Pesticide Residues in Selected Vegetables from Kenyan Markets

& Effectiveness of Household Methods for Residue Reduction

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Scientific Review: Dr Peterson Njogu Warutere, Environmental and Occupational Health, Kenyatta University.

Pesticide Residue Analysis: SGS Kenya Ltd Laboratories

Contributions from:

Kenya Organic Agriculture Network
Eustace Kiarii
Samuel Ndung'u
Wycliffe N. Nyamao

Raniro Consultants
Nyawira Nduhiu

University of Nairobi, Department of Public Health Pharmacology and Toxicology
Nduhiu Gitahi, PhD
Joshua O. Onono, PhD
Joseph Nderitu

Swedish Society for Nature Conservation
Bo Lager

Heinrich Boell Foundation, Nairobi Office
Harun Warui, PhD
Christine Gatwiri
Faiba Kombo

Proofreading: Clay Muganda

Layout and design: Michael Lusaba

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& Effectiveness of Household Methods for Residue Reduction

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Our appreciation goes to the Department of Public Health, Pharmacology and Toxicology, University of Nairobi, and SGS Kenya Laboratories for conducting laboratory analyses with the highest standards of scientific integrity and quality assurance. Their technical expertise and adherence to internationally recognized analytical procedures ensured the reliability and credibility of the study findings.

We also acknowledge and thank the KOAN staff, researchers, field assistants, laboratory personnel, reviewers, and partner institutions whose dedication and professionalism contributed to the successful completion of this study.

We hope that the findings presented in this report will contribute to evidence-based policies, strengthen food safety systems, promote responsible pesticide use, and empower consumers with practical measures to reduce exposure to pesticide residues.

Kenya Organic Agriculture Network - KOAN
Eustace Kiarii - Chief Executive Officer

Foreword

Safe food is fundamental to public health, food security, and sustainable development. As Kenya's agricultural sector continues to intensify to meet the growing demand for fresh produce, the responsible use of pesticides has become increasingly important.

While pesticides play a critical role in protecting crops and improving yields, their misuse can result in pesticide residues that pose potential risks to consumers, farmers, and the environment.

Recent studies have shown that some vegetables commonly consumed in Kenya contain pesticide residues exceeding internationally recognized Maximum Residue Limits (MRLs). These findings underscore the need not only for strengthened regulation and responsible pesticide management but also for practical interventions that consumers can adopt to reduce exposure during food preparation.

This report presents the findings of two complementary studies. The first assessed pesticide residue levels in tomatoes, kale, spinach, and onions obtained from major markets in Nairobi. The second evaluated household food preparation methods to determine their effectiveness in reducing pesticide residues while preserving the nutritional and sensory quality of the vegetables.

The study provides scientific evidence that supports improved food safety practices at multiple levels. For policymakers, the findings reinforce the need for strengthened pesticide regulation, surveillance, and enforcement. For farmers and extension services, they highlight the importance of responsible pesticide use and adherence to recommended pre-harvest intervals. For consumers, the study offers practical, evidence-based household preparation methods that can substantially reduce dietary exposure to pesticide residues.

Beyond documenting the current status of pesticide residues, this report contributes practical solutions for improving public health and strengthening confidence in Kenya's food systems. It is our hope that the findings will stimulate informed dialogue, support policy reforms, encourage further research, and promote safer agricultural production and food preparation practices across the country.

We commend the researchers and partner institutions whose dedication made this work possible and trust that this publication will serve as a valuable resource for researchers, regulators, development partners, extension officers, public health professionals, and consumers alike.

Swedish Society for Nature Conservation (SSNC)
Bo Lager

Preface

Food is more than nourishment. It is fundamental to human dignity, health, livelihoods, and the realization of the right to adequate food. Yet ensuring that food is not only available but also safe has become one of the defining challenges of modern food systems.

As agricultural production intensifies to meet growing demand, the responsible management of pesticides has become increasingly important for protecting consumers, farmers, biodiversity, and the environment.

At Heinrich Boell Foundation (HBF), Nairobi Office, we believe that resilient food systems must be built upon sound science, transparency, environmental sustainability, and the protection of public health. Evidence plays a critical role in informing policies that balance agricultural productivity with the health of people and ecosystems. This publication contributes meaningfully to that objective by generating robust scientific evidence on pesticide residues in vegetables commonly consumed in Kenya while also identifying practical household measures that can significantly reduce consumer exposure.

The report is particularly important because it moves beyond identifying the problem to offering solutions. While the primary responsibility for preventing excessive pesticide residues rests with producers, regulators, and the broader food system, consumers also deserve access to practical, evidence-based information that enables them to make safer food preparation choices. By combining market surveillance with laboratory evaluation of household residue reduction methods, this study provides a comprehensive perspective that is both scientifically rigorous and directly relevant to everyday life.

The findings reinforce the importance of strengthening pesticide governance, promoting good agricultural practices, expanding integrated pest management, and accelerating the transition towards agroecological production systems that reduce dependence on hazardous pesticides while safeguarding biodiversity and human health. They also underscore the need for continued investment in food safety surveillance, public awareness, and collaborative action among government agencies, researchers, farmers, civil society, and development partners.

Heinrich Boell Foundation (HBF) is proud to have supported this collaborative initiative alongside the Kenya Organic Agriculture Network, the Swedish Society for Nature Conservation, the University of Nairobi, SGS Kenya Laboratories, and the many researchers whose expertise made this work possible. We hope this publication will serve as an important resource for policymakers, regulatory institutions, researchers, public health professionals, farmers, consumer organizations, and all those working to build safer, healthier, and more sustainable food systems in Kenya.

Heinrich Boell Foundation,
Joachim Paul - Regional Director,
Kenya, Uganda and Tanzania

Acronyms

CODEX ALIMENTARIUS	The Codex Alimentarius is a collection of internationally recognized standards, codes of practice, guidelines, and other recommendations relating to food, its production, labeling, and safety that are published by the Food and Agriculture Organization and the World Health Organization of the United Nations
EFSA	European Food Safety Authority
EU-MRLs	European Union- Maximum Residue Levels
FAO	Food and Agriculture Organization of the United Nations
GC-MS/MS	Gas Chromatography Tandem Mass Spectrometry
HBF	Heinrich Boell Foundation
HHP	Highly Hazardous Pesticide
ID	Identity
KEPHIS	Kenya Plant Health Inspection Service
KOAN	Kenya Organic Agriculture Network
LC-MS/MS	Liquid Chromatography Tandem Mass
LOQ	Limit of quantification
MKT	Market
PHPT	Public Health Pharmacology & Toxicology
QuEchERs	Quick, Easy, Cheap, Effective, Rugged & Safe
RT	Room Temperature
SoPs	Standard Operating Procedures
WHO	World Health Organization
@	at
+ve	Positive

Definition of Terms

Acceptable Daily Intake (ADI): ADI of a chemical is the daily intake which, during an entire lifetime, appears to be without appreciable risk to the health of the consumer based on all the known facts at the time of the evaluation of the chemical by the Joint FAO/WHO Meeting on Pesticide Residues. It is expressed in milligrams of the chemical per kilogram of body weight.

Active Ingredients: These are the chemicals in a pesticide product that control pests. They must be identified by name on the pesticide product's label together with their percentage by weight.

Blanching: In food processing, it is a brief heat treatment of vegetables and fruits using hot water or steam, which is followed by immediate cooling before freezing or canning.

Food code: This is a collection of standards, guidelines, and codes of practice adopted by the Codex Alimentarius Commission

Half-life (pesticide): The time required for a specific amount of a pesticide to reduce by half due to degradation or dissipation in the environment.

Limit of Quantitation (LOQ): This is the lowest concentration of the analyte that can be quantified. It is commonly defined as the minimum concentration of the analyte in the test sample that can be determined with acceptable precision (repeatability) and accuracy under the stated test conditions.

Maximum Residue Level [MRL]: of a pesticide is the highest level of a pesticide residue that is legally tolerated in or on food or feed when pesticides are applied correctly.

Pesticides: Refers to plant protection products. Broadly, pesticides cover other products not intended for plants used to control carriers of diseases caused by pests, including insects, rats, and mice.

Plant protection products: These are herbicides, fungicides, insecticides, acaricides, repellents, and plant growth regulators, which are mainly used to keep crops healthy, preventing destruction by diseases and infestation.

Pre-harvest interval (**PHI**) is the wait time between a pesticide application and when a crop can be harvested.

Residues: The traces of pesticides left in treated products are called pesticide residues

Reference Dose (RfD): The RfD is an estimate of the quantity of a chemical that a person could be exposed to every day for the rest of their life with no appreciable risk of adverse health effects. The reference dose is typically measured in milligrams (mg) of chemical per kilogram (kg) of body weight per day.

Sauté: is to cook food over high heat, usually in butter or oil. The quick, hot method of cooking browns the outer layer of food and retains the internal flavour.

Executive Summary

Pesticides are widely used in agriculture to protect crops from pests, diseases, and weeds, thereby improving productivity and food security.

However, inappropriate pesticide use, including failure to observe recommended application rates and pre-harvest intervals, can result in pesticide residues remaining on/in food products at levels that may pose risks to human health and the environment.

In Kenya, previous studies have reported pesticide residues exceeding Maximum Residue Limits (MRLs) in commonly consumed vegetables. However, limited information has been available on practical methods that consumers can apply to minimize these residues at the household level before consumption. This study therefore sought to address two important questions:

1. Are there pesticide residues above the acceptable levels on/in selected vegetables marketed in Kenya?
2. Which household food preparation methods are most effective in reducing pesticide residues in/on the selected vegetables while maintaining food quality?

The study was implemented in two complementary phases.

The **first phase** assessed pesticide residues in tomatoes, kale, spinach, and onions obtained from major wholesale and retail markets in Nairobi and Nakuru. Forty-five vegetable samples originating from several food-producing counties were analyzed using both gas and liquid chromatography-tandem mass spectrometry (GC-MS/MS & LC-MS/MS) methods capable of detecting more than 500 pesticide compounds.

The results showed that 35 of the 45 samples contained detectable pesticide residues, although most were below the European Union Maximum Residue Limits (EU MRLs). However, fifteen samples (33%) contained eight pesticide residues exceeding the EU MRLs. Tomatoes accounted for the highest proportion of non-compliant samples, followed by spinach and kale, while no onion sample exceeded the applicable EU MRLs.

The pesticides detected above regulatory limits included; chlorfenapyr, chlorpyrifos, acephate, lambda-cyhalothrin, difenoconazole, linuron, carbendazim, and tebuconazole. Seven of these active ingredients are classified by the World Health Organization (WHO) as Class II (moderately hazardous) pesticides.

The **second phase** evaluated eight household food preparation methods using vegetables experimentally exposed to selected pesticides under controlled laboratory conditions. The treatments included washing under running water, blanching, soaking in salt solution, soaking in baking soda solution, soaking in vinegar solution, cooking, and short-term storage under household conditions.

The findings demonstrated that household food preparation can substantially reduce pesticide residues, although effectiveness varies according to the vegetable, pesticide active ingredient, and preparation method.

Among the methods evaluated:

- Peeling, washing, and blanching achieved the highest overall reduction in onions.
- Washing followed by soaking in a 2% baking soda solution and cooking was the most effective treatment for tomatoes.
- Washing, blanching, and cooking effectively reduced residues in spinach.
- Washing followed by vinegar treatment and cooking produced the greatest reductions in kale.

These findings demonstrate that simple household practices can significantly reduce consumer exposure to pesticide residues without requiring specialized equipment or expensive technologies.

The study highlights the need to strengthen pesticide management throughout the food production chain. Preventing excessive pesticide residues remains the responsibility of producers through adherence to Good Agricultural Practices, Integrated Pest Management, and compliance with recommended pesticide application guidelines. Household preparation methods should therefore be viewed as complementary measures rather than substitutes for responsible pesticide use.

The study recommends strengthening routine pesticide residue surveillance, enhancing farmer training on safe pesticide use, accelerating implementation of updated pesticide legislation, promoting Integrated Pest Management, and increasing public awareness of effective household food preparation practices that reduce dietary exposure to pesticide residues.

The evidence generated by this study provides an important scientific foundation for improving food safety, protecting public health, informing national policy, and empowering consumers to make safer food preparation choices.

PART ONE

PESTICIDE RESIDUES IN SELECTED VEGETABLES FROM KENYAN MARKETS

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Agriculture is central to Kenya's economy, contributing significantly to food security, employment, household incomes, and export earnings. To sustain crop production and minimize losses caused by insects, weeds, fungi, and other pests, farmers rely extensively on pesticides. The World Health Organization (WHO), jointly with the Food and Agriculture Organization of the United Nations (FAO) have categorized some pesticides as Highly Hazardous Pesticides (HHPs) based on their toxicity to human health, persistence in the environment, and toxicity to aquatic life and pollinators. A 2022 report showed that 76 percent of the total volume of pesticides used in Kenya contained one or more active ingredients that are categorized as Highly Hazardous Pesticides (HHPs) (EPF, 2021).

When used according to recommended agricultural practices, pesticides improve crop yields and enhance the quality of agricultural produce. However, inappropriate pesticide use, including excessive application rates, failure to observe pre-harvest intervals, use of unregistered products, and poor handling practices, can result in pesticide residues remaining on food at levels that may threaten human health and the environment. Pesticide residues are trace quantities of pesticide active ingredients, metabolites, or degradation products that remain in or on food following pesticide application during crop production, storage, or transportation. Their occurrence depends on several factors, including pesticide formulation, frequency of application, environmental conditions, crop characteristics, and adherence to recommended pre-harvest intervals.

Fresh vegetables are particularly vulnerable to pesticide contamination because many are consumed raw or undergo minimal processing before consumption. Leafy vegetables such as kale (*Brassica oleracea var. sabellica*) and spinach (*Spinacia oleracea*) possess large surface areas capable of retaining pesticide deposits, while fruits such as tomatoes (*Solanum lycopersicum*) are frequently subjected to repeated pesticide applications throughout the growing season. Although bulb onions (*Allium cepa*) generally exhibit lower contamination because the edible portion develops below the soil surface, changing production practices may increase the likelihood of residue occurrence.

A 2022 report showed that 76% of the total volume of pesticides used in Kenya contained one or more active ingredients that are categorized as Highly Hazardous Pesticides (HHPs)

(EPF, 2021)

Food safety authorities regulate pesticide residues by establishing Maximum Residue Limits (MRLs), which represent the highest legally permitted concentrations of pesticide residues in food when pesticides are applied according to Good Agricultural Practices (GAP). MRLs are established through rigorous scientific risk assessments and are intended to protect consumers while facilitating fair agricultural trade. Compliance with MRLs therefore serves as an important indicator of safe pesticide use rather than a direct measure of toxicity.

1.2 Pesticide uses in Kenya

Kenya has experienced substantial growth in pesticide use over recent decades, driven by increasing agricultural intensification, expansion of horticultural production, and the need to satisfy both domestic and export markets. According to the Pesticides Atlas, Kenya Edition, Kenya's imports of Pesticides increased from 14,600 tons in 2015 to 17,803 tons in 2018, representing a 144% increase in three years. Most of Africa's pesticides are imported from non-African countries, and the majority of exported pesticides remain in the region (FAO, 2024). The volume of Pesticide Control Products (PCPs) imported to Kenya by the end of 2020 was estimated at 19,932 metric tons (PCPB, 2024).

While pesticides contribute significantly to agricultural productivity, concerns have emerged regarding the continued registration and use of several highly hazardous pesticide formulations that have been restricted or withdrawn in other jurisdictions. Reports by the Kenya Organic Agriculture Network (KOAN), the Pest Control Products Board (PCPB), and other organizations indicate that pesticide misuse remains common in some production systems. Reported challenges include excessive application rates, inadequate use of personal protective equipment, failure to observe recommended pre-harvest intervals, improper disposal of pesticide containers, and use of pesticides on crops for which they are not registered. These practices increase the likelihood of pesticide residues entering the food chain and may compromise both domestic food safety and export market access.

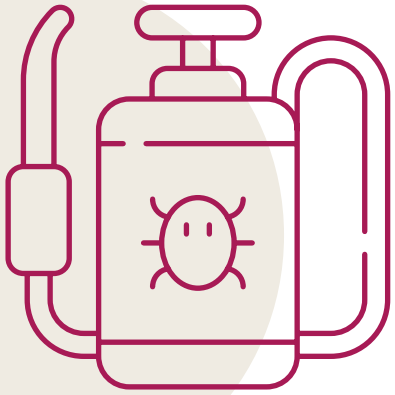
National surveillance programmes have consistently identified tomatoes and leafy vegetables among the commodities most frequently exceeding recommended residue limits. Their high economic value, year-round production, and susceptibility to numerous pests often result in repeated pesticide applications during production.

1.3 Pesticide Residues and Food Safety

Although most pesticide residues detected in food occur below regulatory limits, excessive or repeated dietary exposure to certain pesticides has been associated with adverse health outcomes. Acute exposure may cause symptoms such as nausea, dizziness, skin irritation, and respiratory distress, whereas long-term exposure has been linked to neurological disorders, endocrine disruption, reproductive impairment, developmental abnormalities, and increased risks of certain cancers. Consequently, routine surveillance of pesticide residues remains an important component of national food safety systems.

Reliable determination of pesticide residues relies on advanced analytical techniques capable of detecting multiple compounds simultaneously at very low concentrations. Liquid chromatography–tandem mass spectrometry (LC–MS/MS) and gas chromatography–mass spectrometry (GC–MS/MS) are internationally recognized analytical methods widely used in pesticide residue monitoring because of their sensitivity, selectivity, and analytical accuracy.

