FACTORS CONTRIBUTING TO PESTICIDE RESIDUES IN RAW HONEY AS A CONTEMPORARY PUBLIC HEALTH ISSUE IN MWINGI CENTRAL, KITUI COUNTY, KENYA

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DECLARATION AND APPROVAL

I confirm that I am the sole author of the research thesis and that it has never been submitted to a college or university for consideration for a degree or other honor.

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Supervisors' Approval

This research thesis has been completed by the undersigned student under our supervision, and it has our approval as the undersigned supervisors.

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DEDICATION

To my late parents, John and Krestina, who inspired me, and my family whose support and encouragement were invaluable during my study and research.

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ABSTRACT

Since honey is a natural product, it needs to be safeguarded for consumption by humans and free of any chemicals. Yet, recent studies on honey from around the world have demonstrated a global prevalence of pesticide residues in honey as a public health concern. However, very little is written about the contributory factors involved. Information on residue presence in raw honey from most of the African countries is scanty. Further, there is a lack of homogeneity on the Maximum Residue Limits (MRLs) for pesticides in honey among state jurisdictions. This study, therefore, investigated aspects leading to the occurrence of pesticide residues in raw honey as a contemporary public health issue in Mwingi Central, Kitui County, Kenya, and recommended mitigation measures. To this end, the study sought to determine the socio-demographic factors, pesticide use related factors, pesticide types in use in the study area and their respective concentrations compared to European Union Maximum Residue Limits (MRLs) of honey. The descriptive, cross-sectional study design applying mixed research methods was used in this study. The study used probability-sampling methods, while using a questionnaire for collection. A total of 375 honey samples were purposively collected from 5 wards **(**Kivou, Nguni, Nuu, Mui, Waita in Kitui County, Mwingi Central. Honey samples were prepared in line with the QuEChERS (Quick, Easy, Cheap, Effective, Rugged, and Safe) approach. Liquid chromatography in conjunction with tandem mass spectrometric detection (LC-MS/MS) was applied in this study to detect pesticide residues in honey at Kabete Vet labs, Nairobi, Kenya. Data was analyzed using Bivariate associations, multivariate analysis, Chi-square test, one sample t-test and SPSS. Descriptive statistics- percentages, graphs and frequency distribution tables were employed for data presentation. The research established that 73% of sampled raw honey had traces of pesticides. The pesticide residue concentrations were below the recommended EU MRLs except for Thiamethoxam (0.06), a neonicotinoid. Pesticide use -related factors were found to be statistically significant. Socio-demographic factors examined, except age (P=0.7753), and pesticide types were statistically significant. These findings led to the conclusion that honey samples analyzed from Mwingi pose no health risk to public health. A significant proportion of study participants do not have any training on pesticides use and safety. The following recommendations based on the investigation findings were therefore made: There is need to review the current policy and legal framework and conduct routine market surveillance on pesticide residues in raw honey and that the high level of neonicotinoids observed in sampled raw honey requires further attention in monitoring. Further, farmers and Beekeepers should be continuously trained on public health effects of pesticide residues in raw honey and need for usage of alternative pesticides such as bio pesticides. Future studies should also consider different regions, gender, risk perception and attitude to pesticide use as possible factors to pesticide residues presence in raw honey.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OFABBREVIATIONS / ACRONYMS

ASDSP:	Agricultural Sector Development Support Program
CIP:	Commercial Insect Program
DDT	dichlorodiphenyltrichloroethane
DSPE	Dispersive Solid Phase Extraction
EMCA 99,	National Environment Management and Coordination Act, 1999
EPA:	Environmental Protection Agency, U.S.A
EU:	European Union
GoK:	Government of Kenya
HPLC:	High Performance Liquid Chromatography
ICIPE:	International center for insect physiology and ecology
IEBC	Independent electoral and boundaries commission)
KEBS:	Kenya Bureau of standards
KEPHIS:	Kenya plant health inspectorate services
KFS:	Kenya Forest Service
LC-MS:	Liquid Chromatography-Mass Spectrometry
LOD:	Limits of Detection
LOQ:	Limit of Quantification
LOR:	Limit of Reporting
MRL:	Maximum residue limits

n: sample size

NACOSTI: National commission for science, technology and innovation

NEMA: National environmental management authority

OCs: Organochlorines

OPs: Organophosphates

PCPB: Pest control Products Board

Ppb: Parts per billion parts

SPSS 2007: Statistical package for social sciences

UNDP: United Nations Development Program

QuEChERS: Quick Easy Cheap Effective Rugged Safe

VMD: Veterinary Medicines Directorate

WHO: World Health Organization

WTO SPS Agreement: World Trade Organization Sanitary phytosanitary

DEFINITION OF KEY TERMS

Contemporary: That which is marked by characteristics of the present period (merriam-webster.com).

Contributing: Playing a significant role to bring about end or result (merriam-webster.com).

Honey: Sweet liquid from nectar and honeydew from plants processed before storage for food by bees (Codex Alimentarius standard, 1981).

Health: State of complete physical, social and mental health and not merely the absence of illness or infirmity (WHO).

Pesticides: A substance for preventing, destroying, repellant or mitigating pests (EPA, USA).

Public health: Science and art of illness hindrance, life prolongation and promotion of mental and physical health and efficiency by organized community actions for environmental sanitation, communicable disease control, education in individual hygiene, organized health services among others, for every citizen to realize their birthright of health and longevity(WHO,1978).

Pesticide residue: Substance in food or feed arising from usage of a pesticide that is of toxicological importance (WHO).

Raw honey: As found in the hive or by extraction or straining; not heated above 118 degrees Fahrenheit at production or storage (https://www.thehoneyjarhome.com/what-is-raw-honey).

CHAPTER ONE

INTRODUCTION

1.0: Introduction.

Background information, problem statement, investigation justification, investigation objectives, and research questions are all included in this chapter. The chapter also describes the research's significance, scope, limitations, delimitations, and underlying hypotheses.

1.1: Background of the study.

Honey, being natural is thought to be healthy, pure and nutritious, and this includes its products (Tauber et al. 2019). The high nutritional value of honey is due to its richness in carbohydrates, amino acids, vitamins, and minerals, among others (Kamal et al.,2019). To this end, honey ought to be fit for public health with no contaminants whatsoever (Vapa Tankosic' et al. ,2022). However, recent studies from around the world have demonstrated a global prevalence of pesticides in honey (Mitchell et al.,2017a). An investigation in Argentina detected high quantities of pesticide residues in nearly 100% of honey samples tested (Villalba et al. 2020). Another study found 70% of samples positive, though with concentrations below EU MRLs (Saorla et al.,2021). Clothianidin (neonicotinoid) was found to be the most frequent in honey samples from UK tested, though in minute quantities (Woodcock et al. ,2018). However, Ponce-Vejar et al., (2022) found that neonicotinoids were the most frequently detected, but in higher amounts, with organophosphates coming second. In contrast, clothianidin (neonicotinoid) ranked as second in frequency of occurrence in honey samples (Nenad Stevanovic' et al. ,2024). Even worse and though banned, organochlorine residues have been found present in honey (Gunes et al.2021). The results should also be disseminated to increase the general understanding of food safety concerns that affect the quality of life. Additionally, this investigation will help meet the goal of minimizing or eliminating pesticide residues in honey. Enhancing the investigator's professional development was another goal of this investigation.

Therefore, this study investigated factors that contribute to occurrence of pesticide residues in unprocessed honey as a contemporary public health issue in Mwingi, Kitui County, Kenya, recommended mitigation measures and will serve as the baseline for other researchers in the field.

1.2: Statement of the problem.

Kitui County is a major honey producer in the country. From a public health perspective, honey, being natural is thought to be healthy, pure and nutritious and therefore ought to be fit for public health. However, in Kenya and Ethiopia, honey samples had higher pesticide residues than the set Maximum Residue Limits (MRLs) (Irungu, J et. al.,2016). Yet, and according to Anaduaka et al. (2023), even tiny quantities of pesticide residues in food chain portent public health risk due to subacute / chronic toxicity. Further, other reports indicate that only few previous studies have been undertaken on pesticide residues in honey (El-Nahhal.,2020; Xiao et al.,2022). The available data on pesticide residues in raw honey is also scanty (Nenad Stevanovic' et al.2024). The serious threat posed to public health makes it important therefore, to determine pesticide residues in honey as an urgent and emerging concern in contemporary times (Milone and Tarpy,2021).

This study therefore, set out to investigate factors underwriting to occurrence of pesticide residues in raw honey as a contemporary public health issue in Mwingi Central, Kitui County, Kenya.

1.3: Objective of the study.

The expected output from this research is outlined as the general and the specific objectives.

1.3: General objective.

To investigate factors contributing to presence of pesticide residues in raw honey as a contemporary public health issue in Mwingi Sub-County, Kitui County, Kenya.

1.3.1: Specific objectives

1. To determine the socio-demographic factors contributing to pesticide residues in raw honey as a contemporary public health issue in Mwingi Sub-County, Kitui County, Kenya.
2. To determine the pesticide use-related factors contributing to pesticide residues in raw honey as a contemporary public health issue in Mwingi Sub-County, Kitui County, Kenya.
3. To determine the types of pesticides in use contributing to pesticide residues in raw honey as a contemporary public health issue in Mwingi Sub-County, Kitui County, Kenya.
4. To determine quantities /concentrations of pesticide residues found in raw honey compared to European Union Maximum Residue Limits (MRLs) of honey (0.05 mg / Sub-County kg) as a contemporary public health issue in Mwingi Sub-County, Kitui County, Kenya.

1.4: Justification of the study.

The goal of the investigation was to record the variables that contribute to the residue occurrence in honey that is raw as a current public health concern. This would aid in creating a more effective strategy to evaluate public health risks and implement mitigation strategies for improved public health results. This is supported by the idea that health risks should inform the formulation of public health policy. The results should also be disseminated to increase public awareness of food safety concerns that affect the quality of life. Additionally, this study will help meet the goal of minimizing or eliminating pesticide residues in honey. Enhancing the investigator's professional development was another goal of this investigation.

1.5: Significance of the study.

Researchers, non-governmental and international organizations, the community in the subject matter area, and both the national and local levels of government will find value in the findings of the research. In order to safeguard the health of the public, lawmakers and executioners (including the Ministry of Agriculture, Ministry of Health, National Environmental Management Authority (NEMA), and Kenya Bureau of Standards) will utilize the study's findings to ensure that pesticides are used appropriately and strategically. The results will be used for community workshops and capacity building by governmental and non-governmental organizations that support beekeeping in Kitui County, including ICIPE, UNDP, and Kenya Forest Service (KFS). The findings of this study will aid in raising consciousness of the potential health hazards associated with pesticide residues in honey and suggest preventative measures. This study will give insights on factors contributing to pesticide residues in raw honey and generate specific data on types of pesticides in use and information of use to researchers for future literature reviews to improve and advance knowledge in the area of discipline.

1.6: Research questions.

To enable the researcher to focus and outline relationships between variables and how they interact, this study specifically sought answers to the research questions below:

1. What are the socio-demographic factors contributing to pesticide residues in raw honey as a contemporary public health issue in Mwingi Sub-County, Kitui County, Kenya.
2. What are the Pesticide use- related factors contributing to pesticide residues in raw honey as a contemporary public health issue in Mwingi Sub-County, Kitui County, Kenya?
3. What are the types of pesticides in use contributing to pesticide residues in raw honey as a contemporary public health issue in Mwingi Sub-County, Kitui County, Kenya?
4. What are the quantities /concentrations of pesticide residues found in raw honey compared to European Union Maximum Residue Limits (MRLs) of honey (0.05 mg /kg) as a contemporary public health issue in Mwingi Sub-County, Kitui County, Kenya?

1.7: Hypothesis.

A hypothesis for research was developed to offer a tentative response to the study's research question by outlining expectations for the likely results. Additionally, for statistical hypothesis testing, a null hypothesis was created.

1. Ho: Socio-demographic/pesticide use -related factors and pesticide types are not significantly associated with pesticide residue presence in raw honey in Mwingi, Kitui County, Kenya.
2. H_1: Socio-demographic/pesticide use -related factors and pesticide types are significantly associated with pesticide residue presence in raw honey in Mwingi, Kitui County, Kenya.

1.8: Scope/delimitation of the study.

In Mwingi Central, Kitui County, Kenya, this research investigation examines the variables that lead to the prevalence of pesticide residues in raw honey, a current public health concern. The investigation was restricted to the following five wards: Kivou, Nguni, Nuu, Mui, and Waita. The sixth ward, Mwingi, was excluded from the investigation because it was utilized for pretesting the questionnaire.

Descriptive, cross-sectional (snapshot) study design applying mixed research methods of data gatherng was employed in this invetigation. The target population was all beekeepers in Mwingi Central Sub County who met the inclusion criteria set for this study. Data collection was done from October 2021 to December 2021. Honey samples were purposely set at 375 and collected directly from beehives. Samples were then analyzed at Kabete Vet labs, Nairobi in line with the QuEChERS (Quick, Easy, Cheap, Effective, Rugged, and Safe) approach. Liquid chromatography in conjunction with tandem mass spectrometric detection (LC-MS/MS) was applied. Multiple linear regression models and the Chi-square test were employed in the investigation. This study presented its analyzed data using texts, bar charts, and frequency distribution tables. The study used the default international maximum residue limit (MRL) Codex Alimentarius for standardization for honey of 0.05mg/kg (Irungu, J et. al., 2016).

1.9: Study limitations.

The fear by the community to participate in the study due to perceived loss of market for their honey if found to contain pesticide residues was encountered. However, this fear was addressed through full disclosure of the objectives of the investigation before informed agreement was attained from partakers. Any material information such as any risks the participants may incur was also given full disclosure. The participants as volunteers were also given liberty to opt out of the research as per ethical best practices. Further, a pretesting of the questionnaire was performed prior to the actual study.

The other limitation encountered was the vastness of the study area coupled with the harsh climate with most of the roads in bad shape during rains made communication difficult and hindered access to some selected sites. To mitigate this, purposive sampling technique was used where need arose due to harsh terrain and inaccessibility of some site locations.

CHAPTER TWO

LITERATURE REVIEW

2.0: Introduction.

In this section, relevant literature is reviewed with a focus on empirical literature review, review of the study variables and a critical review. This is followed by theoretical literature review. A conceptual framework is then crafted and a summary of the conceptual framework developed.

2.1: Empirical literature review.

2.1.1: Honey in General.

