not effective as only a few pests could be destroyed. Traps were however used for rodent control.

In view of their education background, majority of the farmers (95 %) were knowledgeable about pesticides and had personally sprayed their farms. This confirmed the report by Adjinah and Opoku (2010) that most farmers preferred to spray their own farms and therefore did not patronize the CODAPEC programme which offered mass spraying of the coca farms. The knowledge of the farmers on pesticides was reflected in their source of acquisition of pesticides which were the certified Agrochemical sellers who had been licensed by the Environmental Protection Authority (EPA) and the Ghana Agricultural Inputs Dealers Association (GAIDA). These agrochemical sellers according to Adu – Acheampong *et al*. (2010) educate farmers in relation to measuring pesticides for use during purchase. Consequently, COCOBOD in its future interventions to reduce pesticide residues in cocoa production could target the education of Agrochemical sellers as change agents.

Most of the farmers preferred to purchase some particular pesticides and the reason provided by these farmers was in agreement with the reasons expressed by Moy and Wessel (2000) who indicated that particular pesticides were chosen by farmers due to their ability reduce food losses and increase profits. The choice of chemical was however guided by their knowledge about the toxicity attributes of the pesticides and further underscored their understanding of pesticide labels and precautionary measures on use. The farmers however have no knowledge of the active ingredients in the pesticides and this confirms the report by Bateman (2010) that farmers usually show less interest in the technicalities associated with the active ingredients in the pesticides.

As regards insecticides usage by farmers, about 25 % of the farmers used more than the recommended rate of Akati Master, whiles smaller groups used overdoses of Confidor (6 %) and Actara (5 %). This implied that farmers did not adhere strictly to application rates recommended by research and gave reasons such as the extent of infection of cocoa trees and the potency of the pesticide for the quantities of pesticides used for spraying.

This study revealed that a good percentage of farmers (54.8 %) benefited from the CODAPEC mass spraying exercise which corroborates the findings of Adu-Acheampong *et al.* (2014) who reported that 58 % of farmers received mass spraying and that the remaining (45.2 %) of the farmers did not benefit from the CODAPEC programme due to the various challenges that affected the programme (Adjinah and Opoku, 2010).

Majority of the farmers (85.7 %) indicated that they were aware that pesticide residue had become a food safety issue and indicated their source of information to be the media. This suggests that the media could also be used to disseminate relevant information to farmers since majority rely on the media for information. Similar sentiments have also been expressed in other studies (Moy and Wessel, 2000; Hamilton and Crossly, 2004; Yeboah *et al.*, 2004; Bateman, 2010).

Regarding farmers' source of information on pesticides application rates, some farmers (47.6 %) acquired the knowledge and skill of measuring the pesticides rates from extension officers. However, About 38 % of farmers learnt it by themselves. This fact of self-tuition should be a cause for concern since it could be a contributing factor to the detection of pesticide residues higher than recommended levels in cocoa analyzed samples.

5.3 Range of Pesticides Used By Farmers for Cocoa Production

The study revealed that a wide range of pesticides were being used by the farmers including Akate Master (*Bifenthrin*) and Confidor 200SL (*Imidacloprid*). The realization of Bifenthrin, active ingredient in Akate Master, in cocoa samples from all the societies and the fact that the levels exceeded (0.14 mg/kg) the Japan and the EU MRL of 0.1 mg/kg should be a concern to the industry in Ghana. Similarly, cases of Imidacloprid MRL exceedances in Ghana's cocoa by Japan over years have been documented by Ntiamoah and Afrane (2012).

More disturbing is the revealing through pesticide analysis of unapproved pesticides such as Permethrin, Profenofos, Fenofos and Chlorpyrifos in the cocoa samples, an indication that some farmers still used unapproved pesticides on their cocoa farms. For instance, permethrin, a synthetic pyrethriod, was found to have a concentration of 0.07 mg/kg which exceeded Japan MRL of 0.05 mg/kg. Fenofos (0.02 mg/kg) was also found to exceed the Japan MRL (0.01 ml/kg) but was within the EU MRL (0.1 mg/kg) whiles Chlorpyrifos (0.14 mg/kg) also exceeded both Japan (0.05 mg/kg) and EU (0.1 mg/kg) MRLs. This implied that the improper use of pesticides by some farmers contributed significantly to the presence of high pesticide residues detected in the cocoa samples analyzed. There was therefore the need for increased and extensive farmer education in this regard.