Kenya's pesticide imports increased from 14,600 tons in 2015 to 19,932 metric tons by 2020, driven by growing agricultural production and market demand. Most pesticides used in Africa are imported from outside the continent (FAO, 2024; PCPB, 2024).



A study conducted in 2020 by KOAN on Kenyan fresh produce showed that 524 (46%) samples had detectable pesticide residues, with 11% of them having been above the EU MRLs

Recent surveillance studies conducted in Kenya have reported pesticide residues exceeding European Union Maximum Residue Limits (EU MRLs) in several vegetables commonly consumed by Kenyan households. A study conducted in 2020 by KOAN on Kenyan fresh produce showed that 524 (46%) samples had detectable pesticide residues, with 11% of them having been above the EU MRLs. The most affected crops were Tomatoes, Spinach, Onions, and Kale, with the outcome often attributed to the misuse of pesticides. According to the Pesticides Atlas (Kenya Edition) report of 2022, by HBF, Kenya had 310 registered pesticide products, where 63% of them were classified as HHPs, and their usage accounted for 76% of the total volume of pesticides. The report further stated that almost 44% of them had either been banned or were heavily restricted in the European Union (EU) due to their negative impacts on human health, persistence in the environment, or toxicity to pollinators and aquatic life.

In 2024, the Pest Control Products Board (PCPB) conducted two baseline studies on pesticide residues in Kale, Tomatoes, and Onions. The first one was in Nyeri, Meru, Kirinyaga, Taita Taveta, and Makueni counties, while the second was on the same foodstuffs but in Kajiado, Nyandarua, and Nakuru counties. Their results showed that of the 105 tested samples, 33 (31%) had pesticide residues exceeding the EU-MRLs. Such findings raise concerns regarding compliance with recommended pesticide use practices, consumer exposure, and the effectiveness of the country's pesticide regulatory framework. Since vegetables constitute a substantial proportion of the Kenyan diet, continuous monitoring of pesticide residues is essential for protecting public health and informing evidence-based policy interventions.

1.4 Problem Statement

Previous pesticide residue monitoring programmes in Kenya have demonstrated that a proportion of vegetables marketed for human consumption contain pesticide residues exceeding internationally recognized Maximum Residue Limits. Although these findings highlight the need for improved pesticide stewardship, there remains limited information regarding the current levels of pesticide contamination in vegetables marketed within Kenya and the implications for consumer food safety.

Furthermore, while regulatory interventions primarily target pesticide use at the farm level, consumers have few evidence-based recommendations regarding household food preparation practices capable of reducing pesticide residues before consumption. Addressing these knowledge gaps is necessary for strengthening food safety, protecting public health, and supporting informed policy development.

1.5 Justification of the Study

Routine surveillance of pesticide residues provides scientific evidence required for evaluating compliance with pesticide regulations, assessing consumer exposure, and informing national food safety policies. The findings generated by this study will contribute to improved understanding of pesticide residue occurrence in vegetables commonly consumed in Kenya and provide baseline information for future monitoring programmes.

The study also generates evidence on practical household preparation methods capable of reducing pesticide residues before consumption. Such information is particularly relevant in settings where consumers rely primarily on domestic food preparation to minimize dietary exposure. The results are expected to benefit regulatory agencies, public health practitioners, agricultural extension services, researchers, development partners, and consumers by providing evidence that supports safer agricultural production and healthier food preparation practices.

1.6 Study Objectives

1.6.1 General Objective

To determine pesticide residue levels in selected vegetables marketed in Kenya and evaluate their compliance with established Maximum Residue Limits.

1.6.2 Specific Objectives

The study sought to:

1. Determine the occurrence and concentrations of pesticide residues in tomatoes, kale, spinach, and onions obtained from selected Kenyan markets.
2. Compare detected pesticide residue levels with Codex Alimentarius and European Union Maximum Residue Limits.
3. Identify pesticide active ingredients responsible for residue exceedances.

1.7 Significance of the Study

The study contributes to national efforts aimed at strengthening food safety systems by generating reliable scientific evidence on pesticide residues in vegetables commonly consumed in Kenya. The findings provide useful information for regulatory authorities responsible for pesticide registration and surveillance, support the implementation of Good Agricultural Practices among producers, and contribute to consumer awareness regarding food safety. The study further establishes a scientific foundation for the second phase of this research, which evaluates practical household methods for reducing pesticide residues before consumption, thereby providing a comprehensive assessment of pesticide exposure and consumer risk reduction strategies.

CHAPTER TWO

2.0 MATERIALS AND METHODS

2.1 Study design

A cross-sectional analytical study was conducted to determine pesticide residue levels in selected vegetables marketed in Kenya. The study involved the collection of vegetable samples from major retail markets supplied by leading vegetable-producing counties, followed by laboratory analysis to identify and quantify pesticide residues. Detected residue levels were compared with the Maximum Residue Limits (MRLs) established by the Codex Alimentarius Commission and the European Union (EU).

2.2 Study area

The sites from where the samples were collected for analysis were guided by earlier studies that had been done by KOAN in 2020 and by the PCPB in 2024, which showed that specific geographical areas were known to produce and release foods with high pesticide residue levels in the market. Four markets (Muthurua, Githurai, and Kangemi) in Nairobi City and Wakulima Market in Nakuru City were purposively selected owing to the large volumes of the four types of food that were traded in them daily.

The markets also exhibit a high level of representativeness of the four selected foodstuffs from the geographical areas that the two studies above had shown to be highly vulnerable in trading foods with high levels of pesticide residues. The traded foods were sourced from Nyeri, Nyandarua, Machakos, Kirinyaga, Kajiado, and Nakuru counties. These counties were also selected to represent regions from which PCPB had selected their samples. Nyeri and Kirinyaga represented the counties they selected in their first study, and Nyandarua and Nakuru represented the geographical regions in their second study.

A new county (Machakos) was brought in. The samples of the foodstuffs were randomly picked from traders from the above markets who consented and disclosed the county from which the foodstuffs were sourced.

2.3 Samples collection and analysis

Four vegetables commonly consumed in Kenyan households were selected for analysis:

Tomato (*Solanum lycopersicum*)
Kale (*Brassica oleracea var. sabellica*)
Spinach (*Spinacia oleracea*)
Bulb onion (*Allium cepa*)

The vegetables were selected based on:

- their high consumption across Kenyan households;
- previous reports of pesticide residue occurrence;
- their economic importance;
- differing production systems and pesticide use patterns; and
- their representation of both leafy and fruit vegetables.

2.4 Sample Size and Sampling Strategy

A total of 45 vegetable samples were collected from selected markets. Sampling was designed to obtain representative produce originating from major vegetable-producing counties previously identified through national pesticide residue surveillance programmes.

A reconnaissance survey was undertaken before sampling to identify markets with high trading volumes and establish the principal sources of vegetables supplied to each market. Traders meeting the inclusion criteria were randomly selected, and one composite sample of each available vegetable was purchased. Each sample was assigned a unique identification code to ensure complete traceability throughout transportation, laboratory analysis, and data management.

2.5 Inclusion and Exclusion Criteria

Inclusion Criteria

Samples were obtained from traders who:

- Were at least 18 years of age;
- Sold one or more of the selected vegetables;
- Obtained produce directly from farmers, brokers, or transporters;
- Could identify the county of origin of the produce; and
- Voluntarily agreed to participate in the study.

Exclusion Criteria

Traders were excluded if they:

- Sold mixed produce whose origin could not be determined;
- Were unavailable during sampling; or
- Attempted to influence the sampling process.

2.6 Sample Collection and Handling

A kilogram of each of the four foodstuffs was purchased from the selected traders from each of the four markets, and the foodstuffs were randomly selected without mixing their disclosed counties of origin. Samples from each trader were given a unique identifier, taking care of the different food products and their source. The food samples were placed in clean, well-marked, and uniquely identified bags and transported at ambient temperatures in a clean crate to the Public Health, Pharmacology and Toxicology (PHPT) laboratories of the University of Nairobi (UoN) for pesticide residue analyses.

Smaller samples were randomly picked from the bulk samples of each of the foodstuffs and placed in zip-lock bags bearing the sample's unique identifier and submitted to the testing laboratory (SGS, Kenya). Samples were prepared using the QuEChERS (Quick, Easy, Cheap, Effective, Rugged, and Safe) method. Upon arrival at the laboratory, all samples were logged, assigned laboratory identification numbers, and stored appropriately before analysis. Strict chain-of-custody procedures were maintained throughout sample collection, transportation, storage, and laboratory processing.

2.7 Laboratory Analysis

Laboratory analyses were undertaken using internationally validated analytical methods for multi-residue pesticide determination. Samples were homogenised before extraction, and pesticide residues were analysed using:

- Liquid Chromatography–Tandem Mass Spectrometry (LC–MS/MS); and
- Gas Chromatography–Tandem Mass Spectrometry (GC–MS/MS).

The analytical methods are capable of detecting more than 500 pesticide active ingredients commonly used in agricultural production. Quality assurance procedures included the use of analytical blanks, certified reference materials, duplicate analyses, calibration standards, and recovery studies to ensure analytical accuracy, precision, and reliability.

2.8 Data Analysis

Detected pesticide residues were expressed as milligrams per kilogram (mg/kg) of fresh vegetable weight. For each pesticide detected, the following were determined:

- frequency of detection;
- concentration range;
- mean concentration;
- compliance with Codex MRLs;
- compliance with EU MRLs; and
- pesticide residue ratio (PRR), calculated as the ratio of the measured residue concentration to the applicable EU Maximum Residue Limit.

Descriptive statistical analyses were performed to summarize pesticide occurrence by vegetable type, county of origin, pesticide class, and market.

2.9 Quality Assurance and Quality Control

To ensure data reliability, all laboratory analyses were conducted in accordance with internationally recognized quality assurance procedures. The analytical laboratory maintained documented standard operating procedures for sample receipt, preparation, extraction, instrument calibration, analysis, and reporting. Instrument performance was routinely verified using calibration standards and quality control samples. Duplicate analyses and recovery tests were performed where appropriate to evaluate analytical precision and accuracy.

2.10 Ethical Considerations

The study involved vegetable samples purchased from public markets and did not involve human or animal

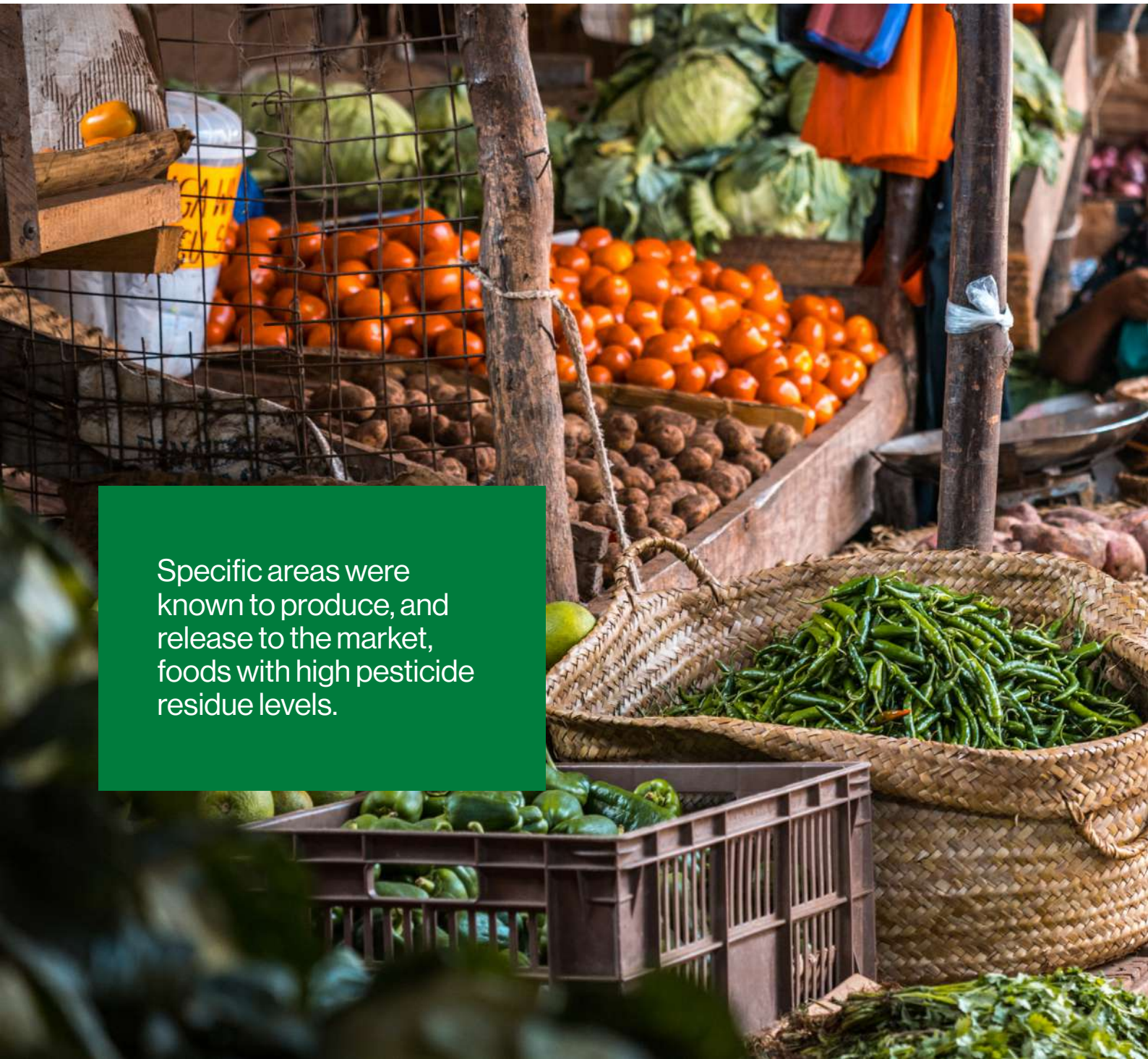
experimentation. Participation by traders was voluntary, and verbal informed consent was obtained before sample purchase. No personal identifiers were recorded, and all information regarding traders and produce sources was treated confidentially. The study was conducted in accordance with accepted ethical principles governing food safety and public health research.

2.11 Limitations of the Study

The study provides a snapshot of pesticide residue levels at the time of sampling and may not fully capture seasonal or annual variations in pesticide use. Information regarding the origin of produce relied partly on trader reports and market records, although reasonable efforts were made to verify sample traceability. Despite these limitations, the study provides robust baseline information on pesticide residues in vegetables commonly consumed in Kenya and establishes an evidence base for subsequent evaluation of household pesticide residue reduction methods.

Table 1: Samples of foodstuffs as submitted for pesticide residue analyses

Market	Foodstuffs				Totals
Nairobi	**Tomatoes**	**Onions**	**Kale**	**Spinach**	
Githurai	5	4	6	4	19
Muthurua	1	2	2	1	6
Kangemi	4	1	-	-	5
Wakulima	3	2	6	4	15
Totals	13	9	14	9	45



Specific areas were known to produce, and release to the market, foods with high pesticide residue levels.

CHAPTER THREE

3.0 RESULTS

3.1 Overview

This chapter presents the findings of the pesticide residue analysis conducted on tomatoes (*Solanum lycopersicum*), kale (*Brassica oleracea var. sabellica*), spinach (*Spinacia oleracea*), and bulb onions (*Allium cepa*) collected from selected Kenyan markets. The results include the occurrence, distribution, and concentrations of pesticide residues, compliance with Codex Alimentarius and European Union Maximum Residue Limits (EU MRLs), and the geographical distribution of contaminated produce.

3.2 Occurrence of Pesticide Residues

A total of **45 vegetable samples** were analyzed for pesticide residues using LC-MS/MS and GC-MS/MS multi-residue analytical methods. Pesticide residues were detected in **35 samples (77.8%)**, while **10 samples (22.2%)** had no detectable residues within the analytical limits of detection. Eight pesticide active ingredients exceeded the applicable EU Maximum Residue Limits in fifteen samples (33.3%). The remaining positive samples contained residues below the established regulatory limits. The pesticides detected above EU MRLs comprised fungicides, insecticides, a herbicide, and a miticide, reflecting the diversity of pesticide products used during vegetable production.