According to Y. R. Tahboub et al. (2006), honey is a sweet, viscous liquid that honeybees make from flower nectars. It is high in minerals, vitamins, enzymes, and carbohydrates, with roughly 38.5% fructose and 31.0% glucose (C. Blasco et al., 2011). In addition to being used as a preservation agent for food, honey is also used as a cough syrup and applied to burns and wounds. Additional data supports honey's antimicrobial properties against methicillin-resistant Staphylococcus strains and other bacteria (M.W. Kujawski, Namiesnik, 2011). According to Godfred Darko et al. (2017), the crops in which the nectar was extracted as well as the surroundings of the beehive influence the quantity of pollutants and the exact structure of a given batch of honey. The plants from which the pollen is collected, the weather, and the kind of bees are additional factors that affect the chemical makeup, flavor, color, and other attributes of honey (Oroian et al., 2018). As a natural product, honey can be used as food and medicine, but it can also be contaminated by a variety of substances, including heavy metals, pesticides, herbicides, and antibiotics. Honey has been consumed as human food from time immemorial. From the recent past, organic foods with confirmed health usefulness such as honey, have been consumed widely and this tendency is likely to continue (Kieliszek et al.,2018). For example, in

2021 alone, the world honey market share was about 9 billion USD, and is projected to grow by 5% in 2030 (Grand View Research, 2022). Honey is also used as an alternative to sugar in the food industry and in cosmetics (Godfred Darko et al., 2017).

According to Kenyan Sessional Paper No. 7, (2013), honey is mainly produced in the dryer areas of Kenya. There is however, scarcity of data on this honey quality trait that would be key in enhanced consumer trust and traceability for trade (Mary Wanjiru Warui et al.,2019). Honey production is majorly by use of traditional log hives (ikuli) and is mainly saturated in Mwingi. There is therefore urgent need for monitoring pesticide residue in raw honey, understanding the contributing factors to its occurrence, and raising awareness on public health concerns. Monitoring of pesticide residues in honey is of significance to elucidate more data on the usage of pesticides within and around farms (Prasanth et al.,2022).

2.1.2: Public Health effects of pesticide residues in honey.

Godfred Darko et al. (2017) state that while honey's quality and nutritional value are significant, its popularity among consumers is influenced by the guarantee of chemical safety. It is well known that when bees consume pollen tainted with pesticides, they transfer residual pesticides to honey (Lika et al., 2021). Thus, current agricultural practices are linked to bee exposure to pesticides. Additionally, as honey is processed, minute amounts of pollutants (pesticides) that the bees bring into the hive become highly concentrated, making honey vulnerable to environmental contamination. Studies also indicate that application of pesticides in farms has negative effects on flowers on which bees forage. Others contaminated through pesticide usage on farms include soils (Wolejko et al.,2020), air (Zaller et al.,2022) and water (Agarski et al.,2023). Wood et al. (2019) further explains with examples that areas with crops that are heavily sprayed with pesticides are candidates for bees to collect more contaminated nectar and pollen. It should, however, be noted that exposure to residues is not just confined to agricultural habitats, though this accounts for the most frequent detections (Saorla et al.2021) as clothianidin and thiacloprid residues were exceptionally associated with honey from urban habitats.

Pesticide residues in honey not only pose public health hazard but also makes honey to be graded as of low quality in the markets (Tudi et al. ,2021). Further, presence of some pesticide residues can cause cancer and are neurotoxic, whilst others cause dysfunctions in the reproductive organs (Khalil et al., 2022). Other public health effects associated with pesticide residues when consumed in honey are; miscarriages, irregular menstrual cycle and cancer of the prostate, among others (Mukiibi et al.,2021). Organophosphates poisoning is due to inhibition of acetylcholinesterase enzyme leading to excess acetylcholine circulating in the body with adverse health outcomes (Erika L. Robb et al.,2023). Chronic effects of organophosphate exposure include muscle weaknesses and embryological nerve poisoning (Costa, Lucio G.,2018 and Jokanović, Milan et al.,2023). Lindane, as an example, was found to be carcinogenic (Mahdavi et al.,2022). Many human health disorders associated with Organochlorines (OC) exposure were noted leading to a ban by 1970s. By 1946, with increased awareness of harm due to residues and potential public health risks, authorities began to seek ways to control pesticide use globally. Kasiotis K.M.et al.,2023 however, concluded that occurrence of pesticide deposits and metabolites in honey does not raise human risk assessment concern, and therefore of no public health concern.

2.2: Review of Variables.

Sociodemographic characteristics, aspects associated with pesticide usage, the kinds of chemical pesticides being used, and the amounts and concentrations of residual pesticides found in the tested honey samples are the variables for the investigation under review.

2.2.1: Socio-demographic factors.

According to an investigation, households' involvement in the commercial insect program (CIP) by ICIPE, which included silk and honey farming in Kitui County, was influenced by the family head's age, occupation, and educational attainment (Mburu P D M., 2015). Therefore, socio-demographic factors (Age, occupation, Education level) contributing to pesticide residues in raw honey as a contemporary public health issue in Kitui County, Kenya, were reviewed.

2.2.1.1: Age.

An individual's age plays a significant role in how they make choices. For this reason, young farmers are believed to be more adaptable when it comes to embracing novel concepts. On the contrary, older farmers do not trust new ideas, including new technology (Belay T. Mengistie et al. ,2015). These new ideas and technology can encompass decision on use or non- use of pesticides on their farms and other health promotional behaviors. A respondent thus explained: 'A number of older farmers still hold DDT in high esteem, associating it with their first improved farm yields or those of their forefathers'.

2.2.1.2: Occupation.

Financial constraints dictate which spraying equipment or pesticide to be purchased. This is well demonstrated in a study by Belay T. Mengistie et al., (2015) who found that farmers from lower-income groups bought cheap but broad-spectrum and therefore, likely toxic pesticides available on the open market. This was in contrast to those from higher-income groups who most likely bought quality pesticides from official channels. The enhancement of small-scale farming depends on profession and, consequently, revenue, which also influences the farmer's choice and purchase of agricultural inputs (pesticides) (Otieno et al., 2010). According to Islam et al. (2016), wealthy farmers used extremely dangerous pesticides more often than small and medium-sized farmers. On the other hand, most of those in formal employment with income have no time for beekeeping and perceive beekeeping as an activity for the unemployed (Mulati,2016).

This situation may apply to Kitui where there is high rate of unemployment with high poverty index of 63.5% (Kitui CIDP 2013-2017). However, in Kitui County, ICIPE programs have led to better income for beekeepers (Kioko, 2010).

2.2.1.3: Education level.

Changing farmers' lifestyle requires education, because illiteracy or semi-literacy is associated with poor reading skills. Low literacy levels among farming group creates fertile grounds for susceptibility to toxicity to human wellbeing and environ (M.P. Ali et al. ,2020). Further, an illiterate farmer will not read the directions about proper pesticide dose rates and use. The Agricultural Sector Development Support Program states that the family head's educational attainment influences choices like investment levels, risk-taking propensity, and the use of technological advances (ASDSP, 2014). This explains why Governments and international community e.g. FAO, WHO, and others are involved in programs such as education, community interventions and legislation to improve behaviour of farmers using pesticide (M.P. Ali et al.,2020). According to an investigation by Belay T. Mengistie et al. (2015), agriculturalists trusted the people who sold their pesticides, but they were unaware of how important the labels' expiration dates were.. Majority of the farmers lacked sufficient knowledge on the potential risks to themselves, consumer and environment.

2.2.2: Pesticide use -related factors.

The Pesticide use- related factors **(**Training on Pesticide use, Seasonal frequency of Pesticide use, Interaction with Local Extension Officers) contributing to pesticide residues in raw honey as a contemporary public health issue in Kitui County, Kenya, are reviewed.

2.2.2.1: Training on Pesticides use.

Public health is negatively impacted by insufficient education, limited availability of knowledge on the safe use of pesticides, and the incapacity to read pesticide labels. For this reason, Kapeleka et al. (2021) state in a survey that farmers as well as local extension agents should receive periodic instruction on current pest issues and pesticide safety. According to Damalas CA and Khan M. (2017), farmers have poor attitudes, perceptions, and awareness regarding the use of pesticides. Inadequate instruction on the safe use of pesticides may be the cause of this (Belay T. Mengistie et al., 2015). For instance, in Kitui County, ICIPE started certifying honey producers as organic honey makers, provided trainings on modern apicultural techniques, and educated the community on the cultivation of bee techniques through the Commercial Insect Program (CIP) (Affognon et al., 2015).

2.2.2.2: Seasonal frequency of pesticide use.

It has been shown that small-scale farmers vegetable farmers heavily rely on the usage of pesticides to control various insects and illnesses (Jones A. Kapeleka et al., 2021). This is most likely because people think that the only way to deal with pest issues is to utilize different kinds of pesticides and spray more often (Damalas CA, Khan M., 2017). Further, low efficacy of pesticides, increased incidence of pests and diseases, coercion from retailers and their technical advice were cited as reasons for high frequency of pesticide use. Globally, the frequency of use of pesticides is one of the main limits on pesticides use usually set before approval (EPA). Pre-harvest intervals are also set requiring products not to be harvested before an interval post application of the pesticide to allow pesticide residues to reduce below tolerance levels. Others have found that while no farmer followed the recommended spraying interval (Belay T. Mengistie et al., 2015), spraying frequency was dictated by the prevailing seasonal conditions and the type of crop. For example, there was more spraying during rainy seasons when pest and diseases are high and crops like tomatoes required higher frequency of spraying per season. Of note is that apiaries located in high potential areas frequently treated with pesticides show high contaminations of honey (Mulati, 2016). Some studies have, however, indicated that a combination of increased application of pesticides in farms and low literacy levels among farming group creates fertile grounds for susceptibility to toxicity to human well being and environ (M.P. Ali et al. 2020) and therefore honey food chain.

2.2.2.3: Frequency of Interaction with Local Extension Officers.

Local authorities and pesticide retailers play significant role in extension service provision. They provide advice and information on choice of pesticides, awareness and behaviour of farmers. This is crucial, especially where the farmers have low levels of education and lack appropriate information (Fan et al. 2015). It has also been proffered that an effective extension system is one that builds the farmers capacity to safe use of pesticides and monitor them at farm levels. This can reduce misuse of pesticides and related health and environmental concerns (Jones A. Kapeleka et al., 2021). However, some believe that there is a lack of trust between farmers, pesticide sellers, and the government, which leads to pesticide misuse (M.P. Ali et al., 2020). In other cases, it was discovered that farmers frequently reject and doubt technical and pesticide retailers because of perceived disparities in interests between the farming group, technical, and retailers (Rios-Gonzalez et al., 2013). For instance, Rahaman et al. (2018) found that farmers in Bangladesh mostly consulted pesticide retailers for advice on how to utilize pesticides, while very few contacted government extension agents.

According to Damalas CA, Khan M. (2017), insufficient extension assistance or education about pesticide use and safety may be the cause of the farmers' low understanding, attitude, and perception regarding chemical pesticides utilization(Belay T. Mengistie et al. 2015). Nonetheless, Jin et al. (2015) demonstrated that the kind of info provided to farmers by pesticide retailers differed based on the farmer's level of acquaintance with them.

2.2.3: Types of pesticides applied.

Chemical pesticides gained prominence for pest control in Post-World War II era. The first-generation pesticides (arsenic, mercury, and lead) gave way to second-generation pesticide (synthetic organic compounds) currently in use. The first-generation pesticides were highly toxic and ineffective (Patricia Muir,2012). Most pesticide types are not biodegradable but are largely bio-accumulative. This can lead to its entry into food chains and therefore of public health concern.

According to WHO, pesticides can broadly be classified based on target organism or targeted use as insecticides, herbicides, fungicide and Acaricides among others. Classification can also be based on their toxic levels namely: There are five categories: extremely dangerous (1A), highly dangerous (1B), moderately dangerous (II), somewhat dangerous (III), and not probable dangerous (IV). CropLife (2018) reports that 15% of the 6400 pesticides sold by their members in 2015 were classified as Absolutely Hazardous Pesticides (HHPs) by the WHO. Other modes of classification are based on active ingredients; organochlorine, organophosphates, carbamates, Pyrethroids, neonicotinoids and inorganic among others).

According to Kenya Pest Control Products Board (PCPB), the number of active ingredients currently registered in 699 products for horticulture, floriculture and forestry is 247, of which only 150 have been approved in Europe and 78 have been banned in the EU. According to the Federation of Agrochemicals of Kenya, Kenya imports 42% of its chemical pesticides from China and 30% from the EU. Between 2015 and 2018, the country's demand for these imports grew from 6400 to 15600 tonnes. Tanzania and Uganda, which are thought to be the sources of 40% of counterfeit pesticides, are where some significant quantities of pesticides enter Kenya (Nampeera et al., 2019). A similar finding was in Ethiopia where a large portion of pesticides were reported to be from illegal sources (Belay T. Mengistie et al. 2015). Among factors likely to drive further demand for pesticide use are population increase and expanding markets (Sharma et al., 2019).

This study focused on organochlorine, organophosphates, carbamates, Synthetic Pyrethroids and neonicotinoids.

2.2.3.1: Organochlorines (OCs)

Organochlorines (OCs) pesticides are synthetic chlorinated hydrocarbon derivatives. OCs are also very toxic, slow to degrade and bio accumulative (Ravindran J et al., 2016). Though banned since the 1970s due to public health and environmental concerns, Organochlorine's (OCs) effects still linger on to date (Lyall, K. et al., 2017). Similarly, due to their affordability and wide spectrum of activity on many pests, they are most widely used in poor countries. Examples are toxaphene, heptachlor, dieldrin, DDT and others.

2.2.3.2: Organophosphates (OPs)

These are esters of phosphoric acid, quickly degraded by hydrolysis on exposure to environment and are more toxic than organochlorine (Chambers et al., 2010). Some organophosphates are denser with a tendency to sink in water as sediments (McDonough, Carrie A. et al.,2018). Although they have been demonstrated to be more severely toxic, the newer generation of organophosphates and carbamates tend to be less enduring in the environment than the initial generation of organochlorines (Godfred Darko et al., 2017). Demetox, dimethoate, and malathion are a few examples.

2.2.3.3: Carbamates

Carbamates are derivatives of carbamic acid. They degrade in the environment but are less toxic than other pesticides though very toxic to bees (Liu et al., 2012). These include Dimethan, Thiourea, carbaryl, and carbofuran among others. To achieve synergy, interaction and control of a wide spectrum of insects(resistant), carbamates and Ops are at times used in combination.

2.2.3.4: Synthetic Pyrethroids

These are organic in nature, similar to natural pyrethrins from pyrethrums. Synthetic Pyrethroids are the majority of the commercial household insecticides. In contrast to the subsequent generations (a chemical known as, cypermethrin, and deltamethrin), which are more constant and resistant to degradation by sunlight and air, this initial generation (bioallethrin, tetramethrin, etc.) is unpredictable in the sun but more harmful to mammals (Luo, Yuzhou et al., 2011). Even though the EU has banned synthetic pyrethroids, they are still being shipped to developing nations in violation of the Sustainable Development Goals (SDGs) of the UN because of the significant prospective hazards to both the public and the environment (UNICEF, 2018).