5.4 Effect of Roasting on the Level of Pesticide Residue in Cocoa Beans

The study revealed that application of heat to the cocoa samples either eliminated the pesticides residue or reduced to acceptable levels. For instance, Alpha-endosulfan which had a concentration of 0.02 mg/kg in the unroasted samples exceeding acceptable levels of both the EU (0.1 mg/kg) and Japan (0.1 mg/kg), was not detected after roasting. This meant that there was a breakdown of the pesticides residue after the exposure of the cocoa beans to heat. Ntow (2001) reported that the use of heat during the processing of foodstuffs and other farm produce helps degrade and reduce the quantity of residue of pesticides found in them.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

On the basis of the results of the study, the following conclusions were drawn:

1. Majority (about 99 %) of the farmers used chemicals to control pest on their cocoa farms an indication that cocoa farmers in the district intensively used pesticides in the control of pests on their farms.
2. Majority (about 99 %) of the farmers had some knowledge about pesticides and performed self -application of the pesticides on their farms. However, only about 48% of them have had the education on recommended dosages on approved pesticides form extension agents and so could use the recommended doses on their own.
3. Some farmers (10 %) used a combination of pesticides to control insects. This practice of combining pesticides for spraying contributed to the presence of pesticides residues in cocoa samples from the district above the Maximum Residue Limits (MRLs)
4. Some farmers used higher doses of all the approved insecticides; Akati Master, Confidor and Actara.
5. Some unapproved pesticides were also being used on cocoa.
6. No pesticide residue was present after roasting of the beans which in the raw state recorded pesticide residues.

6.2 Recommendations

Based on the conclusions of the study, the following recommendations were made:

1. An extension of this pesticide residue study to cover other cocoa producing districts in Ghana.

2. An empirical study into the use of chemicals by cocoa farmers and their impact on the health of farmers and consumers.

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APPENDIX

APPENDIX I QUESTIONNAIRES FOR FARMERS

This questionnaire is intended to facilitate in the investigation of pesticide residue levels in cocoa beans from the Sefwi Wiawso District of the Western (North) Region.

All information(s) provided will be treated as confidential. Please be as objective as possible.

BIO - DATA

1. Gender of respondent a. Male ( ) b. Female ( )
2. Age a. 15 – 20 ( ) b. 21 – 30 ( ) c. 31 – 40 ( ) d. 51 – 60 ( ) e. above 60 ( )
3. Marital Status a. Single ( ) b. Married ( ) c. Divorced ( ) d. Widowed ( )
4. Educational Background a. Non Formal ( ) b. Primary ( ) c. MLSC/JHS ( ) d. Tertiary ( ) e. SHS/VOC/TECH, etc ( )

5. Name of farming community……………………………………………………………

6. What is your major occupation? a. farmer ( ) b. trader ( ) c. teacher ( ) d. others ( )

PESTICIDES CHARACTERISTICS

PESTICIDE KNOWLEDGE

7. Do you know a pest? a. Yes ( ) b. No ( )

8. If yes, explain; …………………………………………………………………..

9. Do you see pests in your farm? a. Yes ( ) b. No ( )

10. How do you control the pests on your farm? a. Use trap ( ) b. Use chemicals ( ) c. By physical methods ( )

11. Do you have any knowledge about pesticide? a. Yes ( ) b. No ( )

12. Have you handle any pesticide before? a. Yes ( ) b. No ( )

13. Where do you buy your pesticide? a. Roadside seller ( ) b. Certified agrochemical sellers ( ) c. from vehicles that come on market days ( ) d. others ( )

14. Have you handle any pesticide before? a. Yes ( ) b. No ( )

15. List all the type of pesticides used in pest control on your cocoa farm.

a. ………………… b. …………… c. ………………….. d. ……………………… e. ………………… f. ……………… g. …………………..