Table 2: Pesticide Residues detected in food samples but below EU-MRL

Food Type	Source	Pesticide Residue	Residue Level (Mg/Kg)	Eu-Mrl (Mg/Kg)
Tomatoes	Kajiado	Azoxystrobin	0.003	3
	Kajiado	Acetamiprid	0.003	0.5
	Kajiado	Chlorfenapyr	0.09	0.01
	Kajiado	Imidacloprid	0.003	0.01
	Kajiado	Lamda-Cyhalothrin	0.006	0.07
	Kajiado	Metalaxyl	0.016	0.3
	Kajiado	Pyridaben	0.010	0.15
	Kajiado	Spirodiclofen	0.043	0.5
	Kajiado	Tebuconazole	0.026	0.9
	Kirinyaga	Acephate	0.017	0.01
	Kirinyaga	Carbendazim	0.015	0.3
	Kirinyaga	Chlorfenapyr	0.040	0.01
	Kirinyaga	Chlorpyrifos	0.005	0.01
	Kirinyaga	Cypermethrin	0.005	0.5
	Kirinyaga	Tebuconazole	0.005	0.9
	Nakuru	Acephate	0.003	0.01
	Nakuru	Carbendazim	0.036	0.3
	Nakuru	Chlorfenapyr	0.020	0.01
	Nyeri	Chlorpyrifos	0.013	0.01
Kale	Nakuru	Cypermethrin	0.008	0.5
	Nakuru	Lamda-Cyhalothrin	0.003	0.07
Onions	Nyeri	Thiophanate	0.005	0.1
	Nakuru	Lamda-Cyhalothrin	0.01	0.07

Food Type	Source	Pesticide Residue	Residue Level (Mg/Kg)	Eu-Mrl (Mg/Kg)
	Nakuru	Thiophanate	0.005	0.1
Spinach	Machakos	Azoxystrobin	0.015	3
	Machakos	Carbendazim	0.005	0.3
	Machakos	Cypermethrin	0.015	0.5
	Nairobi	Azoxystrobin	0.010	3
	Nairobi	Cypermethrin	0.020	0.5
	Nairobi	Tebuconazole	0.140	0.9
	Nakuru	Azoxystrobin	0.002	3
	Nakuru	Cypermethrin	0.020	0.5
	Nakuru	Difenoconazole	0.002	0.08
	Nakuru	Linuron	0.005	0.01

The occurrence of pesticide residues varied among the four vegetables analysed. Tomatoes recorded the highest number of samples with pesticide residues exceeding EU MRLs, followed by spinach and kale. Onion samples contained detectable pesticide residues; however, none exceeded the applicable EU MRLs. These findings indicate that tomatoes and leafy vegetables remain the commodities most vulnerable to pesticide contamination under the prevailing production systems.

Cypermethrin and Azoxystrobin were the most frequently detected pesticides, but at levels below the EU-MRL, particularly in Spinach from all counties. The study further established that out of the same 45 samples submitted for analysis, 15 (33.33%) had eight pesticide residues at levels above EU-MRLs in Tomatoes, Kale, and Spinach, as presented in table 2

Table 3: Pesticide residues above EU-MRL in different food types

Pesticide Residues [EU-MRLs -mg/kg]	Food Type	Source-ID	Pesticide residue, mg/kg)	Ratio of Observed Pesticide Residue(x): EU-MRLs (y)
Chlorfenapyr [0.01]	Tomatoes	Kirinyaga-047	0.05	5
		Nakuru-001	0.04	4
		Nakuru-002	0.02	2
		Kajiado-039	0.19	19
		Kajiado-048	0.05	5
		Kajiado-049	0.03	3
		Kirinyaga-046	0.11	11
LAMBDA-CYHALOTHRIN [0.01]	Kale	Nyandarua Olkalau-012	0.02	2
Difenoconazole [0.08]	Spinach	Nakuru, Bahati-014	0.7	8.75
Linuron [0.01]	Spinach	Nakuru, Bahati-015	0.02	2
Chlorpyrifos [0.01]	Tomatoes	Nyeri-021	0.04	4
		Kirinyaga-019	0.02	2
Carbendazim [0.1]	Spinach	Machakos-034	0.7	7
Tebuconazole [0.02]	Spinach	Nairobi, Ruai-036	0.14	7
Acephate [0.01]	Tomatoes	Kirinyaga-047 (0.07)	0.07	7

The pesticides had the ratio of their Residual Levels (x) against the EU-MRLs (y), ranging from two for Linuron in Spinach and for Lambda-Cyhalothrin in Kale to 19 for Chlorfenapyr in Tomatoes sourced from Kajiado County (Table 3). This indicates pesticide residue levels were two to nineteen times more than the respective EU-MRLs in those foodstuffs. Out of the 15 samples with significant levels of pesticide residues, 10 were in Tomatoes, four in Spinach, and one in Kale.

3.3 Pesticide Residues in Tomatoes

Significant residues were observed in Tomatoes sourced from the following counties, and their proportions were presented in Figure 1 .

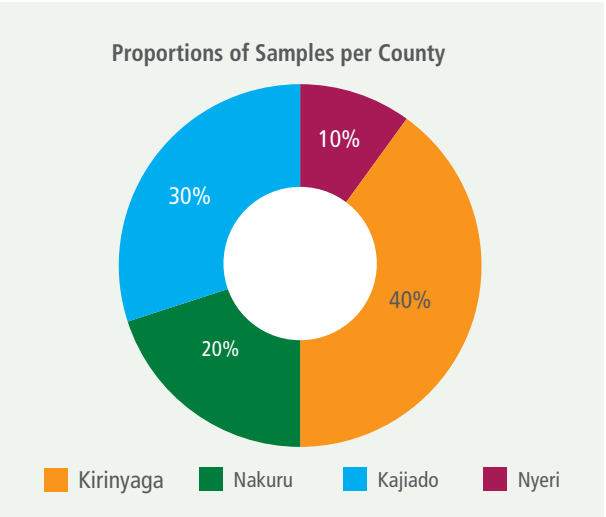


Figure 1: Proportions of observed significant pesticide residues and the counties of samples' origin

Kirinyaga County had the highest proportion of samples with significant pesticide residue levels, while Nyeri County had the lowest. The study examined the ratios of pesticide residue levels in samples collected across various counties relative to the EU-MRLs, and the results were presented in a Pareto Chart in Figure 2. The ratio harmonizes the variations that could have arisen if individual significant pesticide residue levels were to be given. Since different pesticides have different EU MRLs, this ratio creates harmonized data for comparison.

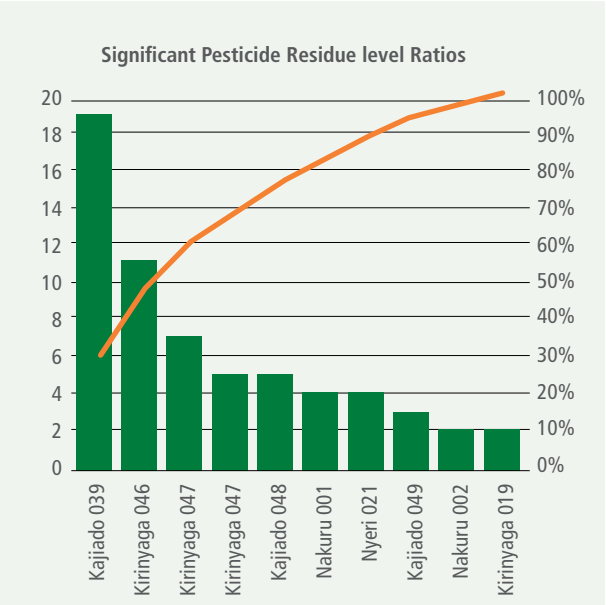


Figure 2: Significant Pesticide Residue Levels Ratios per Counties of sample origin

The study found that sample 039 from a sample of Tomatoes collected from Kajiado County had Chlorfenapyr with the highest pesticide residue ratio, which was 19 times its relative EU MRL. The other two samples from the same county had values of four and three times the relative pesticide residue levels. Three varieties of pesticides were observed to have significant residues. Their proportions are presented in **Figure 3**.

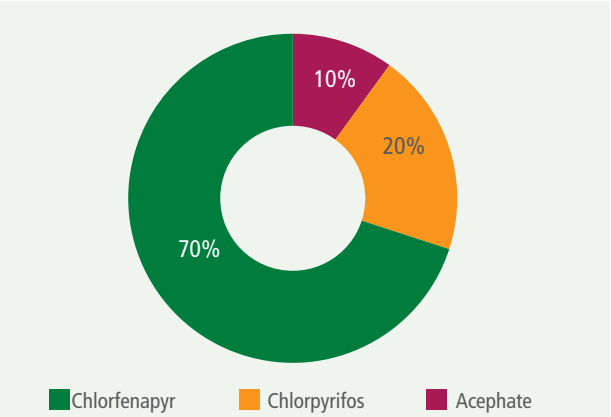


Figure 3: Proportion of varieties of significant pesticides in Tomato samples

The figure shows that Chlorfenapyr was the most frequent significant pesticide residue in the analyzed Tomato samples, where it captured a proportion of 70%.

3.3 Pesticide residues in Spinach samples

Four types of pesticides, namely Difenoconazole, Linuron, Tebuconazole, and Carbendazim, had their significant residue levels detected in Spinach sourced from Nakuru, Nairobi, and Machakos counties. Their respective residue ratios are presented in **Figure 4** below.

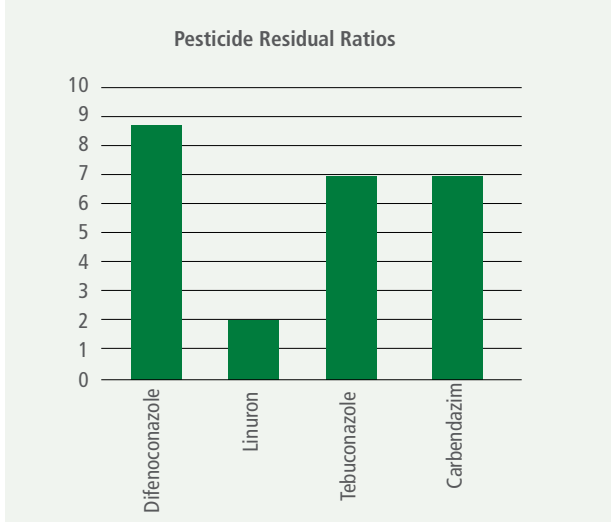


Figure 4: Significant Pesticide Residue Level Ratios per pesticide

Difenoconazole had the highest residue ratio of 8.75, with Linuron having the lowest at two.

3.4 Pesticide residues in Kale samples

Out of 10 analyzed Kale samples, only one from Nyandarua County had significant Lambda-Cyhalothrin residues at a ratio of two.

3.5 Information on Pesticides with Significant Residue Levels

The study explored the information related to the above pesticides that had significant residue levels in relation to Trade Name, the Type of formulation, and the effects on human beings, and the results were presented in Table 4. This information is provided by the Pest Control Products Board (PCPB), which is the Board that regulates the importation, exportation, manufacture, distribution, and use of pesticides in Kenya. Extra information is from other related sources that are cited.

Table 4: Information on Pesticides with Significant Residue Levels

Trade Name and type of formulation	Active ingredient	Human effects	Uses and classification
1	Chlorfenapyr	Mitochondrial dysfunction, myocardial injury, arrhythmias; digestive system injury; kidney injury*	**Miticide** for the control of spider mites WHO Class II Yellow colour Band Moderately hazardous
15	LAMBDA-CYHALOTHRIN	damage due to increased oxidative stress and inflammation **	**Insecticide.** WHO Class II Yellow colour Band Moderately hazardous
21	Difenoconazole	Hepatotoxic Alteration of biochemical parameters Inhibition of AChE***	**Fungicide** WHO Class II Yellow colour Band Moderately hazardous
2	Linuron	Testicular tumors, red blood cell damage, Growth retardation, hepatotoxicity****	**Pre-emergence herbicide for control of Annual grasses and Broad-leaved weeds** WHO Class II Yellow colour Band Moderately hazardous EPA classification -Restricted Use pesticide
29	Chlorpyrifos	Acute cholinergic crisis, intermediate syndrome, and delayed neuropathy, heart damage, and myeloneuropathy *	**Insecticide** WHO Class II Yellow colour Band Moderately hazardous
29	Carbendazim	Wide range of chronic effects. causes embryo toxicity, apoptosis, teratogenicity, hepatocellular and endocrine toxicity*	**Fungicide** **Biocide for preservation** WHO Class II Yellow colour Band Moderately hazardous
34	Tebuconazole	Perinatal exposure produces altered learning in a spatial cognitive task, and hippocampal and neocortical neuropathology*	**Fungicide** WHO Class II Yellow colour Band Moderately hazardous
12	ACEPHATE	Associated with hyperglycaemia, lipid metabolism dysfunction, DNA damage, and cancer, which are rapidly growing epidemics and which lead to increased morbidity and mortality rates and soaring health*	**Insecticide** WHO Class III Blue colour Band Slightly hazardous

** Expert task force (2021) ** Sherif (2014);*** Chen (2014) **** WHO (2019)*

The table shows that seven out of eight pesticides were classified as WHO Class II, indicating they are moderately hazardous (Yellow colour Band) (WHO, 2019). Among these, three are fungicides, three are insecticides, one is a herbicide, and one is a miticide, all of which are marketed under different trade names, sometimes as mixtures with other ingredients. These pesticides are linked to various health effects, ranging from mitochondrial dysfunction at the cellular level to organ damage such as hepatotoxicity, as well as teratogenicity and postnatal mental retardation.

3.6 Summary of Key Findings

The principal findings of the study are summarised as follows:

- Seventy-eight percent of the analysed vegetable samples contained detectable pesticide residues.
- One-third of all samples exceeded the applicable EU Maximum Residue Limits.
- Tomatoes had the highest proportion of non-compliant samples, followed by spinach and kale.
- Eight pesticide active ingredients exceeded regulatory limits.
- Seven of these pesticides were classified by WHO as moderately hazardous (Class II).
- Pesticide residue ratios ranged from two to nineteen times the applicable EU MRLs.
- Most non-compliant samples originated from major commercial vegetable-producing counties.

These findings provide the basis for the interpretation presented in Chapter Four and underscore the importance of strengthening pesticide management, routine residue monitoring, and consumer food safety interventions.

CHAPTER FOUR

4.0 DISCUSSION

4.1 Overview

This study assessed pesticide residue levels in tomatoes, kale, spinach, and onions marketed in Kenya and compared the detected concentrations with internationally recognised Maximum Residue Limits (MRLs). The findings provide important evidence on the occurrence of pesticide residues in vegetables commonly consumed by Kenyan households and their implications for food safety, public health, and pesticide regulation.

Overall, pesticide residues were detected in more than three-quarters of the analysed samples, with one-third exceeding the European Union Maximum Residue Limits (EU MRLs). These findings indicate that although pesticide use is widespread in vegetable production, compliance with recommended pesticide application practices remains inconsistent.

4.2 Occurrence of Pesticide Residues in Vegetables and comparison with previous studies

The high proportion of samples containing detectable pesticide residues demonstrates the extensive use of pesticides in commercial vegetable production. Detection of residues exceeding MRLs suggests inappropriate pesticide use, including excessive application rates, failure to observe pre-harvest intervals, repeated applications, or use of pesticides not registered for specific crops.

The proportion of non-compliant samples observed in this study is consistent with previous investigations conducted in Kenya by the Pest Control Products Board (PCPB) in 2024, where two baseline studies on pesticide residues in Kale, Tomatoes, and Onions were undertaken. The first one was in Nyeri, Meru, Kirinyaga, Taita Taveta, and Makueni counties, while the second was on the same foodstuffs but in Kajiado, Nyandarua, and Nakuru counties.

Their results showed that of the 105 tested samples, 33 (31%) had pesticide residues exceeding the EU-MRLs. That outcome was consistent with the current results, which showed that out of the 45 tested samples, 15 (33%) had pesticide residues that exceeded the EU-MRLs. In the PCPB (2024) study, Tomatoes had the largest proportion (64%) of the pesticide residues that exceeded the EU-MRLs (21 out of 33).

The results were consistent with the current study, which showed that Tomatoes had the largest proportion (67%) of the pesticide residues that exceeded the EU-MRLs (10 out of 15).

The PCPB (2024) study showed that the lowest proportion of foodstuffs with significant pesticide residue levels was Onions (making up only 3%). The result was consistent with the current one on the very low proportion of Onions with pesticide residues that exceeded the EU- MRLs.

The two studies also found Carbendazim in Kale (by PCPB) and in Spinach, yet it is not registered for use in either. The consistency of these findings confirms that pesticide misuse remains a persistent challenge within some vegetable production systems.

4.3 Tomatoes as the Most Contaminated Vegetable

Tomatoes recorded the highest number of samples exceeding EU MRLs. This observation agrees with previous national surveillance studies that have consistently identified tomatoes as one of the commodities most vulnerable to pesticide contamination.

Several factors may explain this finding. Tomatoes are attacked by arthropods, plant diseases, and nematodes, which significantly reduce fruit yield and quality, while weeds compete with tomato plants, further reducing attainable yield. Globally, losses due to these pests are estimated to be about 34.4% of attainable Tomato yield under current production practices. Without crop protection, losses would increase to 77.7% of the attainable yield (Sait Engindeniz, 2006). In Kenya, tomatoes are cultivated throughout the year and are highly susceptible to numerous insect pests and fungal diseases. Consequently, farmers often apply multiple pesticide products during a single production cycle. In addition, the high market demand for tomatoes may encourage harvesting before recommended pre-harvest intervals have elapsed, increasing the likelihood of detectable pesticide residues at the point of sale.

The detection of pesticide active ingredients not registered for tomato production is of particular concern because it suggests non-compliance with pesticide registration requirements and highlights the need for improved farmer training, extension services, and regulatory enforcement.

Globally, pests reduce tomato yields by about 34.4% under current farming practices, and losses could rise to 77.7% without crop protection

(Sait Engindeniz, 2006).

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4.4 Pesticide Residues in Kale and Spinach

Kale is the most preferred vegetable in most Kenyan homes due to taste preferences, availability, cost, convenience, and taste preferences. From the report, kale and spinach also contained pesticide residues exceeding regulatory limits, although less frequently than tomatoes. Leafy vegetables are especially susceptible to residue retention because of their large surface area, rough leaf texture, and waxy cuticle, which facilitate the deposition and persistence of pesticide sprays.