2.2.3.5: Neonicotinoids

Neonicotinoids are neuro-active, similar to nicotine in chemistry and include imidacloprid and thiamethoxam and Clothianidin among others. Presence of neonicotinoids in honey can thus be ascribed to many aspects such as extensive use in farming, tenacity in soils and water (Silva et al.,2019), making them readily bioavailable to bees (Hladik et al.,2018). Being water-soluble, Neonicotinoids can leach into waterways around farmlands (Hladik ML, Kolpin DW. ,2016) and be taken up into nectar and pollen of non–crop plants. Neonicotinoids are the most commonly used pesticides globally. They cause stimulation of nerves at low doses and receptor blocker, paralysis and in higher doses, death. Many of these compounds have been restricted for use by the EU (Cressey, D., (2013). According to Lundin et al. (2015), the application of thiacloprid by spraying, as opposed to seed dressing, can result in higher remnants in food-related sources of honey bees, which may then cause the same residues to appear in honey.

2.2.4. Quantities /concentrations of pesticide residues.

The two UN bodies (FAO/WHO) assess human risks arising from pesticides exposure and recommend appropriate measures to protect public health. They achieve this through Joint FAO/WHO Summit on Pesticide Residues(JMPR), which sets safe intake limits. This ensures that the quantities of pesticide residues consumed by the public over lifetime do not compromise public health. These limits are then used by governments and Codex Alimentarius Commission to develop globally –accepted MRLs for pesticides in food and regulate international trade (WHO,2022). Many countries now use the international maximum residue limit (MRL) Codex Alimentarius for standardization (CODEX international food standards, 2012). There are, however, other international commitments that augment the standard on MRLs. Among these is the Agreement on the Application of Sanitary and Phytosanitary Measures, which encourages governments to follow global requirements while granting them the freedom to establish their own. In spite of this, MRLs differ greatly between jurisdictions (FAO and WHO, 2020), with the US permitting some of the most stringent and the EU setting the lowest for various products. The lack of consistency in MRLs may make it more difficult to control pesticides and promote hazards to health and the environment. In this investigation, the amounts and quantities of pesticide residues in raw honey were contrasted to the honey's 0.05 mg/kg European Union Maximum Residue Limits (MRLs).

2.2.5: Government policy.

WHO recognizes that although pesticides are important in agriculture, they are potentially toxic and a threat to public health due to their persistence in the environment. Further, many banned chemicals such as dichlorodiphenyltrichloroethane(DDT) are still used in poor countries in disregard of the 2001 Stockholm Convention. In order to safeguard public health, WHO seeks to outlaw the pesticides that are most harmful to people and relentless in the environment. They also set maximum recommended levels (MRLs) for food and water (WHO, 2022). Along the food value chains, government agencies and other interested parties are guided by the International Code of Conduct on Pesticide Management (2014), which was co-developed by the FAO and WHO. The CODEX International Food Standards (2012) state that the maximum residue limits (MRL) for chemical products in honey must be uniform across jurisdictions.

Due to public health concerns and other measures, Governments issue policy, and guidelines to regulate the pesticide industry and value chains. As an example, provision of an efficient and effective regulatory services for pesticides that mitigate potential harm to the environment is regulated in Kenya (Pest Control Products Board). National Environment Management Authority (NEMA) established under National Environment Management and Coordination Act, 1999 (EMCA 99), among other functions, establishes and reviews guidelines on land use and their impacts on natural resources. Further, it influences Government policy and other actions on environmental management and in conformity with other relevant international commitments on environment and health, including FAO/WHO.

The overall objective of Kenya's 2012 National Food Safety Policy is to create a comprehensive nutritional security system that guarantees the preservation of food supply and public safety in accordance with WTO SPS and other international agreements. However, the public's knowledge and involvement through training and education are necessary for compliance. For instance, a research investigation by M.P. Ali et al. (2020) revealed that many participants knew that pesticides were bad for the environment, human health, and the nutritional content of food. However, the majority of those surveyed knew why certain pesticides are currently prohibited. Additionally, participants understood that reducing the intake of pesticides could enhance and protect both the environment and human wellness while lowering yields and, consequently, incomes.

2.3: Critical review/Research gaps.

The following study gaps have been determined based on the available literature review:

(i) Reports indicate that only few previous studies have focused much on pesticide residues in honey (El-Nahhal,2020; Xiao et al.2022).

(ii) The available data on pesticide residues in raw honey is also scanty (Nenad Stevanovic' et al.2024).

(iii) Low trust levels exist between farmers, pesticide retailers and government, which contribute to misuse of pesticides (M.P. Ali et al. 2020).

(iv) Damalas CA, Khan M. (2017) have demonstrated existence of low knowledge, awareness, attitude and perception on pesticide use among farmers.

(v) There need to know the type of pesticides in use as this influences its ability to bio accumulate in the environment. The inability to biodegrade also leads to its entry into food chains and therefore of public health concern.

In contrast to earlier research, this investigation concentrated on identifying the variables that contribute to the existence of residual pesticides in raw honey, a current public health concern in Mwingi, Kitui County, Kenya.

2.4: Theoretical literature review.

We reviewed key theories of health habits that help explain why people act the way they do. For this investigation, the Theory of Planned Behavior and its theoretical framework were utilized.

2.4.1: Theory of planned behavior

According to the Theory of Planned Behavior, subjective norms or perceived pressure from society to carry out a specific action are caused by normative beliefs. Additionally, according to the theory, one's intentions and behaviors are shaped by their attitude toward a behavior, subjective norms, and perceived behavioral control (Figure 2.1).

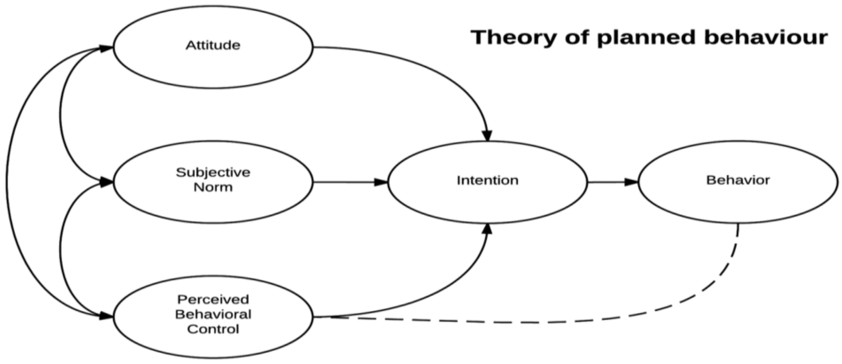

FIGURE 2. 1: THEORY OF PLANNED BEHAVIOR

SOURCE: ROBERT ORZANNA HTTPS://COMMONS.WIKIMEDIA.ORG

2.4.2: Applications of the theory of planned behavior.

This theory was applied in environmental health actions such as safe pesticide usage by beekeepers in the study area. Similarly, Jianhua Wang et al., (2017) was of the view that perceived benefits (health outcome) influenced safe pesticide use by farmers. It is also of note that farmers who believed in receiving a net benefit were more cooperative with peers in pest control (Stallman, H.R et al., 2015). This study therefore, used this model to understand practices and behaviors that could explain factors contributing to presence of pesticide residues in raw honey as a contemporary public health issue in Mwingi, Kitui County, Kenya.

2.5: Conceptual framework.

This conceptual framework's function was to operationalize the theory and offer guidance on gathering information methods (see Figure 2.2 below). The variable that was dependent in the present investigation refers to the predicted effect of the predictor variable, whereas the variable that are independent refer to the presumed cause.

2.5.1: Summary of Conceptual Framework.

In this framework, pesticide residues presence in raw honey (Dependent Variable) is indicated as being caused by independent variables. These include: socio-demographic factors, The types of pesticides used, factors related to the application of pesticides, and amounts and levels of pesticide residues in raw honey in comparison to the European Union's Maximum Residue Limits (MRLs) of honey (0.05 mg/kg). It is believed that the consequence of the variables that are independent is influenced by the intervening variable, which is government policy. The conceptual structure of the research is depicted in Figure 2.2 below.

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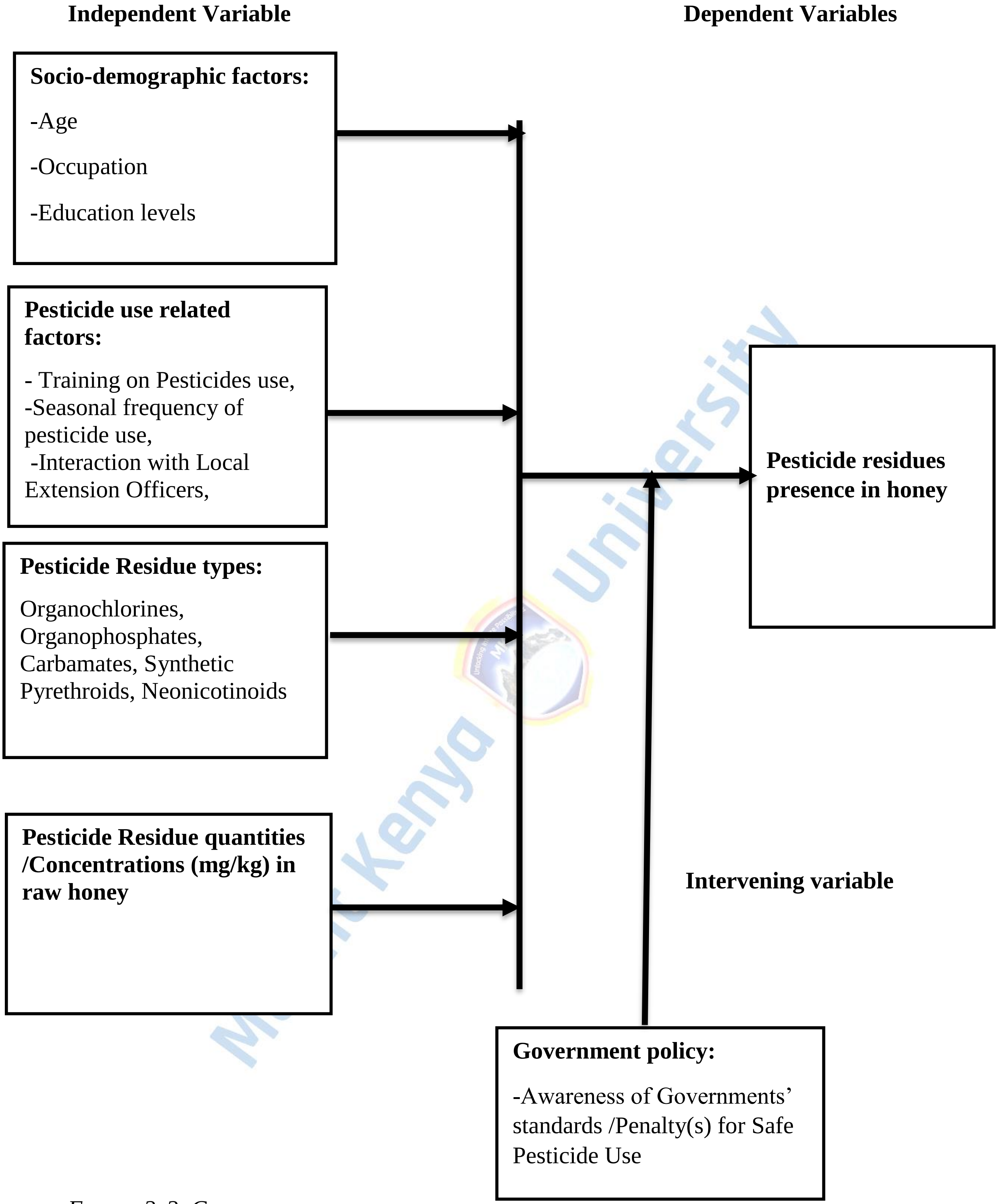


FIGURE 2. 2: CONCEPTUAL FRAMEWORK.

SOURCE: LITERATURE REVIEW BY THE RESEARCHER

CHAPTER THREE

MATERIALS AND METHODS

3.0: Introduction.

This chapter includes the investigation's location and investigation design. The sampling process and the calculation of the sample size are also explained. The chapter also covers methods for gathering data, tools, and procedures, as well as laboratory techniques for pesticide residue analysis. Lastly, the ethical concerns, presenting information strategies, and evaluation methods used in this admirable study are described in detail.

3.1: Study design.

This investigation used a cross-sectional, descriptive (snap shot) research approach. Mixed (qualitative and quantitative) methods of investigation were used to gather data for the present investigation. The investigator chose this design because it enabled the simultaneous examination of numerous characteristics (e.g., age, profession, education level, frequency of pesticide use, etc.). The process was also inexpensive and quick. The 2019 National Census of the Kenya National Bureau of Statistics provided the local economic status data.

3.2: Location of the study.

Kitui County is one of the leading honey producers in the country. According to Kitui CIDP (2018-2022), Kitui County has been both historically and culturally associated with honey production as a viable and sustainable enterprise due to its vast rangelands at 70%. Mwingi Central was selected as the study site due to its endowment with natural acacia bushes conducive for honey production. Kitui honey is considered among the best with some value addition done at Mwingi honey cooperative. Smallholder agriculture is also practiced in Kitui County, with use of pesticides on crops and livestockBeekeeping has been encouraged in Kitui County by both government agencies and non-governmental organizations, including the Kenya Forest Service (KFS), UNDP, and ICIPE through the Commercial Insect Program (CIP), among others (Affognon, 2015). As a result, the "Mwingi Honey and Wild Silk Market Place" was created. To enhance local economies, the County Government has backed 16 additional honey processing facilities. Thus, Mwingi Sub-County, Kitui County, Kenya, was the study's location.

"A location where iron goods are made" is Kitui. According to Kitui (CIDP) 2018–2022, the region is 400–1800 meters above sea level. It shares borders with Machakos and Makueni to the west, Embu to the southwest, and Tharaka and Meru to the north. Taita Taveta and Tana River counties are additional neighbors. The region, which is roughly 30496.4 square kilometers in size, is 160 kilometers from Nairobi. There are six (6) wards in Mwingi Central, one of Kitui County's eight (8) sub-counties: Kivou, Nguni, Nuu, Mui, Waita, and Mwingi.

Kitui County's weather is arid to semi-arid, with unpredictable rains during the two main the seasons of May–June (long rains) and September–October (short rains). The county's primary industry is agriculture. A high rate of unemployment with a high poverty index of 63.5% is recorded, with absolute poverty of 47.5%. The population in the County is estimated at 1012709 people (male: 48%, female: 52%) with Mwingi Central having 151510 people 1(male; 72315, female; 79195) (Kenya National Bureau of Statistics, 2019, National Census). From a public health perspective, Kitui records an annual average of 400 mortality cases from various cancer (Ministry of Health, Kenya).

3.3: Target population.

The entire set of elements to which the investigator hoped to generalize the investigation's results and satisfy the eligibility requirements was the target population (universe) for this investigation. This therefore, was all beekeepers in Mwingi Central Sub County that met the inclusion criteria (Mulati, 2016), namely those that had owned an apiary and practiced beekeeping for at least two years, are residents of the area, 18 years old and above and gave voluntary consent to participate.