16. What do you look at when buying your pesticides? ....

17. Do you understand the labels on the container of pesticides? a. Yes ( ) b. No ( )

18. If Yes, what do they tell you?...

19. Do you know that pesticides are toxic? a. Yes ( ) b. No ( )

20. Do you know the active ingredients contained in the pesticides you use for spraying. a. Yes ( ) b. No (

b. Pesticide Application/Usage

21. Do you use combination of pesticides some times to control insects and diseases on your Cocoa farm? (a.) Yes ( ) b. No. ( ), if yes why? ………………………………………….

22. How many types of pesticides do you mix at a time? a one ( ) b. two ( ) c. three ( ) d. four ( ) e. others ………………………………………………………………

23. How is the mixing done? a. two different types of insecticides ( ) b. two different types of fungicides ( ) c. insecticide and fungicides ( ) d. others ……………………………………

24. What do you use to measure the quantity of pesticides you pour into the spraying machine? ………………………………………………………………………………

25. Name the pesticide you use during the growth stage of the cocoa.……………………

26. Name the pesticide you use during flowering stage.…………………………………

27. Name the pesticide you use during fruiting stage.…………………………………

28. Name the insecticide and fungicides which you use during the harvesting period…………. Why? ....

29. Have you used any of these insecticides for spraying before? (Confodor, Akate Master, Actara) A) Yes B) No. If yes what quantity did you used per the 11 litres knapsack?.................

Insecticide	Quantities used per 11L Knapsack
Confodor	
Akate Master	
Actara	

30. Have you used any of these fungicides for spraying before? (Ridomil Gold, Funguran-OH, Metalm 72 WP, Funkill 50WP, Kocide 2000, Nordox 75WG and Champion) A) Yes B) No. If yes what quantity did you used per the 11 litres knapsack?......................................

Fungicide	Quantity used per the 11 litres knapsack
Ridomil Gold	
Funguran-OH	
Metalm 72 WP	
, Funkill 50WP	
, Kocide 2000	
Nordox 75WG	
Champion	

31. What type of insect pest do you control? a mearly bug ( ) b. capsid ( ) c. others

32. What type of disease do you control?

33. What quantity of insecticide do you use per tank?

34. What quantity of fungicide do you use per tank?

35. Where did you acquire the knowledge for rate measurement? a The Extension Officer ( ) b. I learnt myself ( ) c. I was trained by CSSVD-CU staff and ( ) other (specify) ....

36. Name the type of sprayers you use in spraying your crops? a Motorized/motor blow ( ) b. Knapsack sprayer ( ) c. Others ………………………………………….

37. What are your reasons for choosing/selecting the pesticide you use? a. price is moderate

( ) b. effective control ( ) c. easily available ( ) d. improve cocoa yield ( )

38. How do you know you need to apply chemicals on your cocoa? …………………………

39. What time of the day do you spray your crop? a. Morning ( ) b. Afternoon ( ) c. Evening ( )

And why? ....

40. How efficient are the pesticides you use? a very effective 80 -90% ( ) b. moderate 60-70% ( ) c. poor below 40% ( )

41. How long do you wait after spraying before harvesting………………… And why? ....

42. Do you benefit from the CODAPEC mass spraying exercise? a. Yes ( ) b. No ( )

FOOD SAFETY ISSUES

43. Are you aware that pesticide residue has become a food safety issue? A. Yes ( ) b. No ( )

44. If Yes, where did you get the information? a. Extension staff ( ) b. Radio ( ) other (specify)................

Appendix Ii: Questionnaires for Agrochemical Sellers

This questionnaire is aimed at assessing the types of pesticides cocoa farmers in the Sefwi Wiawso district of Western region patronize. All information provided will be treated as confidential. Please be as objective as possible.

Socio-Economic Characteristics

A. Respondents Characteristics

1. Gender of respondent. 1. Male (…………………..) 2. Female (……………………….)
2. Name of agro input shop……………………………………..
3. Location of agro input shop………………………………………………………..
4. Educational background of shop attendant. (tick) a. [Primary] b. [JSS/ Middle] c. [SSS/SHS] d.

[Tertiary] e. [No. Formal Education]

5. List any special training attended by shop attendant…………………………………………..

6. Is the shop registered? if yes, which organization?..

7. What type of pesticide do you sell to farmers? Tick and give examples

   a) [insecticides] E.

      g………………………………………………………………………………………….

   b) [Fungicides] E.

      g………………………………………………………………………………………… ……

   c) [herbicides] E.

      g………………………………………………………………………………………… …………….

   d) Others [Fertilizers] E.

      g………………………………………………………………………………………… ……………….