Unlike fruits that may be peeled before consumption, leafy vegetables are generally consumed whole, increasing the potential for dietary exposure if residues are not adequately removed during food preparation. The findings therefore reinforce the importance of promoting effective household washing and cooking practices alongside improved pesticide management at farm level.

Leafy vegetables are especially susceptible to residue retention because of their large surface area, rough leaf texture, and waxy cuticle, which facilitate the deposition and persistence of pesticide sprays.

4.5 Low Residue Levels in Onions

No onion sample exceeded the applicable EU MRLs despite the detection of low pesticide residue levels in some samples. The lower contamination observed in onions may be attributed to the growth habit of bulb onions, where the edible portion develops beneath the soil surface and is naturally protected from direct pesticide deposition. Nevertheless, emerging production practices, including the application of herbicides shortly before harvest to accelerate bulb drying, may increase residue occurrence if recommended pre-harvest intervals are not observed. Continued surveillance of onion production systems is therefore warranted.

4.6 Pesticide Hazard Classification and Public Health Implications

Most pesticide active ingredients detected above EU MRLs were classified by the World Health Organization (WHO) as Class II (moderately hazardous). Repeated dietary exposure to moderately hazardous pesticides may contribute to cumulative health risks, particularly among vulnerable populations such as children, pregnant women, older adults, and individuals with compromised health. Long-term exposure to certain pesticide active ingredients has been associated with neurological disorders, endocrine disruption, reproductive impairment, developmental toxicity, and increased risks of some cancers. While this study did not evaluate human exposure directly, the presence of multiple pesticide residues in commonly consumed vegetables underscores the importance of maintaining effective national food safety surveillance programmes.

4.7 Regulatory Implications

The findings demonstrate the continued importance of strengthening pesticide regulation throughout the agricultural value chain. Kenya has established regulatory mechanisms through the Pest Control Products Board (PCPB); however, effective implementation requires adequate inspection, routine residue monitoring, farmer education, and enforcement of existing legislation. The proposed Pest Control Products legislation presents an opportunity to modernise pesticide regulation by strengthening oversight of pesticide registration, distribution, use, and post-registration monitoring. Enhanced regulatory capacity would contribute to safer pesticide use, improved consumer protection, and increased competitiveness of Kenyan agricultural produce in international markets.

4.8 Comparison with International Studies

The findings of this study are consistent with reports from several low- and middle-income countries where vegetables frequently contain detectable pesticide residues, particularly in intensive horticultural production systems. Studies conducted in Asia, Africa, and Latin America similarly report tomatoes and leafy vegetables as commodities with relatively high frequencies of pesticide residue detection.

Despite geographical differences in farming practices, the underlying factors remain comparable, including high pest pressure, intensive pesticide use, inadequate farmer training, and limited compliance with Good Agricultural Practices. These similarities demonstrate that pesticide residue management is a global food safety challenge requiring coordinated action by regulators, researchers, producers, and consumers.

4.9 Implications for Consumer Food Safety

The findings highlight the need for interventions at both production and household levels. Prevention of pesticide residues should remain the primary objective through responsible pesticide use, adherence to Good Agricultural Practices, and compliance with recommended pre-harvest intervals. However, because complete elimination of pesticide residues at the farm level may not always be achievable, consumers should be encouraged to adopt evidence-based household food preparation practices capable of reducing pesticide residues before consumption. The evaluation of such methods is presented in Part Two of this report.

Most pesticide active ingredients detected above EU Maximum Residue Limits (MRLs) were classified by the World Health Organization (WHO) as Class II (moderately hazardous), posing cumulative health risks from repeated dietary exposure, particularly for children, pregnant women, older adults, and people with compromised health.

4.10 Study Strengths and Limitations

A major strength of this study is the use of accredited multi-residue analytical techniques capable of detecting a wide range of pesticide active ingredients with high sensitivity and accuracy. The inclusion of vegetables sourced from several major production regions further enhances the relevance of the findings to national food safety monitoring.

The study was, however, limited by its cross-sectional design, which represents pesticide residue levels only during the sampling period. Seasonal variation, changes in pest pressure, and evolving pesticide use practices may influence residue occurrence over time. In addition, although trader information enabled traceability of produce to source counties, complete verification of farm-level pesticide use was not possible. Future studies should incorporate repeated seasonal sampling, farm-level pesticide use surveys, dietary exposure assessments, and cumulative risk analyses to provide a more comprehensive understanding of pesticide exposure among Kenyan consumers.

4.11 Summary

The study confirms that pesticide residues remain common in vegetables marketed in Kenya and that a substantial proportion exceed internationally recognised regulatory limits. Tomatoes, followed by kale and spinach, were the most affected commodities, while onions generally contained lower residue levels. The occurrence of residues above EU MRLs indicates continued challenges in pesticide stewardship and highlights the need for strengthened regulatory oversight, improved farmer compliance with Good Agricultural Practices, and sustained consumer education. These findings provide the scientific basis for evaluating household pesticide residue reduction methods presented in Part Two of this report and support ongoing efforts to improve food safety and protect public health in Kenya.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This study assessed pesticide residue levels in tomatoes, kale, spinach, and bulb onions marketed in selected Kenyan markets. The findings provide important evidence on the occurrence of pesticide residues in vegetables commonly consumed by Kenyan households and establish a baseline for evaluating household methods of reducing dietary exposure to pesticide residues.

Pesticide residues were detected in the majority of the analysed samples, demonstrating the widespread use of pesticides in commercial vegetable production. Although most residues complied with established regulatory standards, one-third of the samples contained pesticide residues exceeding the European Union Maximum Residue Limits (EU MRLs), indicating non-compliance with recommended pesticide use practices in parts of the production chain.

Tomatoes recorded the highest proportion of non-compliant samples, followed by spinach and kale, while onions contained comparatively low residue levels and no sample exceeded the applicable EU MRLs. The predominance of pesticide residues in tomatoes and leafy vegetables is consistent with their production characteristics, high pest pressure, and frequent pesticide applications during cultivation.

Eight pesticide active ingredients exceeded the applicable EU MRLs, seven of which are classified by the World Health Organization (WHO) as Class II (moderately hazardous) pesticides. Although the presence of residues above regulatory limits does not necessarily indicate immediate health effects, repeated dietary exposure to such residues may increase long-term public health risks, particularly among vulnerable population groups.

The findings demonstrate the continued need to strengthen pesticide stewardship throughout the agricultural value chain. Effective food safety requires responsible pesticide use by producers, routine residue surveillance by regulatory authorities, and increased consumer awareness of measures that reduce dietary exposure.

5.2 Recommendations

The findings of this study have implications for government agencies, regulatory authorities, farmers, researchers, development partners, and consumers. The following recommendations are proposed.

5.2.1 Strengthen National Pesticide Residue Surveillance

The Pest Control Products Board (PCPB), in collaboration with relevant government agencies, should institutionalise routine national surveillance programmes to monitor pesticide residues in fresh produce marketed throughout Kenya. Regular monitoring will facilitate early identification of non-compliant produce, support evidence-based regulatory action, and strengthen consumer confidence in the safety of locally produced food.

5.2.2 Promote Good Agricultural Practices

Farmers should be supported through continuous training and extension services to promote compliance with Good Agricultural Practices (GAP). Particular emphasis should be placed on:

- selecting pesticides registered for specific crops;
- observing recommended application rates;
- complying with pre-harvest intervals;
- using appropriate protective equipment; and
- maintaining pesticide application records.

Improved compliance with GAP will reduce pesticide residues while enhancing environmental sustainability and market access.

5.2.3 Strengthen Regulatory Enforcement

The National and County Government of Kenya should continue strengthening the legal and institutional framework governing pesticide management by supporting implementation of updated pesticide legislation and enhancing the capacity of regulatory agencies responsible for pesticide registration, inspection, residue monitoring, and enforcement. Enhanced regulatory oversight will contribute to safer pesticide use and improved protection of consumers, agricultural workers, and the environment.

5.2.4 Promote Integrated Pest Management

Integrated Pest Management (IPM) and Agroecology should be promoted as the preferred approach to crop production and crop protection. Increased adoption of biological control methods, resistant crop varieties, cultural practices, and other non-chemical pest management strategies will reduce dependence on synthetic pesticides while maintaining agricultural productivity.

5.2.5 Increase Consumer Awareness

Public education programmes should be developed to improve consumer understanding of pesticide residues and safe food handling practices. Evidence-based guidance on washing, trimming, peeling, soaking, blanching, and cooking vegetables should be widely disseminated through agricultural extension services, public health programmes, schools, and mass media.

5.2.6 Support Continued Research

Further studies are recommended to:

- monitor seasonal variations in pesticide residues;
- evaluate cumulative dietary exposure to multiple pesticide residues;
- assess pesticide use practices at farm level;
- investigate pesticide residues in additional food commodities; and
- evaluate practical household methods for reducing pesticide residues under different environmental and culinary conditions.

Such studies will strengthen the national evidence base required for food safety policy and risk assessment.

5.3 Policy Implications

The findings of this study underscore the need for a coordinated, multisectoral approach to pesticide management involving government agencies, research institutions, producer organisations, development partners, and consumers.

National food safety strategies should integrate:

- routine pesticide residue monitoring;
- strengthened farmer and agro dealers education;
- improved enforcement of pesticide regulations;
- promotion of Integrated Pest Management;
- enhanced laboratory capacity; and
- consumer education on safe food preparation practices.

Implementing these measures will contribute to reducing dietary exposure to pesticide residues, improving public health outcomes, strengthening domestic and export market confidence, and supporting sustainable agricultural development in Kenya.

5.4 Conclusion

Ensuring the safety of fresh vegetables requires interventions across the entire food value chain, from pesticide selection and application at farm level to food preparation in the household. While prevention of excessive pesticide residues through responsible agricultural practices remains the most effective strategy, consumers also have an important role in reducing dietary exposure through appropriate food preparation methods.

This baseline assessment demonstrates that pesticide residues continue to occur in vegetables marketed in Kenya and provides the scientific foundation for evaluating practical household interventions. The findings presented in the next part of this report examine the effectiveness of selected household preparation methods in reducing pesticide residues and provide evidence-based recommendations that can further enhance consumer protection and food safety.

PART TWO

EFFECTIVENESS OF HOUSEHOLD METHODS IN REDUCING PESTICIDE RESIDUES IN SELECTED VEGETABLES

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

The findings presented in Part One of this report demonstrated that pesticide residues are common in vegetables marketed in Kenya and that a proportion of samples contained residues exceeding the European Union Maximum Residue Limits (EU MRLs). Although improving pesticide management at the production stage remains the most effective strategy for minimizing consumer exposure, household food preparation practices provide an important additional opportunity to reduce pesticide residues before consumption.

Consumers routinely wash, peel, trim, soak, blanch, or cook vegetables prior to consumption. These practices may substantially reduce pesticide residues depending on the physicochemical properties of the pesticide, the characteristics of the vegetable, and the preparation method used. However, the effectiveness of these methods varies considerably, and evidence specific to vegetables commonly consumed in Kenya remains limited.

Generating locally relevant evidence on practical household preparation methods is essential for developing food safety recommendations that are scientifically sound, affordable, and easily adopted by households. Such information complements regulatory interventions by empowering consumers to reduce dietary exposure to pesticide residues using methods that require no specialized equipment or expensive technologies.

This part of the study therefore evaluated the effectiveness of selected household food preparation methods in reducing pesticide residues in tomatoes, kale, spinach and bulb onions. The selected methods were chosen because they reflect common food preparation practices in Kenyan households and have been reported in previous studies to reduce pesticide residues to varying degrees; they are affordable, convenient and practical.

1.2 Problem Statement

Over the past years, there has been routine monitoring of pesticide residues, which provide valuable information on the occurrence of contamination in food. This, however, has ended up alarming consumers about the dangers of what they are buying and eating from the marketplace. No practical, science-based measures that consumers can use to reduce pesticide exposure after purchase have been provided. Although household food preparation is widely recognized as an important component of food safety, limited scientific evidence is available on the effectiveness of commonly used preparation methods under Kenyan conditions.

Existing studies have largely been conducted in other countries using different vegetables, pesticide formulations, and culinary practices, making direct application of their findings to Kenyan households difficult. Consequently, consumers often rely on anecdotal advice regarding vegetable preparation, with little information on which methods provide the greatest reduction in pesticide residues.

There is therefore a need to evaluate household preparation techniques using vegetables commonly consumed in Kenya under controlled experimental conditions. The evidence generated can support consumer education, strengthen public health recommendations, and complement interventions aimed at improving pesticide stewardship along the food value chain.

1.3 Justification of the Study

Reducing pesticide exposure requires interventions at every stage of the food system, including pesticide selection and application during crop production, regulatory oversight, food distribution, and household food preparation. While farmers and regulatory authorities play primary roles in preventing excessive pesticide residues, consumers also require practical guidance on food preparation methods that effectively minimize dietary exposure.

Common food preparation practices such as washing, peeling, trimming, soaking, blanching, and cooking can substantially reduce pesticide residues, depending on the pesticide's properties, the vegetable, and the preparation method.

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This study provides scientific evidence on the effectiveness of household preparation methods that are inexpensive, readily available, and consistent with normal domestic cooking practices. The findings will contribute to consumer awareness programmes, food safety policies, agricultural extension services, and public health education by identifying methods capable of reducing pesticide residues without compromising food quality.

The study also complements the baseline residue surveillance presented in Part One by moving beyond contamination assessment to evaluate practical interventions for reducing consumer exposure.

1.4 Study Objectives

1.4.1 General Objective

To evaluate the effectiveness of selected household food preparation methods in reducing pesticide residues in tomatoes, kale, spinach, and onions under controlled experimental conditions.

1.4.2 Specific Objectives

The study sought to:

- Determine the effectiveness of washing under running tap water in reducing pesticide residues.
- Evaluate the effects of blanching and cooking on pesticide residue concentrations.
- Assess the effectiveness of soaking vegetables in salt, baking soda, and vinegar solutions before washing and cooking.
- Compare pesticide residue reduction among the different household preparation methods.
- Identify practical household preparation methods that provide the greatest reduction in pesticide residues while remaining suitable for routine domestic use.

1.5 Research Questions

The study addressed the following research questions:

1. To what extent do common household food preparation methods reduce pesticide residues in vegetables?
2. Which preparation methods are most effective for tomatoes, kale, spinach, and onions?
3. Does the effectiveness of household preparation methods vary according to vegetable type and pesticide characteristics?
4. Which methods can be recommended to Kenyan households as practical approaches for reducing dietary exposure to pesticide residues?

1.6 Significance of the Study

This study provides evidence-based guidance on household food preparation methods that reduce pesticide residues in vegetables commonly consumed in Kenya. The findings are expected to benefit several stakeholder groups.

1. Consumers will gain practical recommendations for preparing vegetables in ways that minimize dietary exposure to pesticide residues.
2. Public health professionals and nutrition educators will obtain scientifically validated information that can be incorporated into health promotion and food safety campaigns.
3. Agricultural extension officers will be able to complement messages on Good Agricultural Practices with advice on safe household food handling.
4. Regulatory agencies will obtain evidence that supports integrated food safety strategies combining prevention of pesticide misuse with consumer risk reduction measures.
5. Researchers will benefit from a locally generated evidence base that can inform future studies on pesticide exposure, dietary risk assessment, and food processing technologies.

1.7 Scope of the Study

The study evaluated eight household food preparation methods using tomatoes, kale, spinach, and onions obtained from Kenyan markets. Vegetables were exposed to selected pesticide active ingredients under controlled laboratory conditions before undergoing the various preparation treatments. The effectiveness of

each treatment was determined by comparing pesticide residue concentrations before and after preparation using accredited laboratory analytical methods. The study focused on pesticide residue reduction and did not evaluate changes in nutritional composition, sensory quality, consumer preferences, or economic costs associated with the different preparation methods.

1.8 Linkage to Part One

Part One of this report established the occurrence and distribution of pesticide residues in vegetables marketed in Kenya and identified pesticide active ingredients that exceeded internationally recognised regulatory limits. Building upon those findings, Part Two investigated practical household interventions capable of reducing pesticide residues before consumption. Together, the two studies provide a comprehensive assessment of pesticide exposure, from occurrence in the food supply to evidence-based consumer strategies for reducing dietary risk, thereby contributing to improved food safety, informed public health guidance, and strengthened pesticide management in Kenya.

CHAPTER TWO

2.0 STUDY DESIGN

2.1 Study design

An experimental laboratory study was conducted to evaluate the effectiveness of selected household food preparation methods in reducing pesticide residues in four vegetables commonly consumed in Kenya. The study involved controlled pesticide exposure of vegetable samples, application of selected household preparation methods, and quantitative determination of pesticide residues before and after treatment. The effectiveness of each preparation method was assessed by comparing post-treatment pesticide residue concentrations with those measured in untreated control samples.

2.2 Sampling facilities

Sample preparation and treatment experiments were conducted at the Department of Public Health, Pharmacology and Toxicology (PHPT), University of Nairobi. Laboratory analysis of pesticide residues was undertaken by SGS, an internationally accredited laboratory using accredited analytical equipment for Liquid Chromatography-Tandem Mass Spectrometry (LC-MS/MS) and Gas Chromatography-Tandem Mass Spectrometry (GC-MS/MS).