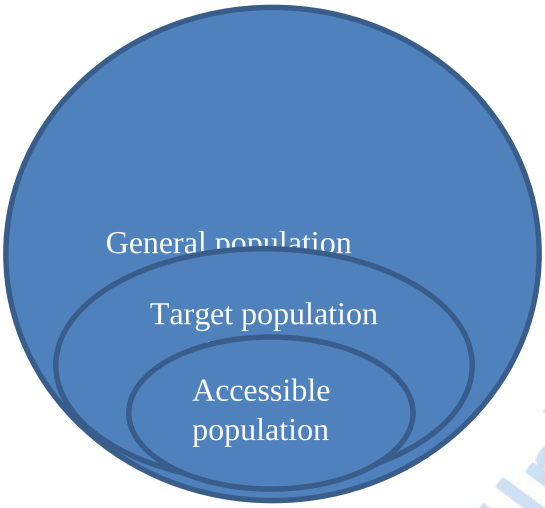


FIGURE 3.1. RELATIONSHIP BETWEEN GENERAL, TARGET AND ACCESSIBLE POPULATIONS.

SOURCE: A LITERATURE REVIEW BY THE RESEARCHER

3.3.1: Size of the Sample determination.

For this research, sample size determination was based on Yamane,1967: $n = \frac{N}{1+N\,(e)^2}$

Where n=desired size of the sample,e= probability of error i.e. the anticipated precision, 0.05 for 95% confidence level, N=estimated population size. Given that the population was 150,000 people in Mwingi sub County, (Kenya National Census(KNBS), 2019), the formula $n = \frac{150{,}000}{(1+150{,}000) \text{ x } (0.05)^2} = 399.9$ was applied. Therefore, the sample population for this study was 400 participants.

3.4: Sampling procedure and techniques.

Probability or random sampling methods were employed in this investigation to enable everyone in the population to have an equal opportunity for selection. Purposive sampling was employed to select the county (Kitui) with beekeeping and relatively high honey production. Simple random sampling was applied in selecting wards, villages, and households for inclusion in the study sample. A sampling frame was obtained from Mwingi Sub- County agricultural offices. The researcher used the lottery method where each population member *N* was given a unique identifier placed in a box and thoroughly mixed followed by a blind-fold selection of *n* numbers. The respondents were randomly and purposively selected from the selected sites with the assistance of staff from the County Department of Agriculture and the local leadership. The participants were then briefed before their consent sought to participate in the investigation. Under Stratified random sampling, the population was sub divided into strata based on engagement in both smallholder vegetable farming and beekeeping for fair representation. This ensured that small subgroups (strata) were represented proportionally to their part of population.

The apiaries from which honey samples were to be obtained were serially numbered and randomly selected using random numbers generation.

3.5: Inclusion criteria/ Exclusion criteria.

3.5.1: Criteria for Inclusion

In this study, only those that engaged in both smallholder vegetable farming and owned an apiary and practiced beekeeping for at least last two years, are residents of the area, are 18 years old and above and gave voluntary consent for participation were included.

3.5.2: Elimination criteria.

In this study, those not meeting the inclusion criteria or are middle-men in honey trade were excluded.

3.6: Data gathering instruments.

The findings designed a questionnaire for this study as a set of questions for gathering information, and for the participants to respond to in a predetermined format (see appendix v: questionnaire for beekeepers in Mwingi, Kitui County). The choice of the questionnaire was because it is low cost and quick to administer.

3.6.1: Test of Reliability.

To avoid random error, the researcher subjected the questionnaire to a test of reliability by use of test-retest method. This technique entailed administration of the same tool twice to the same set of elements. A time lapse in between of a week or more was allowed, while keeping the initial conditions constant. The scores from both tests were then correlated and coefficient alpha determined using Cronbach formula as stated below,

where n is the number of items, vi is the variance of the item score, and Vt is the variance of the total scores:

$$\alpha = \frac{n}{n-1}\left(1 - \frac{\sum_i V_i}{V_t}\right) \quad \text{(Cronbach, 1951, p. 299)}$$

FIGURE 3.2. FORMULA FOR COEFFICIENT ALPHA;

SOURCE: CRONBACH, L. J. (1951)

Reliability of 0.70 or better (but not much beyond than 0.80) was used in this study as recommended for basic research (Nunnally, 1978).

3.6.2: Test of Validity.

Content-validity, or the degree to which data obtained from a particular tool is approximate to the content of a specific idea, was used to validate the survey's results. The tool was given to two sets of professional colleagues at vet labs, Kabete for appropriateness by requesting them to rate it at face value using a Likert scale (McLeod, S. A. 2013): extremely suitable for a given purpose-1, very suitable for that purpose-2; adequate-3; inadequate-4; irrelevant and therefore unsuitable-5.

3.6.3: Data collection methods.

After testing the questionnaire for reliability and validity, a pretest of the instrument was done at Mwingi ward. This being the sixth ward and having been used for pretesting the questionnaire was later to be left out of the study sites. Consent from the participants was sought before data collection as per appendix vi (informed consent form for beekeepers in Mwingi central sub-county, Kitui county, Kenya). The respondents were partly gathered in one place, given instructions and allowed to fill out the questionnaire. To others, the questionnaires were hand delivered. Following that, four hundred (400) participants were given an organized survey by extension employees who had previously held interviewing training. After being completed, the surveys were given back to the investigator for review.

3.7: Laboratory techniques

In the present investigation, methods in the laboratory included collecting honey samples, preparing samples, separating residues, and quantifying them. The present investigation used Liquid Chromatography in conjunction with Tandem Mass Spectrometry (LC-MS/MS), as recommended by Y.A. Naggar et al. (2015). This was detecting pesticides with thermo-labile compounds in honey, especially the pesticides currently being developed. This was informed by the inherent qualities in LC-MS/MS based on its selectivity, sensitivity and broad analytical scope. This made it easier to detect the chemicals at small levels in complex matrices and thus improve sensitivity with minimal matrix effect.

3.7.1: Honey sample collection

The percentage of farmers who practiced both small-scale farmers vegetable growing and beekeeping was used to choose the honey specimens. Seventy-five (75) honey samples were specifically assigned to each of the five wards (Kivou, Nguni, Nuu, Mui, and Waita) in Mwingi Central Sub-County, Kitui County, for the purpose of this investigation. To calm the bees, five- to -ten puffs of smoke into the hive was used before a frame with honey comb removed (Mulati, 2016). By use of a sterile blade, a honeycomb (15g) was excised and honey squeezed and put in a clean 50cc falcon tube capped with appropriate labels. A total of 375 honey samples were purposively collected. These were then placed in a cool box for transport to the Chemistry test center at Vet labs, Kabete, Nairobi, Kenya for residue analysis.

3.7.2: Preparation of sample

As shown in figure 3.3 below, specimens of honey were made using the Quick, Easy, Cheap, Effective, Rugged, and Safe (QuEChERS) approach (Anastassiades et al., 2003).

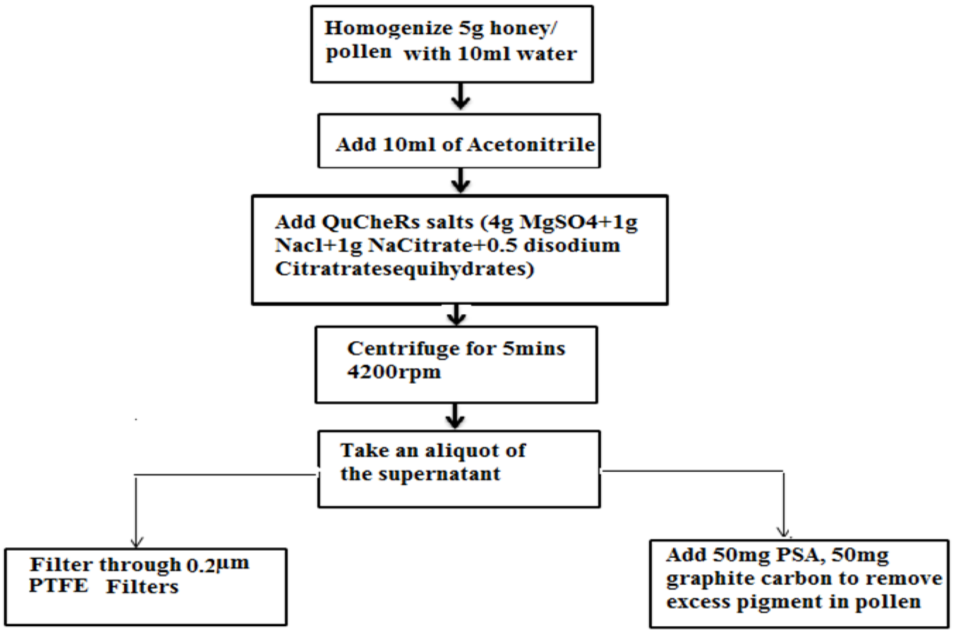


FIGURE 3. 3: PREPARATION FOR SAMPLE FLOW FOR QUECHERS METHOD.

SOURCE: (ANASTASSIADES ET AL.,2003)

For the removal and division phase of the QuEChERS method, sodium chloride and magnesium sulphate were utilized. This was accomplished by washing the samples with dispersive solid phase extraction (Dspe) after salting them out (see figure 3.4 above).

The sample preparation method for this study was therefore a multi-residue assay with recoveries closer to 100%, and able to eliminate contaminants for improved selectivity and concentrating analytes. Care was taken in sample preparation because it is the step that is critical in the analysis and also prone to mistakes leading to compromise of results (M.W. Kujawski, J. Namiesnik, (2011).

3.7.3:sample residue separation and quantification

According to Irungu, J. et al. (2016), a 50 cc falcon tube containing 5 g of sample and 10 cc water was homogenized. Ten cc of acetonitrile was then added, along with four grams of sulfate of magnesium, one gram of chloride of sodium, one gram of trisodium citrate dehydrate, and half a gram of disodium hydrogen citrate sesquihydrate. After that, this was centrifuged at 4200 rpm for 5 minutes. After that, aliquots of the supernatant were taken and put into different tubes for either disinfect up or no cleanup whatsoever. The final solution (1cc) was then ready for LC-MS/MS for analysis (figure 3.4 below). A sample concentration step through evaporation was done to separate Organochlorines, organophosphates and Pyrethroids in honey (Wiest et al. 2011).

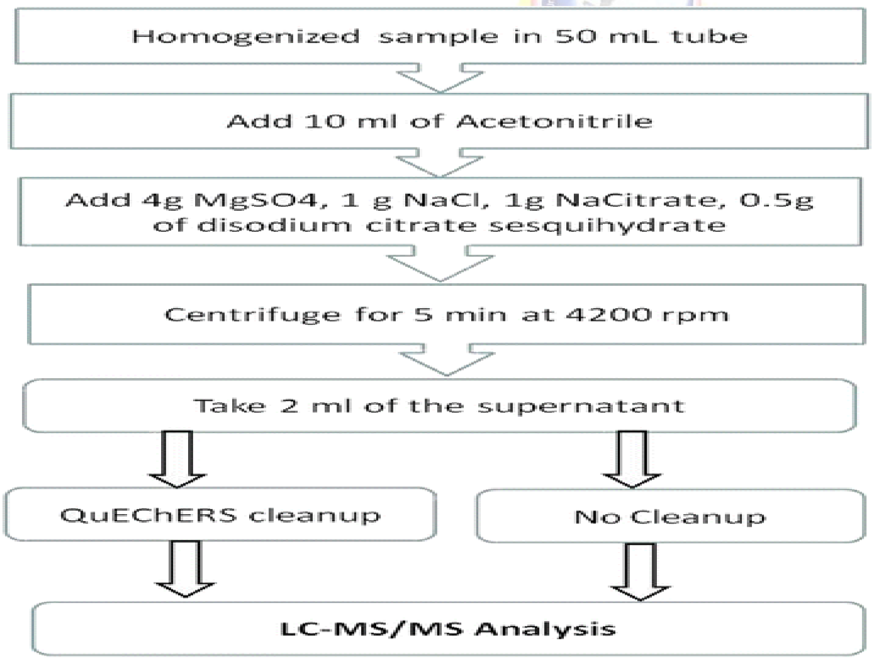


FIGURE 3.4. SCHEMATIC LC-MS/MS ANALYSIS FLOW CHART.

SOURCE: JANET IRUNGU ET AL 2016

3.7.4:sample residue quantification

Peaks of the analyte with a concentration that is unidentified were compared to reference standards with known concentrations that were run at the same analytical settings as samples in order to ascertain the amounts of the recognized pesticides (Irungu et al., 2016). For each target analyte, two (2) transition ions were used for detection. Quantities were provided by the dominant transition ion, while the second intense ion served as confirmation. As advised by the guidelines (SANCO/12571/2013), the LC-MS/MS was utilized to measure residues in g/kg and deliver a combination of qualitative and quantitative results.

3.7.5: Laboratory Quality control.

The developed method for pesticide residue analysis was validated as per SANCO/12571/2013. The process of validation entailed recovery, linearity, limit of quantification (LOQ), matrix effects among others. For each pesticide analyte, typical solutions with known and rising concentrations were used for calibrations. While the other components, including LOQ and LOD, were based on the SANCO (2013) mechanism, the resultant calibration curve was used to figure out the Limit of Reporting (LOR) and Limit of Detection (LOD).

3.8: Analysis of Data and presentation.

Data from the questionnaires were coded and analyzed using Bivariate associations, multivariate analysis, Chi-square, one sample t-test and SPSS. Descriptive statistics-percentages, graphs and frequency distribution tables were used for data presentation (Junyong In and Sangseok Lee, 2017). Text was employed to elucidate findings and tendencies and contextualizing the info. Tables displayed raw data in rows and columns for comparisons, while graphs were for display of data that shows trends and relationships within the data. A bar chart displayed data in separate columns for comparison between discrete categories.

3.8.1: Models for Statistical test for hypothesis.

Two statistical models to test the associations between the variables were deployed in this study.

3.8.1.1: Model 1: multiple linear regression models.

This model assessed the association between the variables that were independent and a single continuous variable that was dependent using the equation: $Y_t = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 +$ where: Y_t: dependent variable (residue levels in raw honey), α: A Constant (the vertical section intersection with Y axis and equals to the values of variables that was dependent where the independent variables coefficients are zero: The Y intercept population parameter. X are the independent variables:X_1: Socio-demographic factors, X_2**:** Pesticide use -related factors, X_3: Type of pesticides used, X_4: concentrations of pesticide used, X_5 Relationship between independent Variables and Dependent Variable. β_1, β_2, β_3, β_4, represent the coefficient values of the independent variables i.e. the slope population parameter, έ; Error term; the unexpected variation in Y

3.8.1.2: Model 2: The Chi-square test.

Assessing the probability that the observations would be made if the null hypothesis were assumed to be true was the aim of the test. So, the test was carried out to compare observed and expected frequencies, i.e., to see if the observed average frequency of a variable attribute matches the theoretical one. This test was used in the investigation to evaluate the hypothesis. Chi-squared is calculated as follows: C^2 is the chi-square, O is the observed value, E is the expected value, i is the ith position in the contingency table, ∑ is the sum of, and K is the number of attribute categories there are.

$$c^2 = \sum_{i=1}^{k} \left[\frac{(O_i - E_i)^2}{E_i} \right]$$

FIGURE 3.3. FORMULA FOR CHI-SQUARE TEST:

SOURCE: GREENWOOD, P.E ET AL. (1996)

3.9: Ethical considerations in this research.