8. Are farmers able to explain their problems clearly to your satisfaction? ………………………….

9. If No, Explain………………………………………………………………………………………… ……………………………..

10. Are you able to explain the use of pesticide to farmers? (TICK) 1. [Yes] 2. [No]……………………..

11. Why?...

12. What do you suggest must be done for you to be able to assist the farmer?.........................

13. Do you think farmers always buy their pesticides from the right source or recognized shop?

    (TICK) a. [Yes] b. [No.] if no, where do you think they also buy form?....................................Why? ………………………………………………………

14. What are some of the problems you think the farmers will face from buying from those source?..

15. What do you suggest must be
done?..

16. Are farmers aware that pesticide are toxic a. Yes ( ) a. No ( )

Appendix Iii: Extraction Procedures:

(A) Extraction Methods.

Blended/milled sample – 10.0g (conical) Flask

- ❖ Add 10ml of distilled water to make it paste for 10min.
- ❖ Add 5g of Na_2SO_4 (To absorb water) and shake
- ❖ Add 20 ml of acetonitrile to homogenized for 2 mins.
- ❖ Sonicate sample for 30 mins.
- ❖ Filter sample with filter paper into round bottom flask (RBF)
- ❖ Filtrate becomes organic layer
- ❖ Repeat procedure A above for 2 times.
- ❖ Add all filtrate (organic layer).
- ❖ Concentrate organic layer to near dryness using rotary evaporator at 60˚C to get rid of acetonitrile.

(B) Cleanup methods

- ❖ Parking process (parking of column).
- ❖ Weigh 3g of silica gel into column
- ❖ Top it up with 3g of alumina
- ❖ Add 0.5g of Na_2S0_4 (To remove water)
- ❖ First condition column with 10 ml of Hexane to moist the adsorbent so that it will not absorb the solvents in the sample.

For Quality Assurance purpose:

- ❖ Add 20ml of hexane to concentrate (sample) but in 2 steps of 10ml each i.e. 10 ml hexane + concentrate to dissolve well.
- ❖ Then elute it onto the column.

- ❖ Then add another 10 ml of hexane into the RBF to take care of what could be left in round bottom flask (RBF) and elute onto the column again.
- ❖ Collect elute into the RBF.
- ❖ Concentrate elute at 60 ^{o}C using rotary evaporator to get rid of Hexane.
- ❖ Then take weight of concentrate.
- ❖ Transfer samples to G.C vial and add 2ml of ethylacetate.
- ❖ Take samples to G.C for chromatographic separation.

EXTRACTION PROCEDURE: 2

1. Weigh 10g of blended cocoa beans into a well labelled 100ml conical flask.
2. Add 10ml of distilled water to the weighed sample and make it into a paste.
3. Leave for 10 minutes.
4. Add 5g of Na_2SO_4 shake.
5. Add 20ml of acetonitrile and homogenize for 20 minutes.
6. Sonicate the sample for 30 minutes.
7. Filter sample with filter paper into a well labeled 25 ml round bottom flask. Filtrate becomes the organic layer.
8. Repeat procedures 5 to 8.
9. Pull together all filtrate.
10. Concentrate the organic layer to near dryness using rotary evaporator at 60^{o}C.(this temperature was used because the pump connected to rotary evaporator creates pressure which reduces the boiling point of the solvent which is 82^{o}C.

CLEAN – UP

1. Weigh 3g each of silica gel first, then alumina into a column and 0.5 g $NaSO_4$(to absorb traces of water)
2. Condition the column with 10 ml of hexane (to moist the adsorbent with the elution solvent, that is hexane)
3. Add 20ml of hexane to the concentrate (sample) in the following steps:

- First 10 ml and elute, followed by another 10 ml to rinse the wall of the round bottom flask and elute into a round bottom flask.

4. Concentrate the elute at 43 ^{O}C because of the pump using the rotary evaporator to near dryness.
5. Pick in 2 ml ethyl acetate into GC vials.
6. Make the sample ready for GC analysis.