2.3 Selection of Vegetables

The study evaluated four vegetables widely consumed in Kenya:

1. Tomato (Solanum lycopersicum)
2. Kale (Brassica oleracea var. sabellica)
3. Spinach (Spinacia oleracea)
4. Bulb onion (Allium cepa)

Just as in the baseline study, the four were selected because:

1. Part One of this study identified them as containing pesticide residues of public health concern. The same selection/sampling criteria for Part One of the study were applied, so it was the same samples of the products that were used for Part Two of the study.
2. they are widely consumed by Kenyan households; and
3. they undergo different household preparation practices before consumption.

2.4 Selection of Pesticides

Seven pesticide active ingredients were selected for controlled exposure based on the findings of Part One and published evidence on their occurrence in vegetables marketed in Kenya.

Selection criteria included:

1. frequency of detection;
2. occurrence above EU Maximum Residue Limits;
3. widespread agricultural use;
4. representation of different pesticide classes; and
5. differing physicochemical properties that influence residue persistence and removal.

The selected pesticides included:

1. Acephate
2. Imidacloprid
3. Alpha-cypermethrin
4. Tebuconazole
5. Lambda-cyhalothrin
6. Linuron
7. Chlorpyrifos

Commercial formulations were prepared according to manufacturers' recommended application rates to simulate normal agricultural use.

2.5 Experimental Exposure of Vegetables

At the PHPT laboratory, the four different types of food samples obtained from the selected markets were separately pooled to constitute an adequate amount for controlled pesticide exposure and later reduction treatment. This was achieved by pooling similar food types of equal amounts from the different traders until the required amounts were achieved. The pools were then exposed to selected pesticides with high nonconformity and detection rates previously reported on/in foodstuffs (Table 5). The storage (ST) group that was not spiked with pesticides was computed from baseline positive samples and submitted for residue testing after seven days of storage.

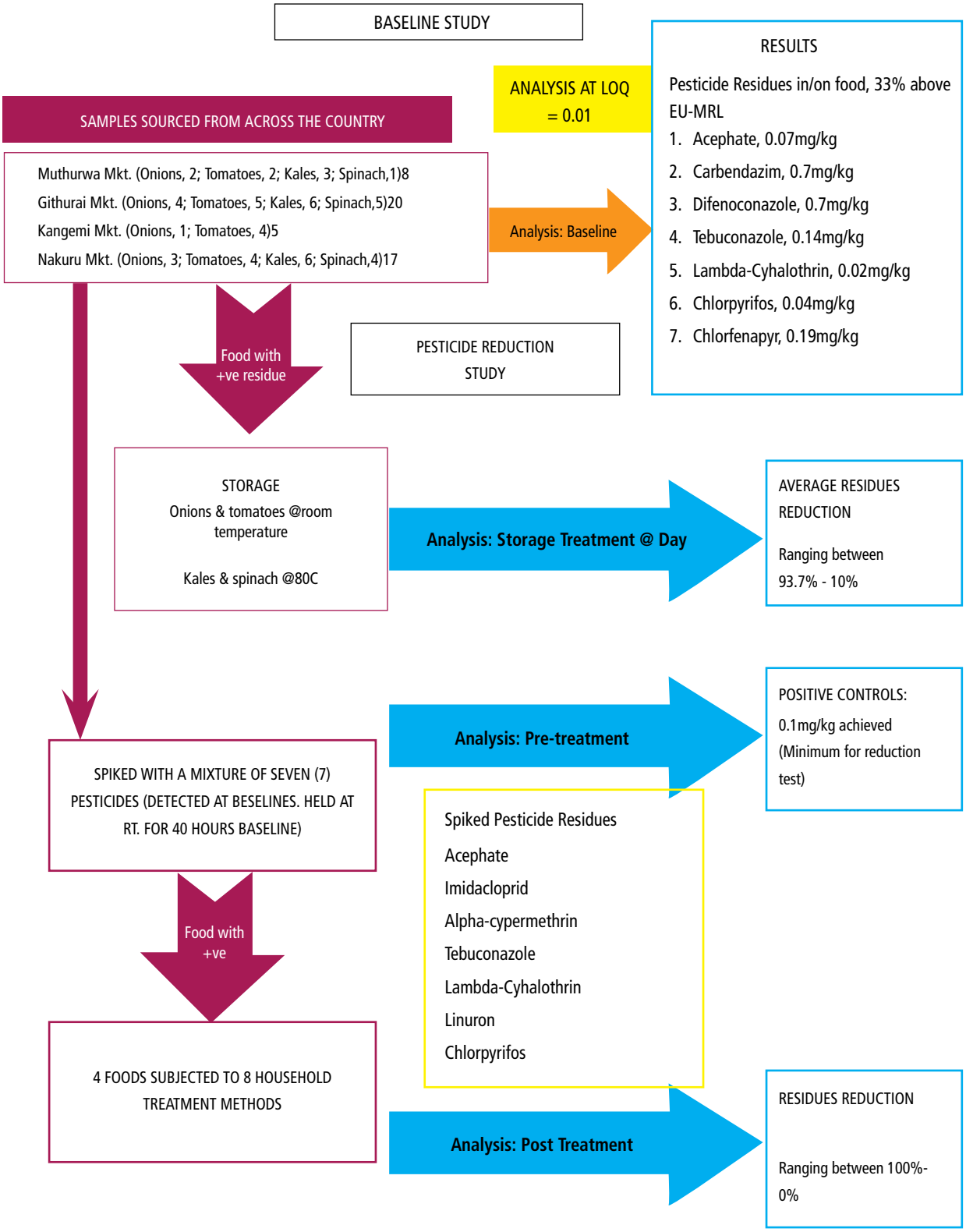
Table 5: Constituting samples for pesticide exposure

Tests		**10 Tomatoes (1kg)/ trader**	**10 Onions (1kg)/ trader**	**Kale (1kg)/ trader**	**Spinach (1kg)/ trader**	**Sample number N = 72**
Controlled Exposure	A pool of 7 pesticides	600g	600g	600g	600g	
Pre-treatment samples		Pool 1	Pool 2	Pool 3	Pool 3	4*2 = 8
Treatment methods		W, B, S, C, BS, BSC, V, ST	W, B, S, C, BS, BSC, V, ST	W, B, S, C, BS, BSC, V, ST	W, B, S, C, BS, BSC, V, ST	
Post-treatment samples		8	8	8	8	8*4 = 64

Key:

W = **Washing** under running [tap] water
B = **Washing** under running [tap] water + **Blanching**
S = **Salty water** (2%) soaking + **Washing** under running [tap] water
C = Salty water soaking + Washing + **Cooking** (Kale & Spinach), (SAUTEING for Onions & Tomatoes)
BS = **Baking Soda** (2% Sodium bicarbonate) soaking + **Washing** under running [tap] water
BSC = Baking Soda (2% Sodium bicarbonate) + Washing + **Cooking**
V = Vinegar soaking (20%) + Washing under running [tap] water **+ cooking**
ST = Room Temperature storage for 7 days (Onions & Tomatoes) and 8^0C for 3 days (Kale & Spinach)] + **Washing** under running [tap] water + **cooking**

Schematic Abstract



CHAPTER THREE

3.0 METHODOLOGY

3.1 Pesticide exposure and treatment

The method by Yang (2022), with minor modifications, was used, where seven pesticides were obtained from local suppliers in the smallest available package. Characteristics of the selected active ingredients, including solubility, category, mode of action, and classification (**Appendix 4**), were considered.

The pesticides were diluted with 20 liters of water to obtain their indicated application concentrations as per the manufacturer's instructions.

The following pesticides were used to contaminate the four foodstuffs.

1. Acephate, 970g/Kg; Orthere 97% pellet
2. Imidacloprid, 200g/L; Emerald, 200SL
3. Alpha-Cypermethrin; 200g/L; Degree max 200EC
4. Tebuconazole, 250g/L; Folicur 250 EW
5. Lambda-Cyhalothrin; 17.5g/L; Duduthrin 1.75 EC
6. Linuron*, 500g/Kg; Linagan 50 WP
7. Chlorpyrifos, 480g/L; Sulban 48EC

** Linuron is a phenylurea herbicide used to control weeds in various crops. It inhibits photosynthesis in plants, preventing their growth. It is tolerated by some leafy vegetables, including some Spinach species. It was thus spiked on the food produce in this study with this in mind.*

The samples were placed in four crates labeled Tomatoes, Onions, Kale, and Spinach. The pesticide mixture was then evenly sprayed on the samples and left for 40 hours in a clean and secure room at room temperature. After exposure, the foodstuffs were each randomly picked from the crates and apportioned to the seven treatment groups (W, B, S, C, BS, BSC & V) and a positive control group as evenly as possible to achieve the 600g required for duplicate tests **(Table 4)**.

3.2 Foodstuff treatment protocol

The selected treatment methods were adopted as carried out by Yang (2022), Phopin (2022), Nguyen (2020), Shashi (2014), and Vidasha and Jaswinder (2013). The methods were designed to closely depict practices in most Kenyan homes with reference to Kenyan recipes (FAO and GoK, 2018).

3.2.1 Pre-treatment preparations

Trimming of the Tomato was achieved by cutting off the stalk, after which it was subjected to the eight treatment methods.

Peeling an Onion was achieved by removing two to three layers, after which the Onions were subjected to all the treatment methods.

***Trimming Kale and Spinach*:** the non-edible stalks were chopped off, after which the edible parts were subjected to all the treatment methods.

The recipe was adopted from the FAO/Government of Kenya (2018) Kenyan Food Recipes.

1. **Washing** under running [tap] water. After pre-treatment preparations, the samples [300gx2] were then washed by hand rubbing under running tap water at **170ml/s** for 2 minutes, and they were then placed on clean dry towels for the excess water to drain. After drying, the samples were packaged and transported to the analytical lab in cool boxes with ice packs.
2. **Washing** under running [tap] water and **Blanching.** After pre-treatment preparations, the samples [300gx2] were then placed in a basin with boiling water for 60 seconds. Samples were then removed and placed on dry towels at room temperature to drain excess water. After cooling, the samples were packaged and transported to the analytical lab in cool boxes with ice packs.
3. **Salty water** (2%) soaking and **washing** under running [tap] water

   After pre-treatment preparations, the samples [300gx2] were then placed in a basin with **2%** table salt, NaCl (20g in 1000mls tap water; w/v) solution for 15 minutes. This was followed by washing under tap water as in **1 above**, drying on towels, and packaging to be taken for testing.
4. **Salty water soaking** + **Washing** under running [tap] water + **Cooking** (Kale & Spinach), (SAUTÉING for Onions and Tomatoes). After pre-treatment preparations, samples [300gx2] were then placed in a basin with 2% table salt, NaCl (20 g in 1000mls tap water; w/v) solution for 15 minutes.

   ### Cooking of Kale and Spinach

   - Samples of Kale and Spinach [300gx2] were chopped separately into 1-inch pieces, then placed into a cooking pan, and covered. Kale was cooked for five minutes while Spinach was on the fire for ten minutes.

   ### Onions

   - Cooking oil was heated over medium-high heat for 1-2 minutes. The chopped Onions (one-inch pieces) were placed in the hot oil and cooked for five minutes or until tender and golden brown.

   ### Tomatoes

   - A large pan was warmed over medium-high heat for 1-2 minutes.
   - Cooking oil was added (one tablespoon of oil per medium-sized Tomato), followed by one-inch chopped Tomatoes.
   - The Tomatoes were sautéed for about 2-3 minutes.
5. **Baking Soda** (2% Sodium bicarbonate) soaking + **Washing** under running tap water. After pre-treatment preparations, samples [300gx2] were placed in a basin with 2% sodium bicarbonate (20g in 1000mls tap water; w/v) solution for 15 minutes. This was followed by washing under tap water as in **1 above**, drying on towels, and packaging to be taken for testing.

6. Baking Soda (2% Sodium bicarbonate) + **Washing** under running [tap] water + **Cooking.** After pre-treatment preparations, samples [300gx2] were placed in a basin with 2% sodium bicarbonate (20 g in 1000mls tap water; w/v) solution for 15 minutes, as in 5 above. This was followed by washing under tap water as in 1 above, and cooking as in **4 above**.
7. **Vinegar** soaking + **Washing** under running [tap] water **+ Cooking.** After pre-treatment preparations, samples [300gx2] were placed in a basin with 20% vinegar (100mls in 900mls tap water; w/v) solution for 15 minutes. This was followed by washing under tap water, as in 1 above, as in **4 above**.
8. **Room Temperature storage** for seven days for Onions and Tomatoes, while Kale and Spinach were stored at 80 °C for three days, after which they were packaged and submitted for testing. The results of the analysis of the pesticide residue level pre-treatment provided comparison levels with those observed after treatment procedures. The post-treatment samples were 64 since each of the four foodstuffs had two samples (300gm X 2), which were taken through the eight treatment procedures. A total of 72 samples were analyzed for pesticide residues, as shown in **Table 2**.

3.3 Pesticide Residues Testing

The control group was submitted for testing using the Quick, Easy, Cheap, Effective, Rugged, and Safe (QuEChERS) method and tested using GC/MS/MS and LC/MS/MS, capable of detecting and quantifying 500 active pesticide ingredients (**Appendix 5**). The testing was conducted at a contracted ISO 17025-certified testing laboratory. .

1. The sample groups were taken through the seven residue reduction treatments (storage was included as the 8th method) in duplicates to make a total of 32 treatments using the provided SOPs. They were then processed for pesticide extractions and submitted for testing using GC/MS/MS and LC/MS/MS.
2. Results obtained were tabulated in an Excel Sheet, and comparative analyses were done to establish the presence of pesticide residues, quantities of pesticide residues removed by the different methods, as well as the efficacy of the treatment methods.
3. Results were interpreted in line with applicable guidelines, including CODEX Alimentarius and the European Union for the evaluation of regulatory compliance.

Table 6: Pesticide Residues Reduction Protocols and Treatment Plan

Food Types	Residue Reduction Treatment Methods								Samples	
	1	2	3	4	5	6	7	8		
	Washing under running water	Washing + Blanching	Salty water (2%) soaking + Washing	Salty water soaking + Washing + Cooking	Baking Soda (Sodium bicarbonate), 2% soaking + Washing	Baking Soda (Sodium bicarbonate) + Washing + Cooking	Vinegar, 20% soaking + washing + Cooking	RT store [7days (Onions & Tomatoes)], 80C [3 days (Kale & Spinach)	Weight of each food produce for treatment	Total number of samples for testing
Tomatoes	300gx2	300gx2	300gx2	300gx2	300gx2	300gx2	300gx2	300gx2	4800g	
Onions	300gx2	300gx2	300gx2	300gx2	300gx2	300gx2	300gx2	300gx2	4800g	
Kale	300gx2	300gx2	300gx2	300gx2	300gx2	300gx2	300gx2	300gx2	4800g	
Spinach	300gx2	300gx2	300gx2	300gx2	300gx2	300gx2	300gx2	300gx2	4800g	
Post-Treatment Samples	4 x 2	4 x 2	4 x 2	4 x 2	4 x 2	4 x 2	4 x 2	4 x 2		64
Pre-Treatment	4 poolsx2									8
Total samples										**72**

The selected treatment methods were adopted as carried out by Yang (2022), Phopin (2022), Nguyen (2020), Shashi (2014), Vidasha and Jaswinder (2013). The methods were designed to closely depict practices in most Kenyan homes with reference to Kenyan recipes (FAO and GoK, 2018).

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CHAPTER FOUR

4.0 FINDINGS

4.1 Pesticide residues analysis on treated samples

The following pesticides' active ingredients were detected in spiked samples before and after reduction treatment methods.

1. Acephate
2. Imidacloprid
3. Alpha-Cypermethrin
4. Tebuconazole
5. Lambda-Cyhalothrin
6. Linuron
7. Chlorpyrifos
8. Methamidophos [metabolite of Acephate]

All seven pesticides spiked on the four food types were detected at different concentration levels before the application of the eight treatment procedures. Among those used to spike, only Imidacloprid and Cypermethrin were detected at levels less than 0.1mg/kg. This was also the case with Methamidophos, which was not directly spiked on the foods but appeared as a metabolite of Acephate (**Table 7**).

Table 7: Pesticide residues in pre-treated samples after spiking at application concentrations

Food Type	Average concentrations of spiked pesticides in pre-treated samples							
	Acephate mg/kg	Methamidophos mg/kg	Chlorpyrifos mg/kg	Imidacloprid mg/kg	Linuron mg/kg	Tebuconazole mg/kg	Cypermethrin (Sum)	Lambda-Cyhalothrin
Tomato	0.19±0.04	0.03	3.6±1.81	0.05±0.01	2.69±0.50	0.39±0.05	0.07±0.01	0.39±0.06
Onion	2.84±0.35	0.06±0.01	3.45±0.42	0.83±0.12	8.37±0.12	1.15±0.20	0.3	1.58±0.03
Kale	10.72±0.10	0.45±0.01	19.27±1.32	3.11±0.75	28.04±3.15	5.77±0.01	0.85±0.16	4.13±1.23
Spinach	6.08±0.88	0.53±0.16	14.92±3.68	2.11±0.14	21.82±4.02	3.42±0.57	0.68±0.04	3.50±0.31

4.2 Average reduction of pesticide residues in/on the four food types

Onions had the best pesticide reduction with all seven treatment methods, ranging between 98.7% and 99.7%. Average reductions, the best being blanching and washing at 99.7%, followed by soaking in salty water, washing under running water, plus cooking, as well as soaking in baking soda, washing in running water, plus cooking at 99.4%. Tomatoes came second, with a high of 68.3 % average reduction achieved after soaking in 2% baking soda plus washing under running water, and cooking. The highest in Spinach was after soaking in salty water, washing under running water, plus cooking, at a 65.5% average reduction; soaking in vinegar, washing under running water, and cooking was the highest for Kale at an average of 62.3% reduction.