Before this study was conducted, ethical approval was sought and gotten from MKU Ethics Review Committee. An introductory letter was then sought and obtained from Mount Kenya University, School of Post-Graduate Studies to facilitate application for clearance from NACOSTI (Kenya) to collect data. After receiving approval from NACOSTI (Kenya), the Ministry of Education and the County Government of Kitui were consulted in order to obtain the necessary authorization and permission to carry out this investigation at the chosen location (Appendices V, VI, & VII).

3.9.1: Confidentiality.

Subjects were informed that the investigation's sole goal was academic, and they were given the guarantee that any info they provided would be kept discrete and not shared with outside parties.

3.9.2: Anonymity.

Subjects in this investigation were guaranteed anonymity regarding their names, titles, and places of residence, among other things, and that the final analysis would not use any of these details. Furthermore, rather than the subjects identities, the main focus of the findings from the research was to be the discussions' content.

3.9.3: Informed consent.

Informed consent was sought from the participants indicating that they understood their role as participants in research. It was also made clear to the participants on what was required of them and their right to opt out of the study if need arose. The Ethics Consent Form (See appendix I: Informed consent form for beekeepers in Mwingi Central, Kitui County, Kenya) for their signature included questions confirming that respondents had read and understood the background information provided. That they were also volunteers, recognized the possible demands on them and their remedy and had acknowledged that they could withdraw at any time.

3.9.4: Respect for persons.

This study strove to respect human dignity, privacy, and autonomy of the participants through respect for culture and community norms.

3.9.5: Safety of the respondents.

Despite not using human subjects, where the goal is to decrease harm and maximize benefits to subjects, consent that is informed, protective gear, anonymity, and respecting the right to withdraw from the investigation at any point during the course of the investigation were all used to ensure that participants were secure.

3.9.6: Professional practice.

This study strove to adhere to professionalism through responsible publication with the aim of publishing to advance research and scholarship. The study also adhered to relevant laws, institutional and governmental policies, and honest reporting of results. Further, the researcher maintained good records of activities in the study and acknowledged all contributors to the study.

CHAPTER FOUR

RESEARCH FINDINGS AND DISCUSSION

4.0. Introduction.

This chapter provides the investigation findings from investigation questionnaires and laboratory analysis addressing the four (4) research questions of the study. The chapter has been structured to be consistent with the research objectives of the study stated in chapter one, and further provides an interpretation of the analyzed data. The findings are compared to other empirical studies and plausible explanations for the observations provided.

4.1. Research Presentation, Interpretation and Discussions.

Below are the respondents who participated in the research as described and the research findings presented in tables, figures, and graphs.

4.1.1: Rate of questionnaire return.

Three hundred seventy-five (375) out of a total of four hundred (400) questionnaires given out were returned duly and properly completed. This translates to 94% response rate (table 4.1 below). The rate of questionnaire return was therefore satisfactory.

TABLE 4.1: RATE OF QUESTIONNAIRE RETURN.

Respondents n=375	**No. of questionnaire distributed**	**No. of questionnaire returned**	**Rate of questionnaire return %**
Male	200	190	95 %
Female	200	185	92.5%
Total	400	375	94 %

SOURCE; STUDY FINDINGS BY RESEARCHER.

4.1.2: Pesticide residue Recovery and positivity rates in Raw Honey.

Each ward was assigned seventy-five (75) samples (Table 4.2 below).

A total of 375 honey samples were therefore purposively collected from 5 wards **(**Kivou, Nguni, Nuu, Mui, Waita in Kitui County, Mwingi Central.

TABLE 4.2; SAMPLES PER WARD

Ward		Kivou	Nuu	Nguni	Mui	Waita	Total
No. samples	**n=375**	75	75	75	75	75	375
No.positive		58	43	56	62	54	273
Non. negative		17	32	19	13	21	102

SOURCE; STUDY FINDINGS BY RESEARCHER.

In all the three hundred seventy-five (375) honey samples tested, (273) or (73%) of the samples were positive for the pesticide residues analyzed. One hundred and one (101) or (27%) honey samples were negative for the pesticide residues tested (table 4.3) below.

TABLE 4.2: PESTICIDES PREVALENCE IN RAW HONEY.

Pesticide detection n=375	Freq.	Percent (%)
Positive	273	73
Negative	102	27
Total	375	100

SOURCE; STUDY FINDINGS BY RESEARCHER.

4.1.3: Pesticide residue types found in Raw Honey.

The most widespread pesticide group found in this study was Neonicotinoids (mean frequency 5.6 %), (table 4.4 below). This was followed by organophosphates at 5.3 %, synthetic Pyrethroids at 4.2 %, carbamates at 2.9 %.

The least widespread pesticide group was organochlorines with 2.1 %.

Table 4.4 below provides a summary of the frequency of detection of specific pesticides.

TABLE 4.3: FREQUENCY OF DETECTION OF SPECIFIC PESTICIDES.

Pesticide Group	Type of pesticide detected	No. detected	Frequency of detection %	Mean frequency %
Carbamates	Fenobucarb	8	2.9	2.9
Synthetic Pyrethroids	Permethrin-1	15	5.49	
	Cyfluthrin	8	2.9	
	Cypermethrin	4	1.46	4.15
	Deltamethrin	0	0.0	
	L-Cyhalothrin	30	10.9	
Organophosphates	Quinalphos	15	5.49	
	Diazinon	8	2.9	
	Malathion	11	4.02	
	Dimethoate	4	1.46	
	Chlorpyrifos	52	19.0	5.31
	Parathion	4	1.46	
	Phenthoate	8	2.9	
Organochlorines	oa'-DDT	11	4.03	
	Aldrin	4	1.46	
	Dieldrin	4	1.46	
	Heptachlor	4	1.46	2.14
	p, p-DDE	4	1.46	
	p, p'-DDT	4	1.46	
	Alachlor	8	2.9	
	Methoxychlor	8	2.9	
Neonicotinoids	Thiacloprid	8	2.9	
	Clothianidin	8	2.9	5.6
	Imidacloprid	8	2.9	
	Thiamethoxam	38	13.9	

SOURCE; STUDY FINDINGS BY RESEARCHER.

4.1.4: Pesticide Residue Concentrations(mg/kg) in raw honey.

Tables 4.5 and 4.6 below illustrates the different pesticides residues found in raw honey.

Majority of the positive samples for pesticide residues had lower concentrations than the EU MRLs recommended standard of 0.05mg/kg for specific pesticides.

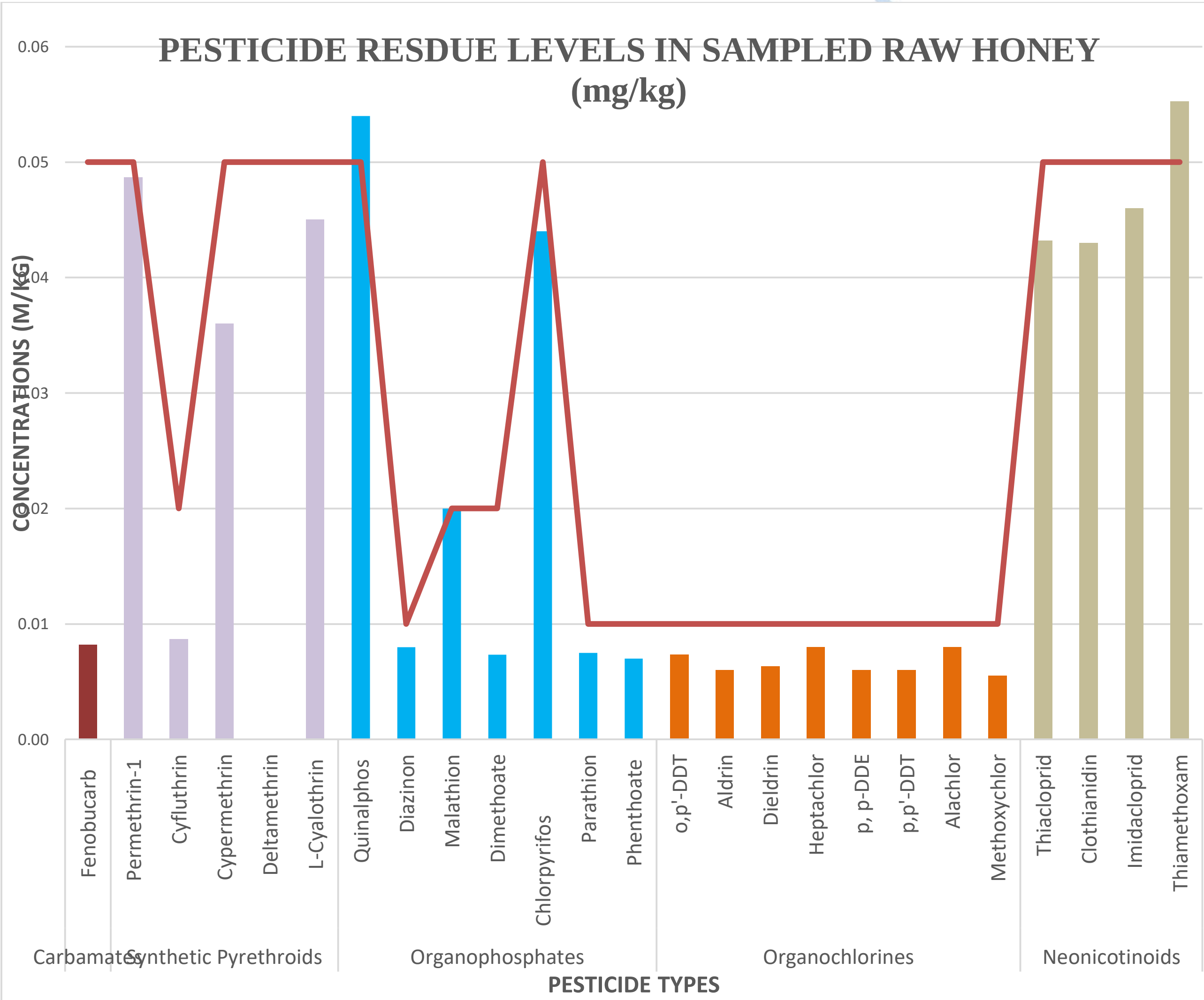
TABLE 4.4: PESTICIDE RESIDUE CONCENTRATIONS IN SAMPLES OF RAW HONEY.

Pesticide Group	**Type of pesticide detected**	**Mean pesticide residue concentrations (mg/kg) per site**					**Mean (mg/kg)**	***Default European Union MRL of 0.05mg/kg for Honey**
		Kivou	Nuu	Nguni	Mui	Waita		
Carbamates	Fenobucarb	0.009	0.007	0.009	0.007	0.009	0.01	0.050*
	Permethrin-1	0.049	0.049	0.048			0.05	0.050*
	Cyfluthrin	0.008			0.009	0.009	0.01	0.02
Synthetic Pyrethroids	Cypermethrin	0.042		0.046	0.046		0.04	0.050*
	Deltamethrin	0.00	0.00				0.00	0.050*
	L-Cyalothrin	0.047	0.043			0.045	0.05	0.050*
	Quinalphos	0.054	0.055		0.056		**0.055**	0.050*
	Diazinon	0.009		0.007	0.007	0.009	0.01	0.01
	Malathion	0.02		0.025	0.015		0.02	0.02
Organophosphates	Dimethoate	0.008			0.006	0.008	0.01	0.02
	Chlorpyrifos	0.042		0.044		0.046	0.04	0.050*
	Parathion	0.009		0.006			0.01	0.01
	Phenthoate	0.007	0.009		0.005	0.007	0.01	0.01
	o,p'-DDT	0.009		0.007		0.006	0.01	0.01
	Aldrin	0.003	0.009		0.006		0.01	0.01
	Dieldrin	0.006		0.008		0.005	0.01	0.01
Organochlorines	Heptachlor	0.009			0.007		0.01	0.01
	p, p-DDE	0.006	0.005		0.007		0.01	0.01
	p,p'-DDT	0.005				0.007	0.01	0.01
	Alachlor	0.007		0.009			0.01	0.01
	Methoxychlor	0.003			0.008		0.01	0.01
Neonicotinoids	Thiacloprid	0.045	0.04	0.046	0.042	0.043	0.04	0.050*

Clothianidin	0.048	0.045	0.042	0.037		0.04	0.050*
Imidacloprid	0.049		0.046		0.043	0.05	0.050*
Thiamethoxam	0.057		0.055	0.057	0.052	**0.06**	0.050*

SOURCE; STUDY FINDINGS BY RESEARCHER.

TABLE 4.5: GRAPH: PESTICIDE RESIDUE CONCENTRATIONS IN SAMPLES OF RAW HONEY.



SOURCE; STUDY FINDINGS BY RESEARCHER.

Only two (2) of the samples positive for pesticide residues had higher concentrations than the EU MRLs recommended standard. These were namely: Neonicotinoids (Thiamethoxam) with a mean concentration of 0.06 mg/kg, and organophosphate, Quinalphos 0.055 mg/kg (0.06). Those with pesticide residue levels equal to their MRLs were Imidacloprid (0.05mg/kg) and synthetic Pyrethroids: L-Cyhalothrin (0.05mg/kg) and Permethrin-1 (0.05mg/kg). The mean concentration of pesticide residues for Carbamates was 0.01 mg/kg, which is lower than the recommended European Union standards (0.05 mg/kg). Most Synthetic Pyrethroids, Organophosphates, carbamates, Neonicotinoids and organochlorides were within the recommended levels.

4.1.5: Socio-demographic characteristics of the study participants.

The socio-demographic factors examined in this study were; Age, occupation(income), and Education level (table 4.7 below).

TABLE 4.6: SOCIO-DEMOGRAPHIC CHARACTERISTICS OF STUDY PARTICIPANTS.

Gender	**Freq.**	**Percent%**
Male	190	50.6
Female	185	49.3
Total	375	100
Age	**Freq.**	**Percent%**
18-35	85	22.6
36-45	93	24.8
46-55	98	26.1
Above 56	99	26.4
Total	375	100
Level of Education	**Freq.**	**Percent%**
College/University	60	16
No education	50	13.3
Primary Level	133	35.5
Secondary Level	132	35.2
Total	375	100
Occupation	**Freq.**	**Percent%**
Business/Self Employment	132	35.2
Formal Employment	45	12
Informal Employment	189	50.4
Other	9	2.4
Total	**375**	**100**
Total n=375	**375**	**100**

SOURCE; STUDY FINDINGS BY RESEARCHER.

4.1.5.1: Age.

From the table above, males were 50.6 %, whilst females were 49.3%. This indicates that both gender was equally distributed. From the table above, 26% was for both aged 46-55 years old and above 55 years old. Youths (18- 45) were a combined 47%. Older respondents (45 years and above) were a combined 52.5% and thus the majority.

4.1.5.2: Education levels.

The participants had an equal proportion of 35% among those with the primary and secondary levels of school education. Those without any education accounted for 13.3 % of the total number of study participants.