On average, soaking in salty water, washing under running water plus cooking gave the highest average residue reduction at 72.4%; this was followed by washing in running water plus blanching at 70.0%, then soaking in baking soda plus washing and cooking at 69.8%, while soaking in baking soda, washing plus cooking had 69.8% reduction. This was followed by a vinegar soak at 64.6, washing under running water at an average reduction of 61.3%, and lastly, a 56.6% average reduction was achieved with soaking in baking soda plus washing under running water, as shown in **Table 8** and **Figure 5**.

Table 8: Averages of residue reduction across all detected pesticides in the four food produce

	Treatment Methods	% Average Residue Reduction in Food Produces				
		Tomatoes	Onions	Kale	Spinach	Treatment Average
1	Washing in running water	49.8	99.3	44.4	51.6	61.3
2	Washing in running water + Blanching	56.4	99.7	60	63.8	70.0
3	2% Salt soaking + Washing in running water	50.2	97.4	50.3	56	63.5
4	2% salt soaking + washing + cooking	64.1	99.4	60.4	65.5	72.4
5	2% baking soaking + washing in running water	69	99.3	29.6	28.6	56.6
6	2% baking soaking + washing + cooking	68.3	99.4	56.7	54.9	69.8
7	20% Vinegar soaking + washing +cooking	49.6	98.7	62.3	47.7	64.6
	Product Average	58.2	99	52	52.6	
8	Keeping at RT & 80C for 7 days	4.0 *		3.8	1.5	4.5

*Tomato samples were used in place of Onions since none had pesticide residues.

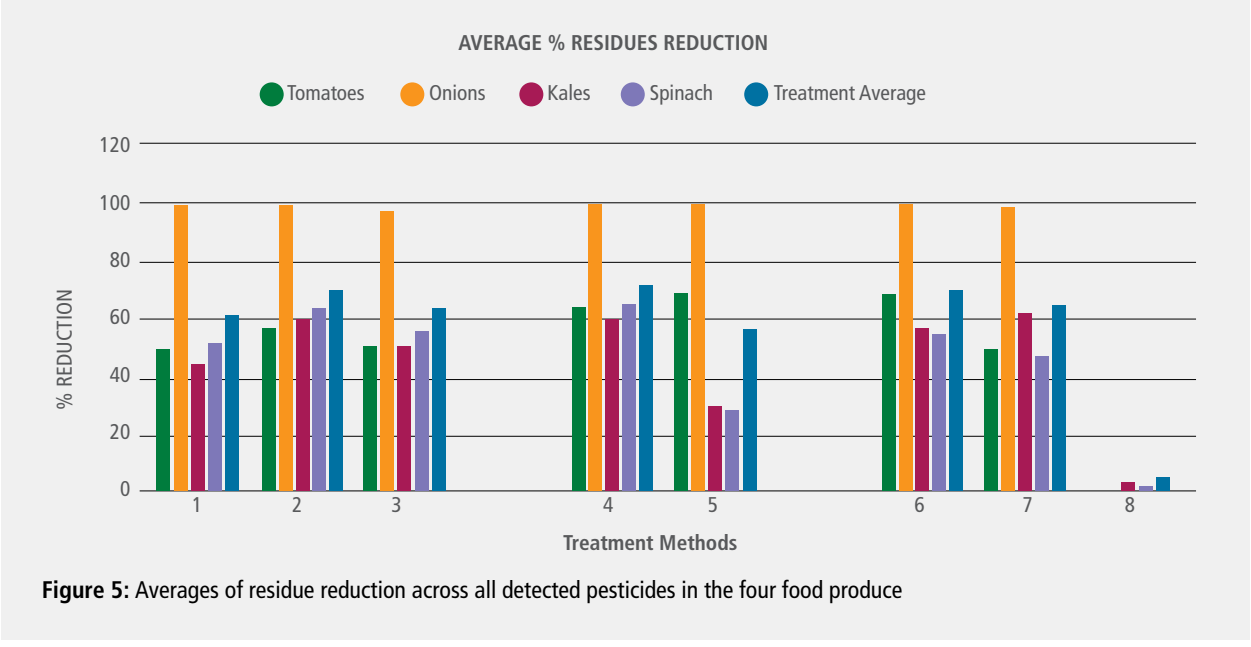


Figure 5: Averages of residue reduction across all detected pesticides in the four food produce

4.3 Reduction of pesticide residues in food produce using different treatment methods

Pesticide reductions were computed in percentages as shown (**Table 5**) using pre-treatment values for every active ingredient found on/in Onions, Kale, Spinach, and Tomatoes (**Appendix 7**). In general, none of the seven treatment methods was able to completely reduce ALL the active ingredients in the four farm produce. A combination of more than two treatment methods yielded a very desirable reduction in all four types of farm produce.

There were 15 instances where no change in reduction was observed (0%), whereas six treatments in Kale recorded an increase ranging from 1% to 39%. Onions gave very good reduction percentages ranging from a low of 97% to a high of 100%, as shown in **Table 5** and **Appendix 7**.

Table 9: Percent reduction of pesticide active ingredients per food produce using different treatments.

Percent (%) Reduction of Spiked Pesticides Residues Active Ingredients.								
Treatment Methods	**Acephate**	**Methamidophoe**	**Chlorpyrifos**	**Imidacloprid**	**Linuron**	**Tebuconazole**	**Cypermethrin (Sum)**	**Lamda-Cyhalothrin**
ONIONS								
Wash under running water	96	100	100	99	100	100	100	100
Wash with water & blanch	99	100	100	100	100	100	100	100
2% salt soak & wash	95	99	100	99	91	100	100	100
2% salt soak, wash & cook	98	99	100	98	100	100	100	100
2% baking soda soak & wash	98	99	100	98	100	100	100	100
2% baking soda soak, wash & cook	99	98	100	97	100	100	100	100
20% Vinegar soak, wash & cook	97	99	99	96	100	98	100	100
KALE								
Wash under running water	34	42	50	46	24	28	76	71
Wash under water & blanch	54	48	77	59	49	32	78	79
2% salt soak & wash	-39	64	32	38	-3	8	89	65
2% salt soak, wash & cook	47	63	59	38	-7	34	75	73
2% baking soda soak & wash	8	59	27	40	-9	12	-1	7
2% baking soda soak, wash & cook	43	67	64	51	2	53	63	72
20% Vinegar soak, wash & cook	42	69	60	46	-11	46	66	69
SPINACH								
Wash under running water	20	34	57	58	30	41	84	79
Wash with water & blanch	42	39	76	67	58	36	87	97
2% salt soak & wash	31	73	51	53	14	35	87	80
2% salt soak, wash & cook	52	45	74	47	57	57	84	84
2% baking soda soak & wash	46	32	58	37	34	22	87	84
2% baking soda soak, wash & cook	46	32	58	37	34	22	87	84
20% Vinegar soak, wash & cook	9	53	47	30	22	12	79	77
TOMATOES								
Wash under running water	35	34	0	32	33	64	92	90
Wash with water & blanch	16	26	33	49	33	60	85	97
2% salt soak & wash	8	7	-22	-11	50	13	92	81
2% salt soak, wash & cook	0	81	11	19	33	45	100	95
2% baking soda soak & wash	73	-10	22	-12	50	-12	-38	-41
2% baking soda soak, wash & cook	51	62	0	51	83	69	62	71
20% Vinegar soak, wash & cook	-64	62	11	12	33	31	62	69

4.4 Reduction of Pesticide Residues per Treatment Procedure: Comparing pesticide residues.

4.4.1 Percentage reduction of pesticide residues on/in Tomato, Onion, Kale, and Spinach after washing under running tap water

Tomatoes: The treatment procedure, when carried out, was able to remove all the pesticide residues of Imidacloprid, but it was least effective in removing residues of Linuron and Acephate (34% for each) and moderately effective in removing residues of Tebuconazole (64%) and Cypermethrin (86%) among other specific pesticide residues, as presented in **Figure 6**.

Onions: washing under running tap water removed most of the pesticide residues, the least being 93%, while six pesticide residues were fully removed (100%), as shown in **Figure 7.**

Kale: The treatment method reduced Methamidophos by 24%, which was the least, and Cypermethrin at the highest of 76%, with an average reduction of all the pesticide residues at 42%, as shown in **Figure 8**.

Spinach: Acephate was the least reduced at 20%, while 84% of Cypermethrin was reduced; the method has an average reduction of 45% across all pesticides. **(Figure 9.)**

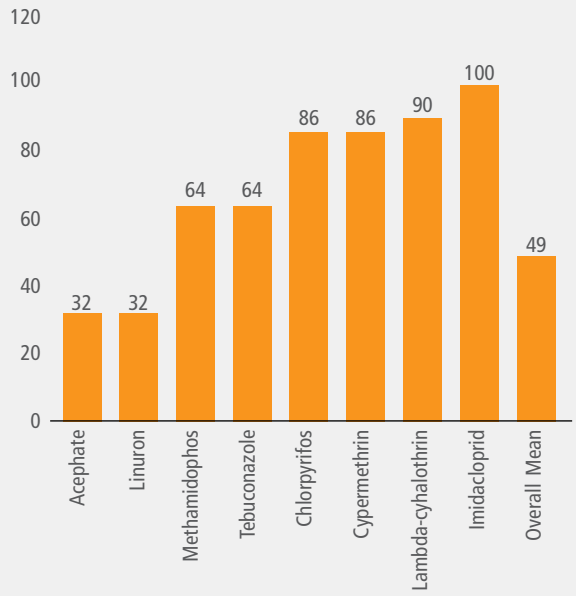


Figure 6: Percentage Reduction of Pesticide Residues in Tomatoes

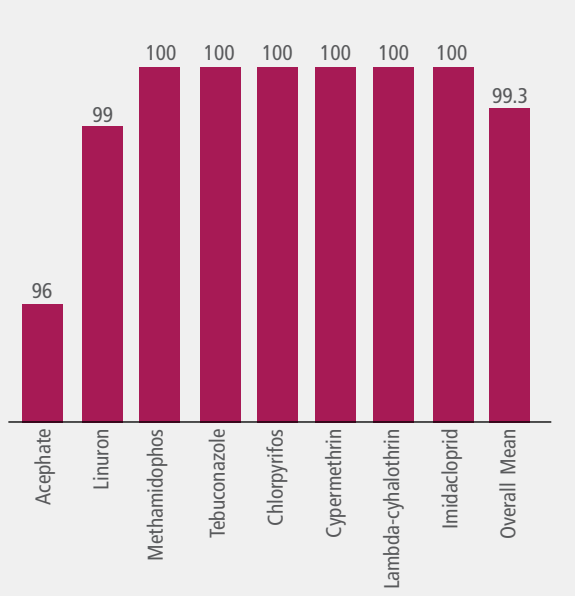


Figure 7: Percentage Reduction of Pesticide Residues in Onions

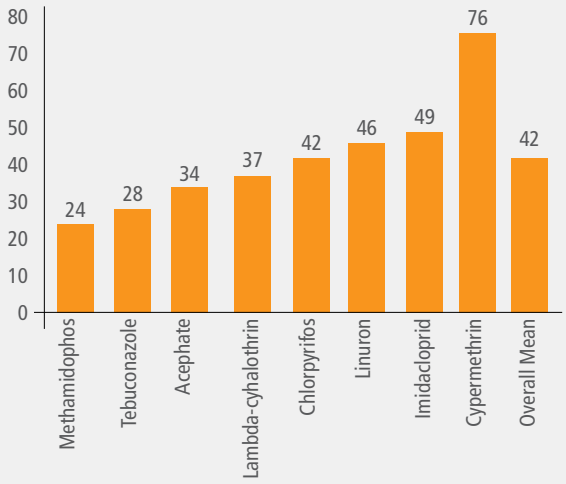


Figure 8: Percentage Reduction of Pesticide Residues in Kale

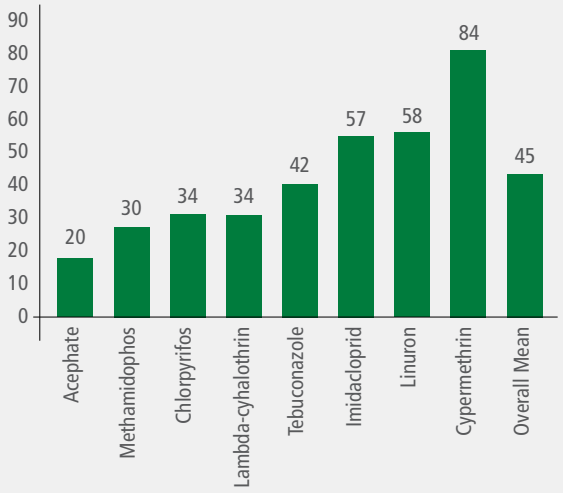


Figure 9: Percentage Reduction of Pesticide Residues in Spinach

4.4.2 Observations after washing under running tap water and Blanching

The treatment was effective in lowering all pesticide residues of Cypermethrin in all four foodstuffs, just as the washing under running tap water had done. The procedure did not reverse any of the results that washing under running tap water alone had achieved. The treatment procedure was generally least effective in lowering pesticide residue levels for Tomatoes, whose overall reduction mean was 51.25%, moderately effective for Kale and Spinach, with overall reduction mean of 57.25% and 64.13%, respectively. The overall reduction mean for Onions was 99.75%, as presented in **Figures 10, 11, 12, and 13.**

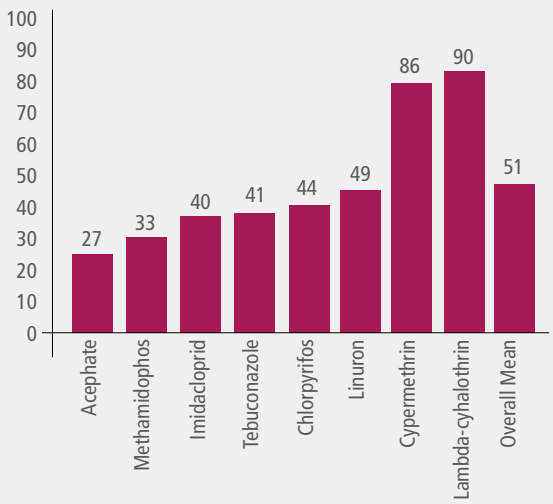


Figure 10: Percentage Reduction of Pesticide Residues in Tomatoes

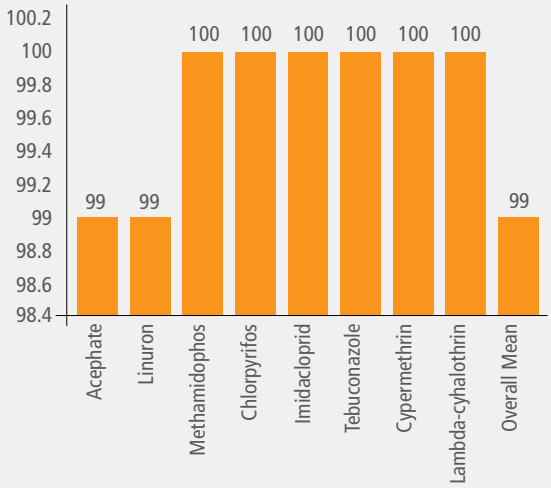


Figure 11: Percentage Reduction of Pesticide Residues in Onions

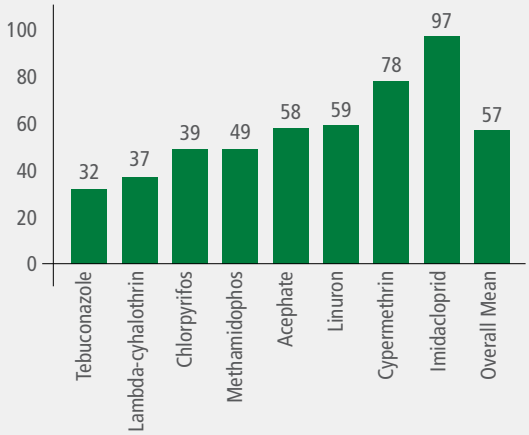


Figure 12: Percentage Reduction of Pesticide Residues in Kale

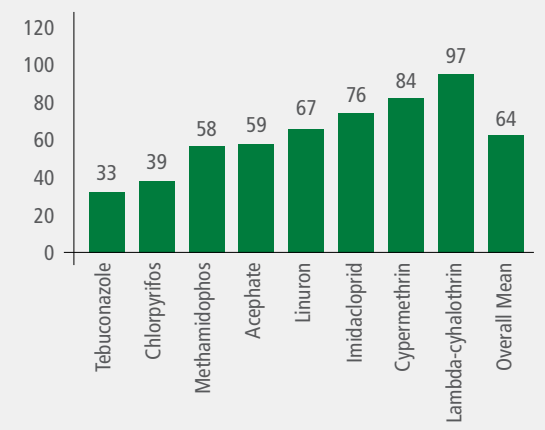


Figure 13: Percentage Reduction of Pesticide Residues in Spinach

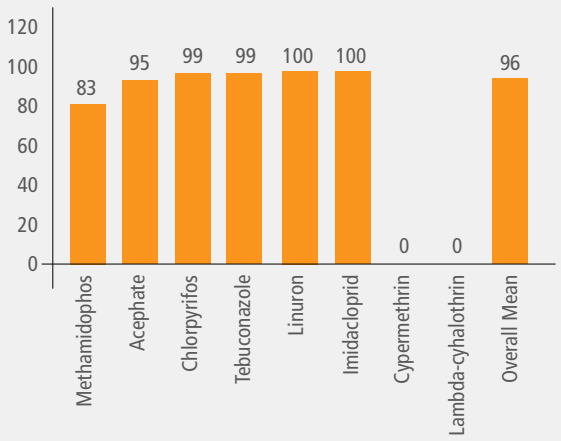


Figure 15: Percentage Reduction of Pesticide Residues in Onions

4.4.3 Observations after soaking in salty water (2%) and washing under running tap water

The procedure raised Linuron residue levels in Tomatoes and Methamidophos and Acephate levels in Kale beyond pretreatment levels. As observed in the washing under running tap water, the method did not reduce residue levels of Imidacloprid in Tomatoes. The treatment procedure was generally least effective in lowering pesticide residue levels for Tomatoes, whose overall reduction mean was 38.4%, moderately effective for Kale and Spinach with overall reduction mean of 49% and 49.5%, respectively. The overall reduction mean for Onions was 96%, as shown in **Figures 14, 15, 16, and 17**.

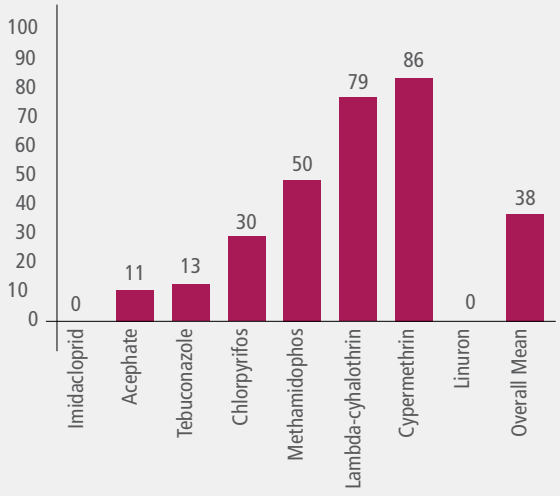


Figure 16: Percentage Reduction of Pesticide Residues in Kale

Figure 14: Percentage Reduction of Pesticide Residues in Tomatoes

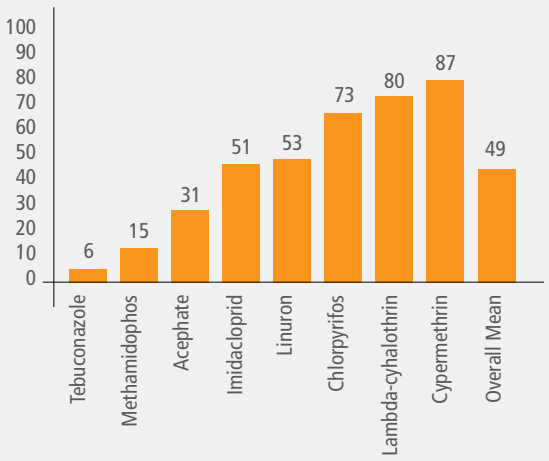


Figure 17: Percentage Reduction of Pesticide Residues in Spinach

4.4.4 Observations after soaking with Salty water, washing under running tap water, and Cooking/ sautéing.

The treatment was effective in lowering all pesticide residues in all four foodstuffs except for Acephate in Tomatoes and Methamidophos in Kale. The other significant reductions of pesticide residues were for Methamidophos, Imidacloprid, and Tebuconazole in Onions.

The treatment procedure was least effective in lowering pesticide residue levels for Tomatoes, whose overall reduction mean was 50%, moderately effective for Kale and Spinach, with overall reduction mean of 51% and 67%, respectively. The overall reduction mean for Onions was 99.25%, as shown in **Figures 18, 19, 20, and 21.**

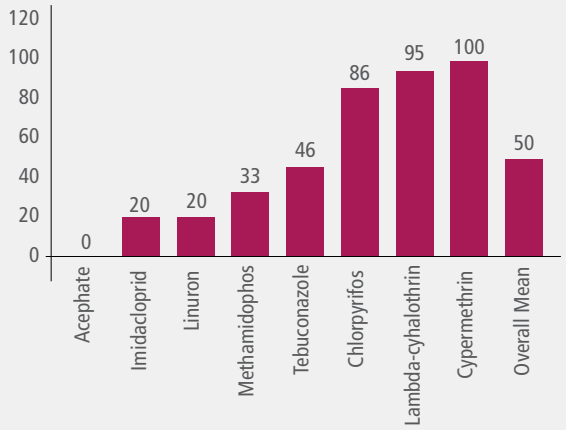


Figure 18: Percentage Reduction of Pesticide Residues in Tomatoes

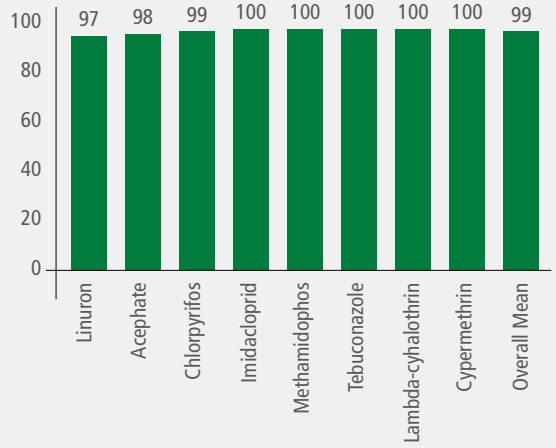


Figure 19: Percentage Reduction of Pesticide Residues in Onions

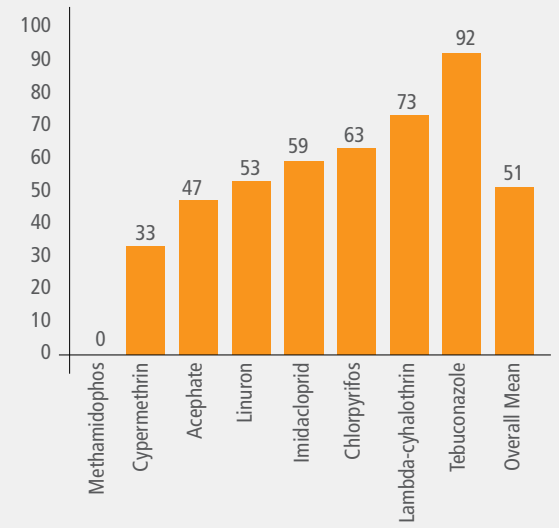


Figure 20: Percentage Reduction of Pesticide Residues in Kale

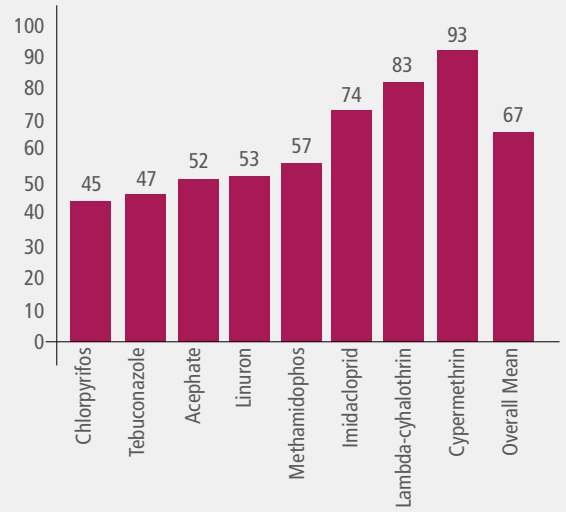


Figure 21: Percentage Reduction of Pesticide Residues in Spinach

4.4.5 Observations after soaking in Baking Soda (2% Sodium bicarbonate) and washing under running tap water

The treatment was effective in lowering most pesticide residues in Onions, Spinach, and Kale; however, as for Tomato samples, the residues of Cypermethrin rose to 38% above the pretreatment levels. Similar rise of pesticide residues in Tomatoes was observed for Linuron (12%), Tebuconazole (12%), and Lambda-cyhalothrin (41%). A rise in pesticide residue levels was also observed for Methamidophos (9%) in samples of Kale. The procedure was most effective on Onions, where it was able to lower the residues to levels of between 94% and 100%. The treatment procedure was least effective in lowering

pesticide residue levels for Kale, whose overall reduction mean was 29%, moderately effective for Tomatoes (only four pesticide residues reduced), and Spinach, with each having an overall reduction mean of 34%. The overall reduction mean for Onions was 99.13. **(Figures 22, 23, 24, 25.)**

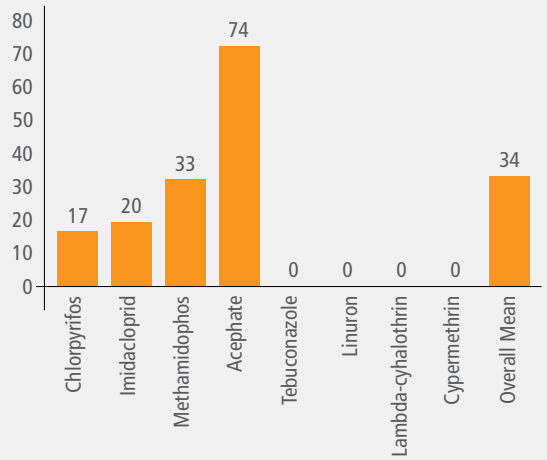


Figure 22: Percentage Reduction of Pesticide Residues in Tomatoes

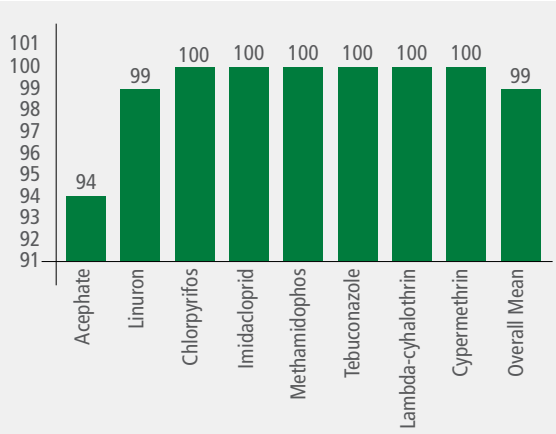


Figure 23: Percentage Reduction of Pesticide Residues in Onions

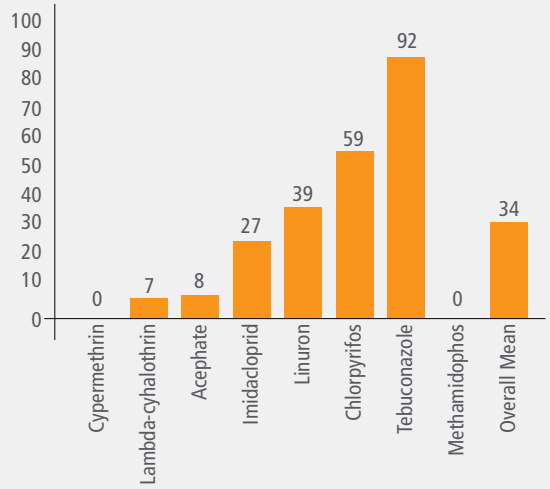


Figure 24: Percentage Reduction of Pesticide Residues in Kale

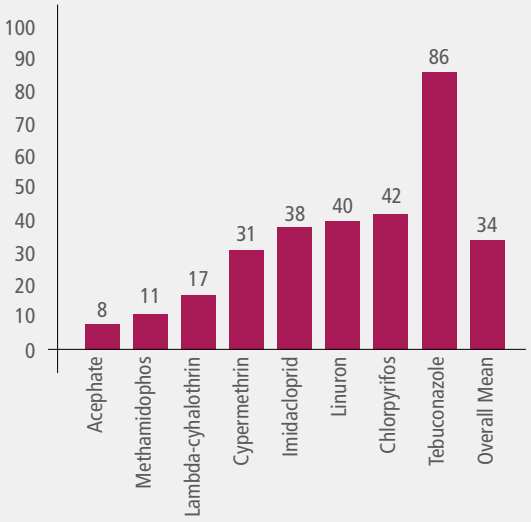


Figure 25: Percentage Reduction of Pesticide Residues in Spinach

4.4.6 Observations after soaking in Baking Soda (2% Sodium bicarbonate), washing under running tap water, and cooking/ sautéing.

Though the treatment process was effective in lowering pesticide residues, it wasn't able to achieve any drop of Cypermethrin in Kale and Imidacloprid in Tomatoes. Methamidophos increased in Kale post-treatment.

The treatment procedure was generally least effective in lowering pesticide residue levels for Spinach, whose overall reduction mean was 43%, moderately effective for Kale and Tomatoes with overall reduction mean of 49.86% and 53.6%, respectively. The overall reduction mean for Onions was 99% as presented in **Figures 25, 26, 27, 28.**

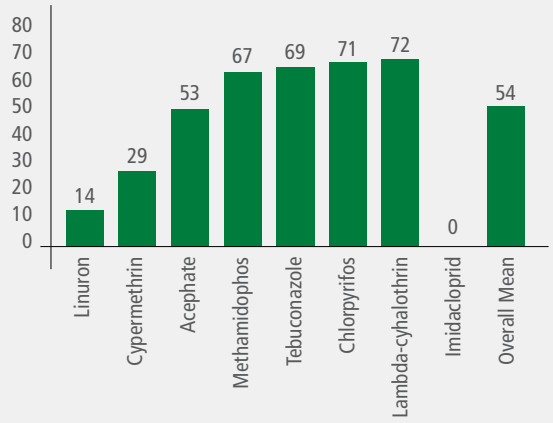


Figure 26: Percentage Reduction of Pesticide Residues in Tomatoes

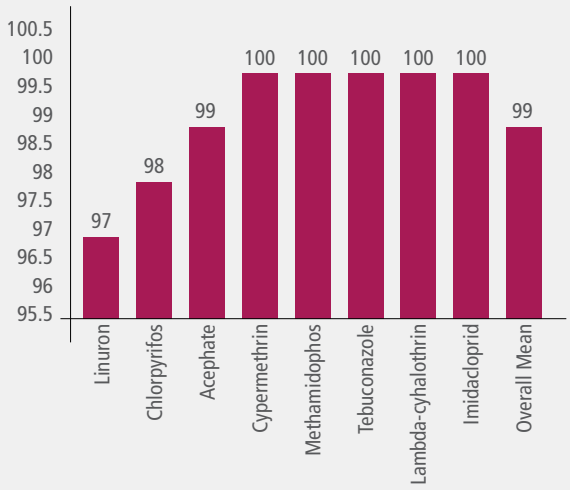


Figure 27: Percentage Reduction of Pesticide Residues in Onions

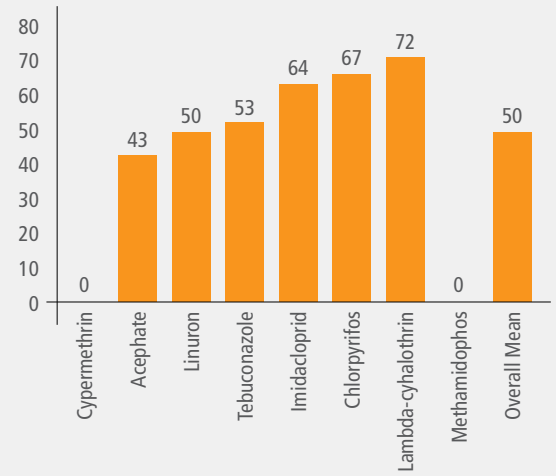


Figure 28: Percentage Reduction of Pesticide Residues in Kale

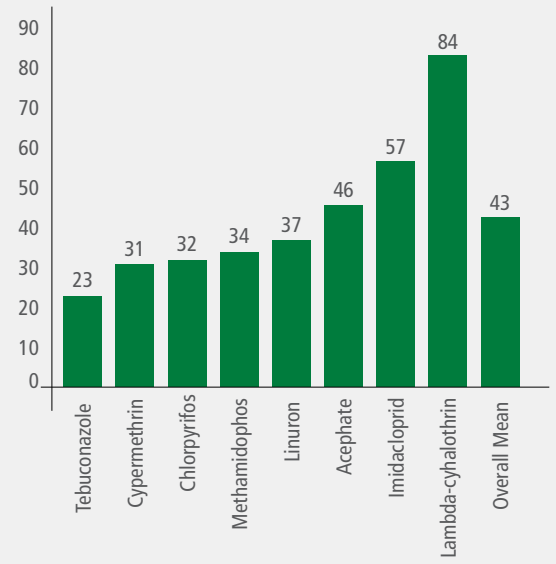


Figure 29: Percentage Reduction of Pesticide Residues in Spinach

4.4.7 Observations after soaking in 20% Vinegar, washing under running tap water, and cooking/ sautéing

The treatment was effective in lowering pesticide residues in all four foodstuffs, with Onions having the highest percentage reduction. There was, however, a rise in levels of Acephate in Tomatoes and Methamidophos in Kale post-treatment. The treatment procedure was least effective in lowering pesticide residue levels for Spinach, whose overall reduction mean was 39.6%, moderately effective for Tomatoes and Kale with overall reduction mean of 47.1% and 56.7%, respectively. The overall reduction mean for Onions was 97%. **Figures 30, 31, 32, 33.**