4.1.5.3: Occupation.

Informal employment accounted for a half (50.4%), formal employment 12%, business/self-employment at 35.2%, while others were 2.4%. The study findings indicate that those on Less than a dollar per day (100/=) were 49 %, more than a dollar per day were 38 %, don't know 8%, and 5% were unwilling to respond.

4.1.6: Pesticide use-related factors

Pesticide –use related factors examined included: seasonal frequency of spraying livestock/crops, training on pesticide use and safety, and the frequency of interaction of the respondents with local extension officers. The tables 4.8 to 4.11 below illustrate the study findings;

4.1.6.1: Seasonal Frequency of Pesticides use among study participants.

TABLE 4. 7: FREQUENCY OF SPRAYING LIVESTOCK/CROPS.

Spray Livestock n=375	**Freq.**	**Percent.%**
Fortnightly	186	49.6
Monthly	57	15.2
Quarterly	54	14.4
Weekly	78	20.8
Total	375	100
Frequency spraying crops	**Freq.**	**Percent.%**
Fortnightly	229	61.1
Monthly	75	20.0
Quarterly	47	12.5
Weekly	24	6.4
Total	**375**	**100**

SOURCE; STUDY FINDINGS BY RESEARCHER.

About half of study participants (49.6%) sprayed pesticides on their livestock every fortnight,20.8% sprayed every week, 15.2% on a monthly and 14.4% sprayed every quarter. Regarding spraying crops, 61.1% sprayed every fortnight, 20% monthly, and only 6.4% every week (table 4.8 above). Majority of participants therefore sprayed their livestock and crops with pesticides fortnightly.

4.1.6.2: Training on Pesticides use and safety.

Majority of study participants 64.5% had not received any training on pesticide usage and safety, only 35.5 % had obtained training on pesticide use (Table 4.9 below).

TABLE 4. 8: TRAINING ON PESTICIDE USE AND SAFETY.

Training on pesticides use and safety	Freq.	Percent
No	242	64.5
Yes	133	35.5
Total n=375	**375**	**100**

SOURCE; STUDY FINDINGS BY RESEARCHER.

Qualitative responses noted those who had received training were trained by agricultural extension workers from the county government. *"I was trained by officers from the agriculture at a Baraza on how to mix, spray and on the frequency of spraying pesticides (Un un-named study respondent, Nuu ward).*

4.1.6.3: Frequency of Interaction with local extension workers.

Table 4.10 below shows frequency of interaction of the respondents with local extension officers.

TABLE 4.9: FREQUENCY OF INTERACTION WITH LOCAL EXTENSION OFFICERS.

Interaction with Local Extension Officer	Freq.	Percent
Monthly	189	50.4
Weekly	7	1.9
Never	179	47.7
Total n=375	**375**	**100**

SOURCE; STUDY FINDINGS BY RESEARCHER

About half of the study participants in the survey (50.4 %) attested to having interacted with local extension officers monthly. Only 1.9% interacted with local extension workers every week. A whole 47.7% had never interacted with local extension workers.

4.1.6.4: Self-Rated Accessibility to Market information

Respondents were asked to provide self-rated accessibility to market information on pesticide use and safety.

TABLE 4.10: SELF-RATED ACCESSIBILITY TO MARKET INFORMATION.

Rate	Freq.	Percent %
Very Good	8	2.1
Good	178	47.5
Poor	105	28.0
Very poor	84	22.4
Total n=375	**375**	**100**

SOURCE; STUDY FINDINGS BY RESEARCHER.

The results showed that 47.5% self-rated themselves as good in accessing market information, 28% claimed they were poor, 22.4% were self-rated as very poor and only 2.1% were very good in accessing market information on pesticide use and safety.

4.2: Test of Hypothesis.

This study hypothesized that;

Ho: Socio-demographic/pesticide use -related factors and pesticide types are not significantly associated with pesticide residue presence in raw honey in Mwingi, Kitui County, Kenya.

H_1: Socio-demographic/pesticide use -related factors and pesticide types are significantly associated with pesticide residue presence in raw honey in Mwingi, Kitui County, Kenya.

The hypothesis was subjected to bivariate, Chi^2 test and multivariate analysis from logistic regression. The analytical finds were the presented in tabular form.

Tables 4.12 to 4.15 below are the findings;

TABLE 4.11: BIVARIATE ASSOCIATION, PESTICIDE USE RELATED FACTORS ON PESTICIDE RESIDUES IN RAW HONEY.

Pesticide use related factors on pesticide residues in raw honey			
Frequency of spray crops	**Negative**	**Positive**	***χ^2(df), p-value***
Fortnightly	32(14%)	197(86%)	***61.11(3), p=0.0001****
Monthly	44(58.7%)	31(41.3%)	
Others	18(38.3%)	29(61.7%)	
Weekly	8(33.3%)	16(66.7%)	
Frequency of spray Livestock			
Fortnightly	39(21%)	147(79%)	***60.29(3),p=0.0001****
Monthly	38(66.7%)	19(33.3%)	
Others	17(31.5%)	37(69.5%)	
Weekly	8(10.3%)	70(89.7%	
Training on Pesticide Use and Safety			
No	84(34.7%)	158(65.3%)	***20.65(2),p=0.0001****
Yes	17(12.8%)	115(87.1%)	
Frequency of Interaction with Local Extension Officers			
Monthly	33(17.5%)	156(82.5%)	***Fisher's Exact Test, p=0.0001****
Weekly	67(37.4%)	112(62.3%)	
Never	2(28.6%)	5(71.4%)	
Self-Rated Accessibility to Market Information			
	Negative	Positive	
Good	44(24.7%)	134(75.3%)	***10.98(3), p=0.012****
Poor	40(38.1%)	65(61.9%)	
Very Poor	15(17.9%)	69(82.1%)	
Very good	3(37.5%)	5(62.5%)	

***p<0.05**

SOURCE; STUDY FINDINGS BY RESEARCHER.

4.2.1: Bivariate Associations.

Table 4.12, shows statistical significance observed on frequencies of spraying crops with pesticides, χ^2 *(61.11, df=3, p=0.0001)* and livestock. χ^2*(60.29df=3, p=0.0001)*. Similarly, statistical significance (*p< 0.05) on training on pesticide use χ^2 (*20.65(2), p=0.0001)*. Interaction with local agricultural extension officers (fishers Exact *p=0.0001***)**, and self-rated efficacy to access market information χ^2(*10.98 df=3, p=0.012***)** is observed.

TABLE 4.12: MULTIVARIATE ANALYSIS.

Multivariate analysis from logistic regression. Notes *** p<.01, ** p<.05, * p<.1

Factors					[95% Co	Interval]	Sig
Training on Pesticides use and safety	**Coef.**	**St. Err.**	**t-value**	**p-value**	**Lower**	**Upper**	
No	1						
Yes	3.493	1.595	2.74	***0.006***	1.427	8.549	***
Frequency of Spraying Crops							
Fortnightly	1						
Monthly	0.273	0.118	-3.01	***0.003***	0.117	0.636	***
Quarterly	0.391	0.172	-2.13	***0.033***	0.165	0.927	**
Weekly	0.219	0.131	-2.55	***0.011***	0.068	0.705	**
Frequency of Spraying Livestock							
Fortnightly	1						
Monthly	0.443	0.206	-1.75	0.081	0.178	1.104	*
Others	1.426	0.659	0.77	0.443	0.576	3.53	
Weekly	5.059	2.788	2.94	**0.003**	1.718	14.896	***
Frequency of Interaction with Local Extension Officers							
Monthly	1						
Weekly	0.366	0.149	-2.47	***0.013***	0.165	0.812	**
Never	0.466	0.444	-0.8	0.423	0.072	3.011	
Self-Rated Accessibility to Market Information							
Good	1						
Poor	2.064	0.856	1.75	0.081	0.916	4.651	*
Very Poor	3.942	1.874	2.88	***0.004***	1.552	10.011	***
Very good	0.307	0.256	-1.42	0.156	0.06	1.57	
Constant	3.328	1.234	3.24	0.001	1.609	6.883	***
Mean dependent var		0.73		SD dependent var.			0.445
Pseudo r-squared		0.245		Number of observations			374
Chi-square		106.754		Prob> chi2			*0.0001*

TABLE 4.13: TABULATION OF SOCIO-DEMOGRAPHIC CHARACTERISTICS: OCCUPATION AND LEVEL OF EDUCATION.

Socio-demographic characteristics and Pesticides Concentration Residues in Honey

Occupation	Pesticide Concentration Negative	Positive	Total	Pearson Chi^2
Business/Self Employment	31	101	132	
Formal Employment	8	37	45	
Informal Employment	63	126	189	Fisher's Exact *p*= ***0.0195****
Other	0	9	9	
Total n=375	**102**	**273**	**375**	
Level of Education	**Negative**	**Positive**	**Total**	
College/University	18	42	60	
No education	23	27	50	*df=21.38,**p=0.0001****
Primary Level	42	91	133	
Secondary Level	19	113	132	
Total n=375	**102**	**273**	**375**	

***significant at p<0.05**

TABLE 4.14: TABULATION OF PESTICIDES CONCENTRATION AND AGE;

Tabulation of Pesticides Concentration							
	Age						
Pesticide Concentration	18-25	26-35	36-45	36-46	46-55	Above 55	Total
Negative	3	18	28	0	26	27	102
Positive	4	58	65	2	72	72	273
Total	7	76	93	2	98	99	375
Pearson Chi^2	2.51						
Prob.	**0.7753**						

Notes: *** p<.01, ** p<.05, * p<.1

SOURCE; LITERATURE REVIEW BY RESEARCHER.

4.2.2: Multivariate Analysis.

Table 4.13 shows that spraying of crops monthly, weekly, quarterly was a predictor of the presence of pesticide residue in raw honey. Frequencies of spraying crops χ^2 (*61.11, df=3, p=0.0001)* and livestock. χ^2*(60.29df=3, p=0.0001),* Training on the use of pesticide χ^2 (*20.65(2), p=0.000),* Interaction with local agricultural extension officers (fishers Exact *p=0.0001***)**, and self-rated efficacy to access market information χ^2(*10.98 df=3, p=0.012***)** were found to be statistically noteworthy.

Tables 4.14 and 4.15 above show logistic regression model. Logistic regression model was able to predict 44.5% of independent variables in the entered data. Occupation

(Fisher's Exact *p*= **_0.0195*)_** was statistically associated with pesticide residues in raw honey in the study area. Levels of education (*df=21.38,* **_p=0.0001*)_** were found to be statistically significant. Age (P=**0.7753**) was not statistically significant (Table 4.15) above.

TABLE 4.16: ONE SAMPLE T-TEST FOR PESTICIDE RESIDUE TYPES AND CONCENTRATIONS

					[95% Conf.Interval]		
Variable	**No of honey sampled per locations**	**Mean Concentrations mg/kg from locations**	**Std. Err.**	**Std. Dev.**	**Lower**	**Upper**	**p-value**
fenobucarb	5	0.008	0.000	0.001	0.007	0.010	**_0.0001*_**
permethrin1	3	0.049	0.000	0.001	0.047	0.050	*0.0572*
cypermethrin	3	0.045	0.001	0.002	0.039	0.050	*0.0572*
lcyalothrin	3	0.045	0.001	0.002	0.040	0.050	**_0.049*_**
quinalphos	3	0.054	0.001	0.002	0.049	0.059	*0.0742*
diazinon	4	0.008	0.001	0.001	0.006	0.010	**_0.0001*_**
malathion	3	0.020	0.003	0.005	0.008	0.032	**_0.0091*_**
dimethoate	3	0.007	0.001	0.001	0.004	0.010	**_0.0002*_**
chlorpyrifos	2	0.043	0.001	0.001	0.030	0.056	*0.093*
parathion	2	0.008	0.002	0.002	-0.012	0.027	**_0.0255*_**
phenthoate	4	0.007	0.001	0.002	0.004	0.010	**_0.0001*_**
opddt	3	0.007	0.001	0.002	0.004	0.011	**_0.0004*_**
aldrin	3	0.006	0.002	0.003	-0.001	0.013	**_0.0015*_**
dieldrin	3	0.006	0.001	0.002	0.003	0.010	**_0.0004*_**
heptachlor	2	0.008	0.001	0.001	-0.005	0.021	*0.0152*
ppdde	3	0.006	0.001	0.001	0.004	0.008	**_0.0004*_**
ppddt	2	0.006	0.001	0.001	-0.007	0.019	**_0.0145*_**
alachlor	2	0.008	0.001	0.001	-0.005	0.021	**_0.0152*_**
methoxychlor	2	0.006	0.003	0.004	-0.026	0.037	**_0.0357_**
thiacloprid	5	0.043	0.001	0.002	0.040	0.046	**_0.0031*_**
clothianidin	4	0.043	0.002	0.005	0.036	0.050	*0.0584*
imidacloprid	3	0.046	0.002	0.003	0.039	0.053	*0.1472*
thiamethoxam	4	0.055	0.001	0.002	0.051	0.059	**_0.0212*_**

Notes: * p<.05

SOURCE; STUDY FINDINGS BY RESEARCHER.

Tables 4.16 above show one sample t-test was utilized to assess the statistical difference in pesticide concentration residue levels in honey sampled in four locations against the minimum recommended EU level of 0.05 mg/kg. The bolded results have a statistical difference in pesticide concentrations.

4.3: Discussion of Individual Objective Results.

The goal of the investigation was to identify the factors that contribute to the current public health concern of pesticide residues in honey that is raw in Mwingi Sub-County, Kitui County, Kenya. The results are discussed below.

4.3.1: Socio-demographic characteristics of the study participants.

Age, occupation, and educational attainment were the sociodemographic traits of the study subjects that were examined, as will be covered in more detail below.

4.3.1.1: Age.

In this study, an equal proportion of study participants 26% were aged 46-55 years old and above 55 years old. Youthful respondents (18- 45) were a combined 47%, a minority. Older respondents (45 years and above) were a combined 52.5% and thus the majority.

Age (P=**0.7753**) was not statistically significant. However, studies show that youthful farmers are more flexible in making decisions on adoption of new ideas. On the contrary, older farmers do not trust new ideas, including new technology (Belay T. Mengistie et al. 2015). A respondent thus explained: ‘A number of older farmers still hold DDT in high esteem, associating it with their first improved farm yields or those of their forefathers’. Given the above observations and the majority in this investigation being elderly, presence of pesticide residues in honey in the sampled sites could be attributed to old age.

4.3.1.2: Occupation.

This study found that participants in informal employment was at half (50.4%), while 12% had formal employment. Business/Self Employment at 35.2%, while others were 2.4%. The findings in this study are in concurrence with Kitui CIDP (2018-2022) report that indicates that Kitui County has a high unemployment rate attributed to a lack of vocational skills. Analysis of the findings in this study indicate that; Occupation (Fisher's

Exact *p*= ***0.0195*)*** was statistically associated with pesticide residues in raw honey in the study area. This seems to agree with the finding that income is vital for the improvement of smallholder agriculture and informs the purchase and choice of farm inputs (pesticides) by the farmer (Otieno et al., 2010). In another investigation, Belay T. Mengistie et al. (2015) found that farmers from lower-income groups bought cheap but broad-spectrum and likely toxic pesticides available on the open market as opposed to those from higher-income groups who most likely bought proper pesticides from official channels. Further 21% of the respondents indicated that ability to afford or the price of the pesticide was at the top of their selection consideration. But according to Islam et al. (2016), wealthy farmers used extremely dangerous pesticides more frequently than small and medium-sized farmers.

4.3.1.3 Education.

Regarding respondents' level of education, the respondents had an equal proportion of 35% among those with primary and secondary levels of school education. Those who reported having not received any education accounted for 13.3 % of the total number of study participants. Levels of academic achievement have been shown to be statistically significant in this study (df=21.38, p=0.0001*). This supports claims that low literacy levels in Kitui County are caused by low transition rates, poor enrollment, high secondary school dropout rates, and insufficient educational facilities (Kitui CIDP 2018-2022). Similarly, a study by Fatmawati et al.,2018 found a significance between education level and farmer behaviour in deployment of agro ecological technology. Migration to sustainable agriculture that is eco-friendly was also found to be influenced by education (Maini, E.et al.,2021, and Melchior, I.C. ,2021). Literate farmers therefore, understand better and are more aware of public health and environmental concerns of pesticide use as compared to those that are illiterate. Illiteracy or semi-literacy is therefore associated with poor reading skills. Further, an illiterate farmer will not read the directions about proper pesticide use.

4.3.3: Pesticide use- related factors.

Training on Pesticides use and safety, seasonal frequency of pesticide use, and interaction with local extension officers were investigated. The findings are discussed below.

4.3.3.1: Training on pesticides use and safety.

According to descriptive statistical analysis, 65% of research participants lacked any instruction on proper utilization of pesticides. Additionally, the inferential analysis demonstrates that the presence of pesticides in raw honey was statistically significantly correlated with training on the application of pesticides and safety (p=0.0001*).

This finding is consistent with a survey (Kapeleka et al.,2021) where it was established that 89% of sampled smallholder vegetable producers had not received training in pesticides use and safety. As M.P. Ali et al. (2020) concluded, pesticide use protective behavior of farmers is largely as a result of inadequate knowledge and both government and pesticide retailer's inertia. Further, knowledge and training by farmers on proper pesticide handling in the developing world is limited and as such, they do not handle these products well (Wumbei et al.,2019). This necessitates continuous pesticide safety education and training to farmers. Therefore, a proper system to manage pesticides at end-user level is key in pesticide regulation (Shammi et al.,2020). As observed by Jones A. Kapeleka et al. (2021), there is a need for regular training for farmers and local extension workers on contemporary issues on pests and safety in the use of pesticides. The downside is, as observed by Wanjiru Warui et al. (2019), that the scarcity of data on honey quality trait, key in enhanced consumer trust and traceability for trade, calls for building capacities of honey producers through training along the value chain. To mitigate against this, therefore, a robust training on safe use of pesticides is needed.

4.3.3.2: Frequency of pesticide use on crops/livestock.

This study has shown that about half of study participants (49.6%) sprayed pesticides on their livestock every fortnight, while 61.1% sprayed crops every fortnight. Findings in this survey have shown that at least half of the study participants frequently sprayed their crops and livestock every two weeks. It is clear from the inferential evaluation that there was a significant correlation between the frequency of pesticide use (p=0.0001*) and the presence of pesticides in the honey that was raw sample. The idea that using various pesticides and spritzing more frequently is the only way to address pest issues is likely the reason for the heavy reliance on pesticides to control various diseases and pests (Jones A. Kapeleka et al., 2021). (Damalas CA, Khan M..2017). Similarly, it was discovered that the crop type and the current seasonal conditions determined the frequency of spraying (Belay T. Mengistie et al. 2015).

For instance, more spraying was done during rainy seasons when diseases and pests are more prevalent and crops like tomatoes need more frequent spraying. Additionally, the elevated rate of pesticide use was attributed to a number of factors, including low chemicals efficacy, an increase in illness and pest incidence, retailer coercion, and their technical advice. Wood et al. (2019) further agrees that areas with crops that are heavily sprayed with pesticides are candidates for bees to collect more contaminated nectar and pollen. Of note is that apiaries located in high potential areas frequently treated with pesticides show high contaminations of honey (Mulati, 2016). It is to be noted that a combination of increased application of pesticides in farms and low literacy levels creates fertile grounds for susceptibility to toxicity to human health and environment (M.P. Ali et al. 2020).

4.3.3.3: Frequency of Interaction with Local Extension Officers.

Findings in this study indicate that, only 1.9% interacted with local extension workers every week. A whole 47.7% had never interacted with local extension workers. Therefore, about half of the respondents interacted with officers on monthly basis and about half reported not to have interacted with the agricultural local extension officer. This outcome is consistent with Kapeleka et al. (2021), who found that 89% of those who participated had not heard from local extension agents regarding pesticides. Additionally, Rahaman et al. (2018) note that farmers primarily consulted pesticide retailers for advice on utilizing pesticides, with very few contacting government extension agents. According to an additional investigation, people who participated trusted and depended more on the advice of local leaders or the community regarding pesticides than they did on information from other sources. This is explained by the low levels of trust that exist between government extension agents, farmers, and pesticide retailers, all of which lead to pesticide misuse (M.P. Ali et al. 2020).

Subsequent investigation reveals a statistical correlation (p=0.013*) between the presence of residual pesticides in unprocessed honey and interactions with local extension agents of the government. Additionally, it has been noted that insufficient pesticide management training prevents extension agents from offering their clients adequate services regarding the appropriate use of chemical pesticides (Belay T. Mengistie et al. 2015).

Also to be noted is that an effective extension system that is able to build the capacity of the farming folks on pesticide safety and monitor them at farm levels can reduce misuse of pesticides and related health and environmental concerns (Jones A. Kapeleka et al. 2021). It is crucial to regularly train Extension employees on new and modern pest control topics as well as safe pesticide usage (Jones A. Kapeleka et al. 2021). In order to include small-scale farmers and beekeepers, public-based extension methods must be reorganized to be integrated and targeted at particular value chains.

It is reassuring that Governments and the international community e.g. FAO, WHO, and others are involved in programs to improve the behavior of farmers using pesticide including education, community interventions, and legislation (M.P. Ali et al. 2020).

4.3.4: Pesticide Residue Types and Concentrations in Raw Honey.

Tables 4.16 above show results of a number of pesticide types and concentrations with a statistical difference in pesticide concentrations. This study established that 73% of sampled raw honey had traces of pesticides in varying concentrations in comparison to the EU MRLs for specific pesticides. Organophosphates, carbamates, synthetic pyrethroids, and neonicotinoids were among the pesticide residues discovered. The results of the present investigation also concur with those of Kapeleka et al. (2019), who claimed that organic phosphate carbamates, and synthetic pyrethroids are among the most commonly utilized pesticides in developing nations. In a similar vein, 70% of samples tested positive by Saorla et al. (2021), albeit with concentrations below EU MRLs. This is also in line with Mitchell et al. (2017a), who found neonicotinoids in 79% of honey samples from Europe and noted that traces of pesticides in honey are common throughout the world.

This study further established that majority of the positive samples for pesticide residues had lower concentrations than the EU MRLs recommended standard of 0.05mg/kg for specific pesticides. The findings in this study agree with a similar study in Ghana which found that all pesticide residues recovered from honey samples were of very low concentration and lower than their respective EU MRLs and therefore posed no risk to consumers (Godfred Darko et al.,2017). Similarly, and according to Mitchell et al. (2017a), pesticide residue concentrations found in honey show considerable variations, but are usually lower than the recommended MRLs for human consumption. This is in contrast to earlier findings in Kenya and Ethiopia, where honey samples showed

Malathion pesticide residues at about twice the set Maximum Residue Limits (MRLs) of honey (Irungu, J et. al., 2016). This could be explained by the fact that there is a general tendency for farmers to use higher doses of pesticides than recommended. There is also false belief among farmers that higher doses translate to better result or as from experience when the recommended dosage proves ineffective (Belay T. Mengistie et al. 2015). Despite being illegal in their native nations, the rising export of synthetic pyrethroids, such as L-Cyhalothrin (0.05 mg/kg), to developing nations is the reason for their continued existence. A 2018 UNICEF report that claims that synthetic pyrethroids that are prohibited in the EU are being shipped to developing nations supports this. Contrary to the UN Sustainable Development Goals (SDGs), this is the case even though the significant long-term risks to the environment and public health are well known. Additionally, it has been discovered that a significant number of pesticides, estimated at 40% fake, enter Kenya from Tanzania and Uganda (Nampeera et al., 2019).

Neonicotinoids' capacity to linger and build up in the surroundings is responsible for the substantial amount of Thiamethoxam pesticide residues (0.06m/kg) found in the study. As an illustration, Neonicotinoids have recently been found in organic seeds and soils, including ones to which they had never been applied (Guilleminot et al. 2019).

Others have noted that because neonicotinoids are soluble in water, they can seep into the waterways surrounding agricultural areas (Hladik ML, Kolpin DW. 2016). This eventually finds its way into non-crop plants' nectar and pollen. As a result, they are bioavailable to honeybees throughout the year (Hladik et al., 2018) and eventually end up as residues in honey. Their prevalence may be explained by the fact that organophosphates are the most widely used class of pesticides in the nation. This is consistent with research conducted in Ghana (Godfred Darko et al., 2017). However, even though remnants of previous use can still be found in the environment, the limited use of organochlorine and the prohibition of DDT seem to benefit the environment (Godfred Darko et al. 2017). According to Lundin et al. (2015), applying thiacloprid by spraying rather than seed dressing may increase residues in the sources of nourishment that honey bees consume, which may then cause the same residues to show up in honey. This study however, indicated that Carbamates were within the recommended levels. This can be attributed to their ability to degrade in the environment and are less toxic than other pesticides though very toxic to bees (Godfred Darko et Al 2017).

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1: Introduction.

This chapter provides an overview of how the results from the previous chapter were interpreted. The chapter's organization aligns with the investigation goals outlined in the first chapter. Based on the investigation's findings, the investigator then draws conclusions and offers suggestions for further action.

5.2: Summary.

From a public health perspective, honey, being natural is thought to be healthy, pure and nutritious, and this includes its products (Tauber et al. 2019). To this end, honey ought to be fit for public health with no contaminants whatsoever (Vapa Tankosic' et al. 2022). However, recent studies from around the world have demonstrated a global prevalence of pesticides in honey. In a study, Saorla et al. (2021) found 70% of samples positive, though with concentrations below EU MRLs. Ponce-Vejar et al. (2022) found that neonicotinoids were the most frequently detected, but in higher amounts, with organophosphates coming second. In Kenya and Ethiopia, honey samples showed Malathion pesticide residues at about twice the set Maximum Residue Limits (MRLs) of honey (Irungu, J et. al., 2016). Other reports indicate that only few previous studies have been undertaken on pesticide residues in honey (El-Nahhal,2020; Xiao et al.2022). The available data on pesticide residues in raw honey is also scanty (Nenad Stevanovic' et al.2024). The serious threat posed to public health makes it important therefore, to determine pesticide residues in honey as an urgent and emerging concern in contemporary times (Milone and Tarpy,2021). Kitui County is a major honey producer in the country. This study therefore, set out to investigate factors causative to incidence of pesticide residues in raw honey as a contemporary public health issue in Mwingi Central, Kitui County, Kenya. This study hypothesized that Ho: Socio-demographic/pesticide use -related factors and pesticide types are not significantly associated with pesticide residue presence in raw honey in Mwingi, Kitui County, Kenya. This study also recommended mitigation measures and will serve as the baseline for other researchers in the field.

The present investigation employed a descriptive, cross-sectional research approach with a combination of data collection techniques. Liquid chromatography combined with mass spectrometry (LC-MS/MS) was used in laboratory techniques to analyze pesticide residues. The QuEChERS (Quick, Easy, Cheap, Effective, Rugged, and Safe) method was used to prepare the honey samples (Anastassiades et al., 2003). The study used the default international maximum residue limit (MRL) Codex Alimentarius for standardization for honey of 0.05mg/kg (Irungu, J et. al., 2016). Recovery of the pesticides from the spiked samples ranged from 85-94 % (75-105% considered satisfactory) across the tested pesticide groups. From all honey sampled, 73% tested positive for pesticide residues, while 27% of the samples tested negative. Majority of the positive samples had pesticide residue concentrations below the EU MRLs recommended standard of 0.05mg/kg for specific pesticides, and therefore, of no public health concern. Frequencies of spraying crops χ^2 *(61.11, df=3, p=0.0001)* and livestock. χ^2*(60.29df=3, p=0.0001)*, Training on the use of pesticide χ^2 *(20.65(2), p=0.000)*, Interaction with local agricultural extension officers (fishers Exact *p=0.0001)*, and self-rated efficacy to access market information χ^2*(10.98 df=3, p=0.012)* were found to be statistically significant. Similarly, Occupation (Fisher's Exact *p= 0.0195*)* and Levels of education (*df=21.38, p=0.0001*)* were found to be statistically significant and therefore associated with pesticide residues in raw honey in the study area. Age (P=**0.7753**) was not statistically significant. From the inferential analysis, it is evident that Socio-demographic/pesticide use -related factors and pesticide types are significantly associated with pesticide residue presence in raw honey in Mwingi, Kitui County, Kenya. The hypothesis has therefore been rejected.

5.3: Conclusion.

The findings in this study lead to the following conclusions:

i) Socio-demographic/pesticide use -related factors and pesticide types were statistically significant and therefore associated with pesticide residues in raw honey in the study area.

ii) Majority of the pesticide residues detected were of very low concentrations, lower than the recommended EU MRLs and therefore, pose no health risk to public health.

iii) A significant proportion of study participants do not have any training on pesticides use and safety as it was noted that there is limited interaction between local agricultural officers and the beekeeping farmers in the study area.

5.4: Recommendations:

The investigator therefore makes the following recommendations based on the study findings:

i) The National Government to review the current policy and legal framework to address identified pesticide use -related factors to protect public health.

ii) The County governments together with the public health departments to collaboratively conduct routine market surveillance on pesticide residues in raw honey and advise the public accordingly.

iii) The high level of neonicotinoids observed in sampled raw honey is a public health concern that requires further attention in monitoring by the Kitui County Government.

iv) All farmers and Beekeepers should be continuously trained by County Governments on public health effects of pesticide residues in raw honey.

v) Future studies should consider different regions, gender, risk perception and attitude to pesticide use as possible factors in pesticide residues presence in raw honey.

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Appendices

Appendices I: informed consent form

This informed consent form is for the beekeepers in Mwingi Central Sub County, Kitui County, who I am inviting to participate in research, titled "**Factors contributing to pesticide residues in raw honey as a contemporary public health issue in Mwingi, Kitui County, Kenya".**

Name of Principle Investigator

Mukok George Symplisius

Name of Organization

Mount Kenya University

Name of Sponsor

Government of Kenya (GOK)

Name of Project and Version

Student research project for thesis

Background

Informed Consent is a voluntary agreement to participate in research. It contains a summary of the purpose of the research, procedures, and duration of participation, reasonable, foreseeable risks of discomforts, expected benefits and alternative procedures or course of treatment, if any. Participant will be sent an informed consent form before the interview. This Informed Consent Form has two parts:1. Information Sheet 2. Certificate of Consent.

Part 1: Information sheet.

1. Introduction

My name is Mukok George Symplisius, of Mount Kenya University. I am doing research on factors contributing to pesticide residues in raw honey as a contemporary public health issue in Mwingi, Kitui County, Kenya. Before you decide to participate, you are free to consult anyone you feel comfortable with about the research. You are also at liberty to seek further explanations on words that you may not understand as I take you through the information and at any other time.

2. **Purpose of the research.**

   The objective of this research is to investigate factors contributing to pesticide residues in raw honey as a contemporary public health issue in Mwingi, Kitui County, Kenya. I wish to understand the following: what are the factors contributing to pesticide residues in raw honey, what are the types of pesticides commonly used among study group, including frequency of their application. This knowledge might help us to learn the quantities of pesticides residue present in raw honey from study area and how to better control the occurrence and safeguard public health.

3. **Type of Research Intervention**

   Your participation in this study will entail administering a questionnaire. Participants may need to be photographed, audio- or video-recorded in the course of the study. You will also be requested to allow the researcher to take samples of raw honey from your apiaries for purposes of laboratory analysis only.

4. **Participant Selections**

   You have been selected at random to participate in the study. The reason why you have been chosen is because of your experience as a beekeeper having owned an apiary and practiced beekeeping for at least two years, a resident of the area, 18 years old and above and will give voluntary consent of participation. I have selected participants equitably and avoided exploitation of vulnerable populations or populations of convenience.

5. **Voluntary participation.**

   You are voluntarily participating in this study. You are at liberty to opt out in the event you change your mind about participating with no penalty or loss of benefits to which you are otherwise entitled.

6. **Procedures**

   We are here to investigate factors contributing to pesticide residues in raw honey as a contemporary public health issue in Mwingi, Kitui County, Kenya. If you accept the invitation to participate in this research, you will be requested to answer a few questions on factors contributing to pesticide residues in raw honey such as occupation, awareness, level of education, Gender, Government food safety policies; the types of pesticides commonly used, including frequency of their application. In focus group discussions you will be engaged in a small but diverse group of ten (10) people, whose responses will be studied in an open discussion guided by myself. Tape records, if used, will be kept confidential.

Duration

The study will last for a period of two (2) months and the visit to you for interviewing is once lasting for about one hour.

Risks

There is a minimal risk that you may share some personal or confidential information by chance, such as income, level of education, awareness, gender and Government policy but should you feel any discomfort in the discussion you can decline to answer any question or take part in the study without having to give reason as to why.

7. Benefits

While there will be no direct benefit to you, your voluntary participation will enable me generate information that the Government (National and County) can use to deter acts of contamination of honey and safeguard public health. The community will benefit from awareness on public health risks of pesticide residues and improve their livelihood through trade in residue -free honey. This study will make a contribution to and information of use to researchers for future literature reviews to improve and advance knowledge in the area of discipline.

8. Reimbursements

Your participation in this study is voluntary and highly appreciated. However, your transport expenses will be promptly met by the researcher.

9. Confidentiality

The information collected from this study will be kept private and confidential through assigning a number rather than a name and all records kept under lock and key, accessed only by the researcher through a pass word.

10. Sharing the Results

The results of this study may be presented at community barazas, at a conference, shared with colleagues through the Internet, published in a thesis and peer reviewed publications or archived for future research.

11. Right to Refuse or Withdraw

Your choice to participate in this study is purely voluntary. This means that you reserve the right to refuse or withdraw from it at any time with no consequences whatsoever. You also have the right to review your remarks at the end of the interview to add or retract some statements.

12. Who to Contact

In case of any questions or clarifications that you may need later that you were not able to seek now, you may contact the following people whose contacts are given below:

Dr. Mukok George Symplisius	0722876219	dr.gmukok@gmail.com
Dr. J. J. Nyamai, PhD	0799067806	jumajos@mku.ac.ke
Dr. Jesse Gitaka, PhD	0722425613	jgitaka@mku.ac.ke

15. Review and approval

This proposal has been approved after review by **Mount Kenya University Ethics Review Committee.** The IREC contact person is **The Chairman, MKU IREC, P.O Box 342-01000, Thika.**

Appendices II: Certificate of Consent

1. PARTICIPANT

I declare that i have understood the contents 0f this form and voluntarily agree to participate in this study and to retain a copy of the signed consent form. I also agree to observe confidentiality.

Print Name of Participant__________________

Signature of Participant ___________________

Date ___________________________________

2. Witnesses

I hereby witness and confirm that the participant has given consent to participate voluntarily.

Name of witness____________ **Signature/Thumb of participant** [ ]

Signature ___________

Date ________________________

3. Statement by researcher.

Having accurately read out the information sheet to the potential participant, the participant has been made aware that the following will be undertaken:

1.Obtain the services of an interpreter fluent in both English and the language understood by the participant/representative.

2. Participant to be offered a written copy of the informed consent form signed by both themselves and the participant.

3. The researcher will retain one copy of the consent form signed by both themselves and the participant.

Name of Researcher ________________________

Signature of Researcher __________________________

Date ___________________________

(Source: https://www.who.int/rpc/research_ethics/informed_consent/en/)

Appendices III: Questionnaire for Beekeepers in Mwingi, Kitui County

I am Mukok George Symplisius, student at Mount Kenya University pursuing Master of Public Health degree course. Having cleared the course work, I am now on a study project whose title is: Factors Contributing to Pesticide Residues in Raw Honey as a Contemporary Public Health Issue in Mwingi, Kitui County, Kenya."

The study aims at investigating factors contributing to presence of pesticide residues in raw honey as a contemporary public health issue in Mwingi, Kitui, County, Kenya. The specific objectives are to determine factors contributing to residue levels in raw honey, ascertain the types of pesticide used, examine seasonal frequency of pesticide use and determine quantities of pesticide residues in raw honey. Data for this study is collected using a questionnaire. As one of the selected respondents, please give your honest answers to all the parts of the questionnaire. The information gathered is strictly confidential and is for academic purposes only.

Instructions

The questionnaire has sixteen (16) questions. Please answer all questions to the best of your knowledge. You may answer by filling in the spaces provided or ticking (√).

Background information

Questionnaire number ……………………

Enumerator's Name………………………

Respondent's name………………………

Respondent's mobile number……………

Date………………Time……………Sub county………. Ward…………. Village…………… 1. Gender: Male (1) Female (2) Please tick (√)

2. Your age bracket in years? Please tick (√)

(1) 18-25 (2) 26-35 (3) 36-45 (4) 46-55 (5) Above 55

3. What is your main occupation? Please tick as appropriate.

(1) Informal employment (2) Formal Employment (3) Business/self-employment.

4. What other sources of income do you have? Please indicate………………………………...

5. Do you access credit facilities available in the County? (1) Yes (2) No

6. What is your highest level of education? Please tick (√)

(1) No education (2) Primary level (3Secondary level (4) others (please specify) ………………………………………………………………………………………

7. What crops/livestock do you spray with pesticides on your farm? Please list………………………………………………………………………………………
……

8. Which pesticides do you use for spraying your crops/livestock? Please list………………………………………………………………………………………
…….

9. Who decides the budget allocation for pest control at the household level on the farm in this community?

10. Who controls the income or proceeds from sale of harvested honey?

11. What is the frequency of spraying your:

(a) Crops? (1) weekly (2) fortnightly (3) monthly (4) others

(b)Livestock? (1) Weekly (2) fortnightly (3) monthly (4) others. Please tick (√)

12. Do you receive any training on good pesticide use and safety? If yes, please explain………………………………………………………………………………………
…….

13. How frequent do you interact with the local extension officers? (1) Weekly (2) Monthly

(3) Never

14. Are you aware of the Government's standards for safe pesticide use? (1) Yes (2) No

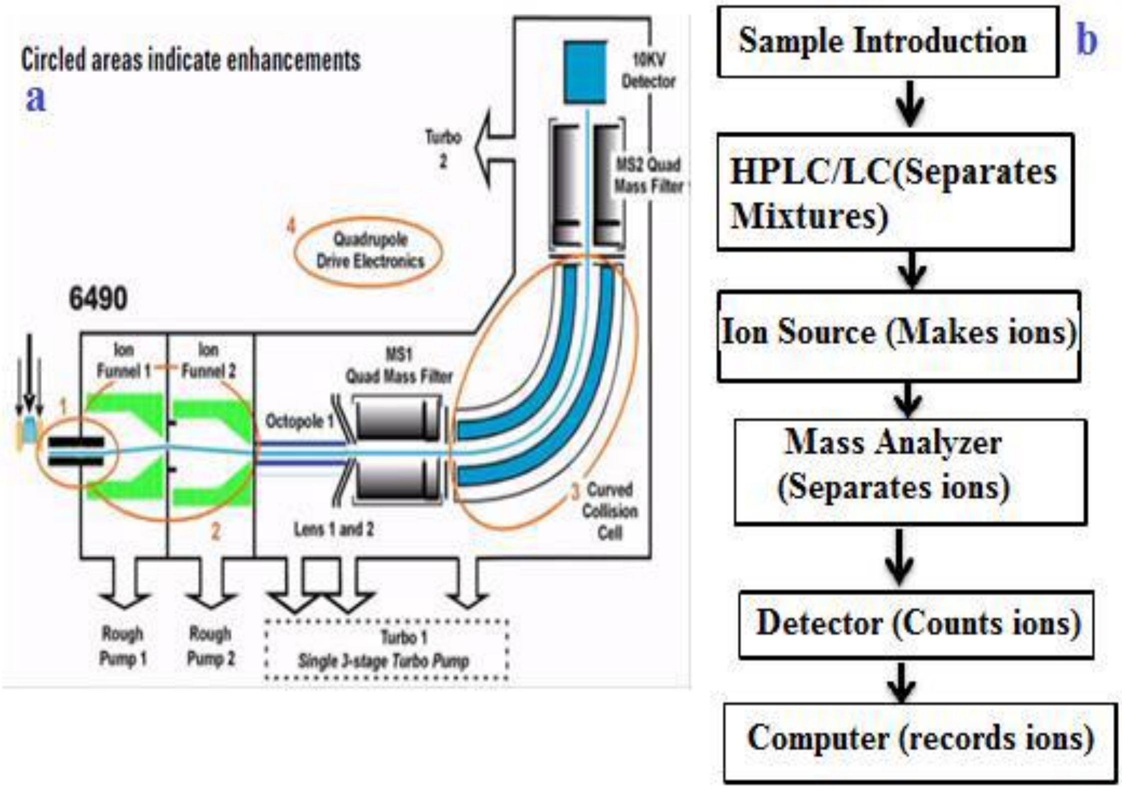
If yes, please explain……………………………………………………………………….

15. Do you know of the Government's penalty for those who don't adhere to safe pesticide use? (1) Yes (2) No

If yes, please explain………………………………………………………………………………

16. How do you rate your accessibility to market information? (1) Very good (2) good (3) poor (4) very poor. Please tick (√)

Appendices IV: Cross-section of LC-MS/MS equipment; (b) Schematic diagrams for LC-MS/MS sample analysis.



a) Cross-section of LC-MS/MS equipment; (b) Schematic diagrams of LC-MS/MS sample analysis. **Source: Mulati, (2016).**

Appendices V: ERC Certificate

Mount Kenya University

REF: **MKU/ERC/1308**
TO: **MUKOK GEORGE SYMPLISIUS** REG: **MPH/2017/68738**

Date: 10 June, 2019

Dear Sir/Madam,

RE: FACTORS CONTRIBUTING TO PESTICIDE RESIDUES IN RAW HONEY AS CONTEMPORARY PUBLIC HEALTH ISSUE IN MWINGI, KITUI COUNTY, KENYA

This is to inform you that **Mount Kenya University** has reviewed and approved your above research proposal. Your application approval number is **713.** The approval period is **10/06/2019 – 09/06/2020.**

This approval is subject to compliance with the following requirements:

i. Only approved documents including (informed consents, study instruments, MTA) will be used
ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by **Mount Kenya University.**
iii. Death and life threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to **Mount Kenya University** within 72 hours of notification
iv. Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to **Mount Kenya University** within 72 hours
v. Clearance for export of biological specimens must be obtained from relevant institutions.
vi. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.
vii. Submission of an executive summary report within 90 days upon completion of the study to **Mount Kenya University.**

Prior to commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology and innovation (NACOSTI) https://oris.nacosti.go.ke and also obtain other clearances needed.

Yours sincerely,

The Chairman
Mount Kenya University
Ethics Review Committee
P.O. Box 342-01000, Thika

Prof. Francis W. Muregi
Chairman, Mount Kenya University ERC

Main Campus, General Kago Road, P.O. Box 342-01000 Thika. Tel: +254 67 2820 000,
Cell: +254 720 790 796, 0709 153 000
Email:info@mku.ac.ke, Web: www.mku.ac.ke
Chartered and ISO 9001 : 2015 Certified Institution.
Unlocking Infinite Possibilities

Appendices VI: NACOSTI Permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Ref No: 249245

Date of Issue: 12/February/2021

RESEARCH LICENSE

This is to Certify that Mr.. Mukok Symplisius George of Mount Kenya University, has been licensed to conduct research in Kitui on the topic: Factors contributing to pesticides residues in raw honey as contemporary public health issue in Mwingi, Kitui County, Kenya for the period ending : 12/February/2022.

License No: NACOSTI/P/21/9042

249245

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

Appendices VII: Permit from the county commissioner

THE PRESIDENCY

MINISTRY OF INTERIOR AND COORDINATION OF NATIONAL GOVERNMENT

Telegrams............
E-mail: *cckitui@gmail.com*
When replying please quote Ref. and date

OFFICE OF THE
COUNTY COMMISSIONER
P.O.BOX 1-90200
KITUI.

K.C.603/III/118

28th May 2021

Dr. Mukok George Symplisius
Mount Kenya University
P.O. BOX 342-01000
THIKA

RE: RESEARCH AUTHORIZATION: LICENSE NO. NACOSTI/P/21/9042

Reference is made to a letter from National Commission for Science, Technology and Innovation Ref. No. 249245 dated 12th February 2021 on the above subject matter.

You are hereby authorized to carry out research on **"Factors contributing to pesticide residues in raw honey as contemporary Public Health issue in Mwingi"** for aperiod ending 12th February 2022

J.M. KIHARA
FOR: COUNTY COMMISSIONER
KITUI COUNTY

COUNTY ... KITUI
P.O. ... 90200
KITUI

Appendices Viii: Turnitin Report

Dr. George Mukok

Mukok Thesis

THESIS

STUDENT THESIS

Mount Kenya University

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Appendices IX: Map of Kitui County