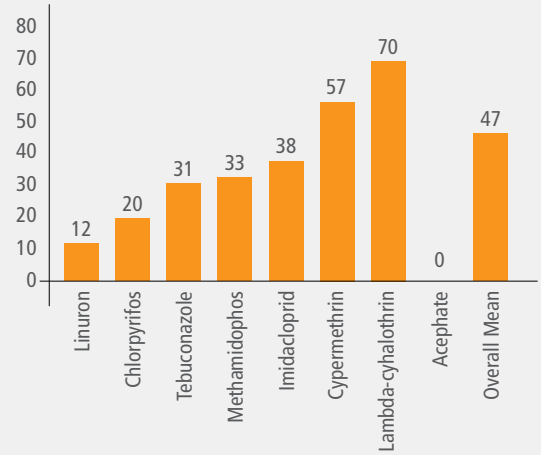


Figure 30: Percentage Reduction of Pesticide Residues in Tomatoes

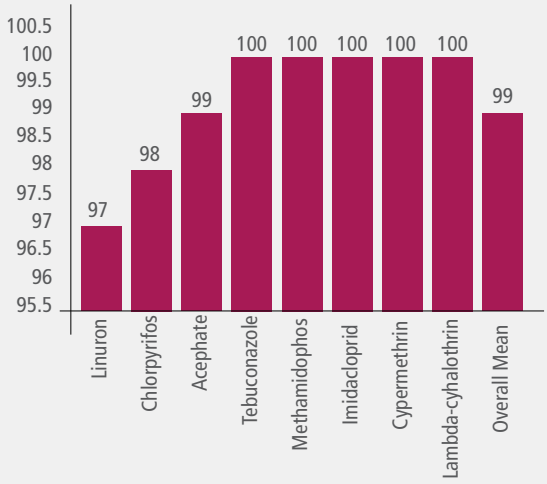


Figure 31: Percentage Reduction of Pesticide Residues in Onions

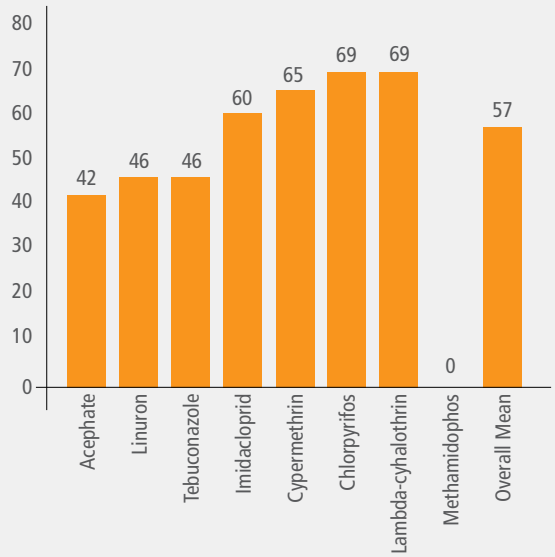


Figure 32: Percentage Reduction of Pesticide Residues in Kale

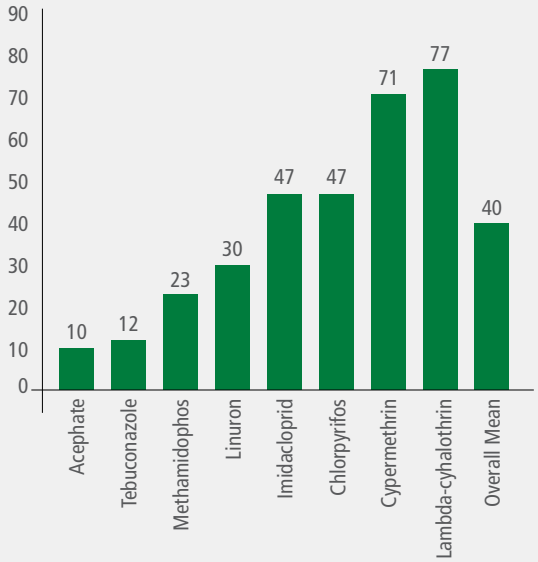


Figure 33: Percentage Reduction of Pesticide Residues in Spinach

4.5 Reduction of Pesticide Residues per Food Type - Comparing pesticide residues.

4.5.1 Reduction of Individual Pesticides in Tomatoes

In Tomatoes, all eight pesticides had different levels of residue reduction. Though some, including Cypermethrin and Lambda-cyhalothrin, seemed to form a cluster with high reduction levels, others had no consistent reduction levels. Imidacloprid and Linuron were poorly reduced across all the treatment procedures. Soaking with 2% baking soda and washing, followed by cooking, had the best reduction across all seven active ingredients, except for Imidacloprid, which recorded zero change. **(Figure 9; Table 5).** Storage of Tomatoes at room temperature for over seven days gave over 80% residue reduction for Acephate and Carbendazim. (**Figure 11).**

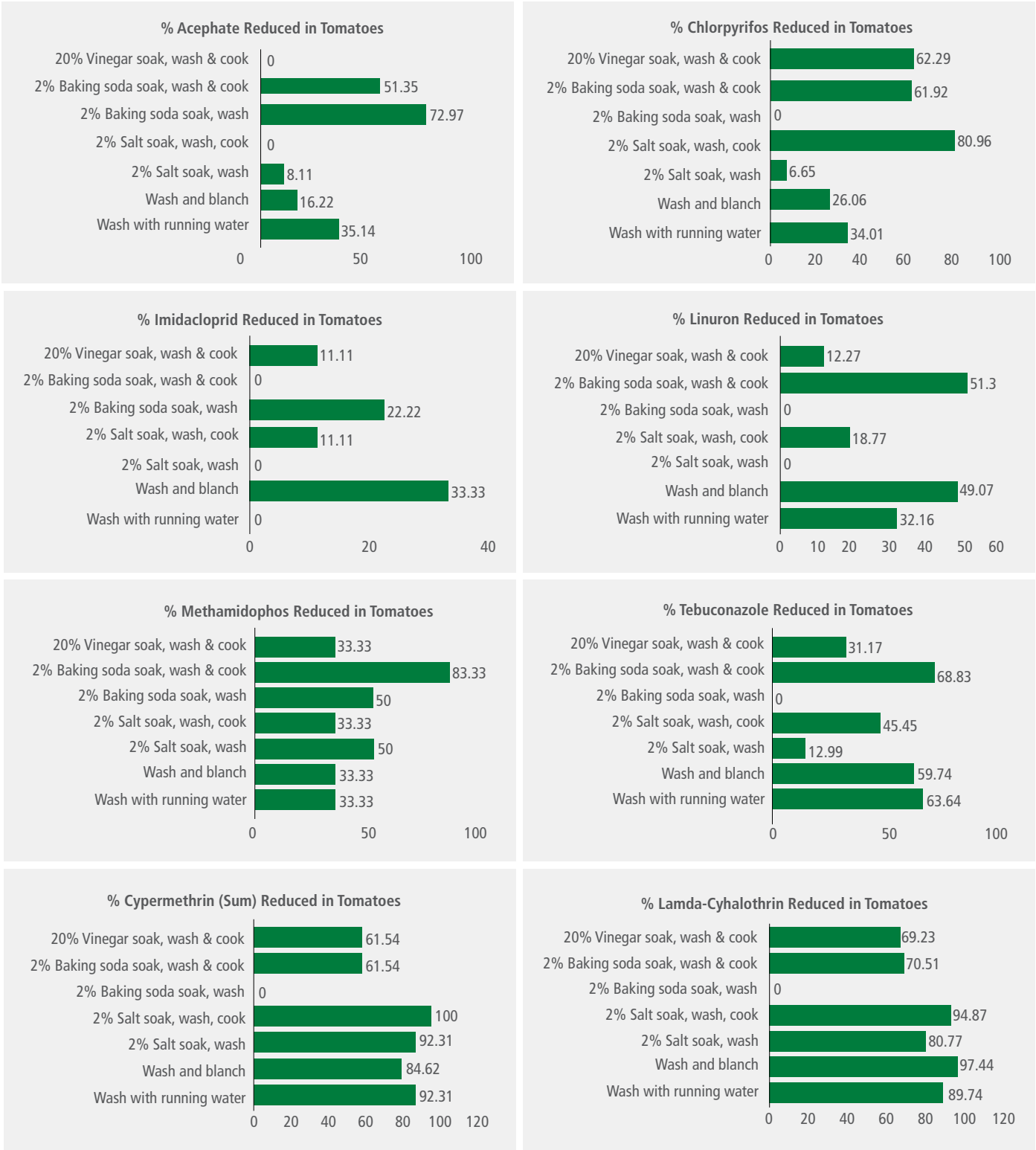


Figure 34: Percent reduction of the active ingredient in Tomatoes

4.5.2 Reduction of Individual Pesticides in Onions

Onions had excellent residue reduction with all the tested pesticides. Since none of the residues were detected at baseline, it was not possible to test storage as a residue reduction method in Onions. The least reduced residue was Methamidophos at 90.9%, which was observed after the Onions were soaked in salty water and washed in running water **(Figure 15; Table 5).**

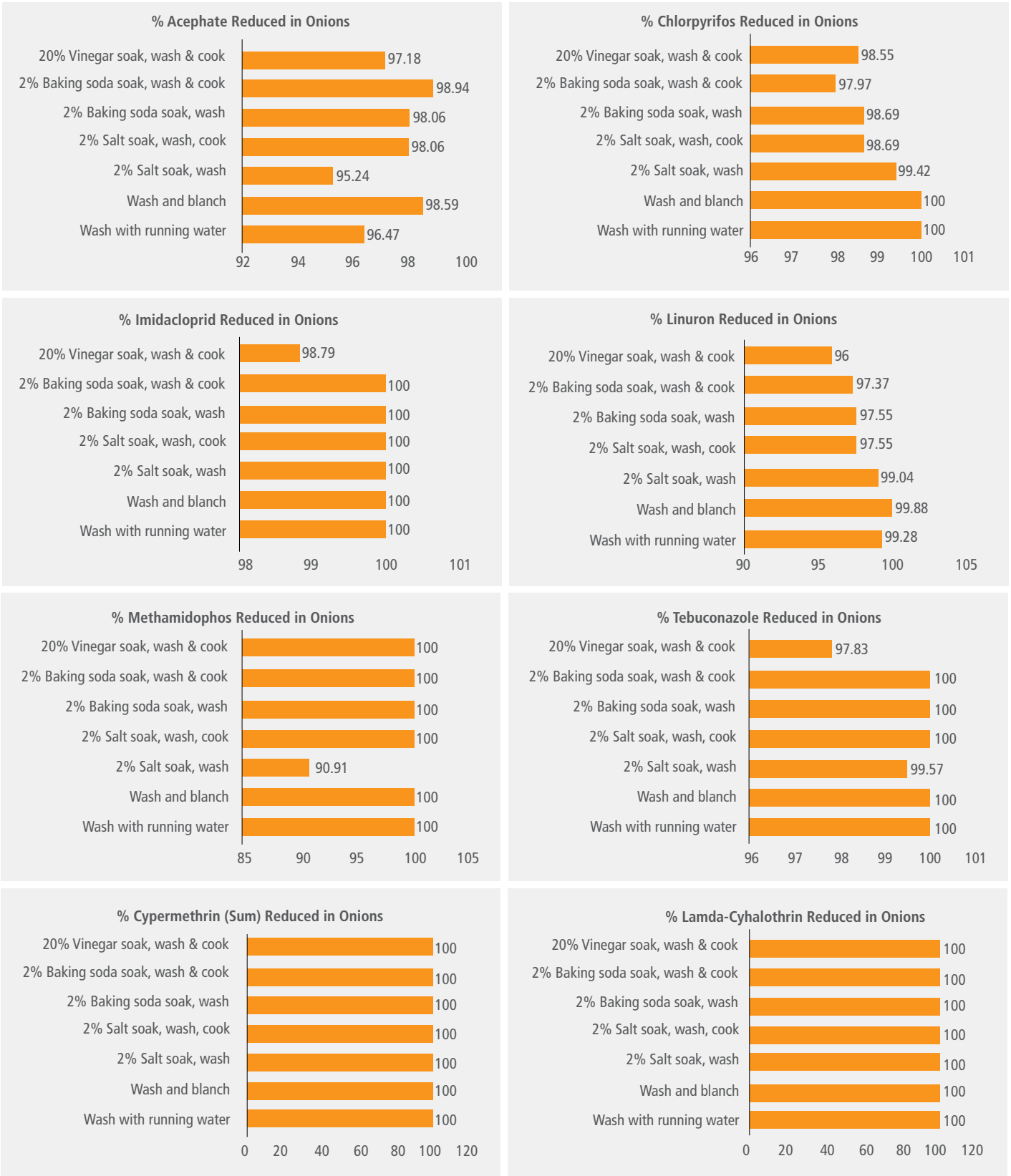


Figure 35: Percent reduction of the active ingredient in Onion

4.5.3 Reduction of Individual Pesticides in Kale

All the methods that incorporated cooking as a procedure resulted in remarkable pesticide residue reduction compared with the same methods minus the cooking part. Cypermethrin, Lambda, and Cyhalothrin had better reduction levels compared with the other six pesticides. Only washing and blanching methods removed substantial amounts of Methamidophos (**Figure 4**).

Storage of kale for over seven days resulted in 10% and 25% reduction of Cypermethrin and Lambda-cyhalothrin, which was lower compared to that in Tomatoes, though with different pesticide residues.

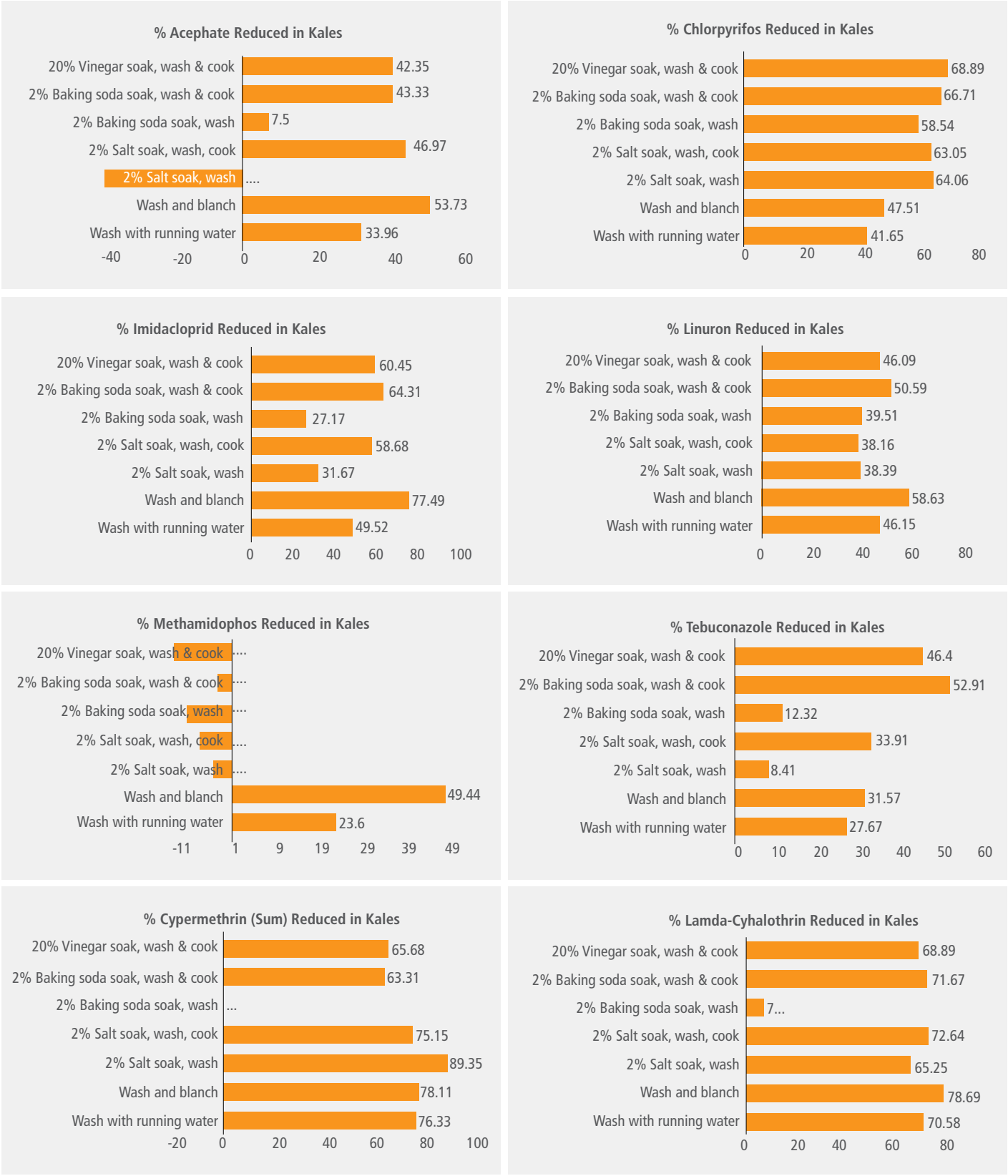


Figure 36: Percent reduction of the active ingredient in Kale

4.5.4 Reduction of Individual Pesticides in Spinach

Spinach had generally better residue reduction than all the other farm produce, except Onions, with Cypermethrin and Lambda-cyhalothrin pesticides, yielding over 77% reduction with all the treatment methods. The other six pesticides were between 9.5% and 74.1% residue reduction. Soaking in salty water, washing, and finally cooking Spinach had the overall best average residue reduction **(Figure 17; Table 5).**

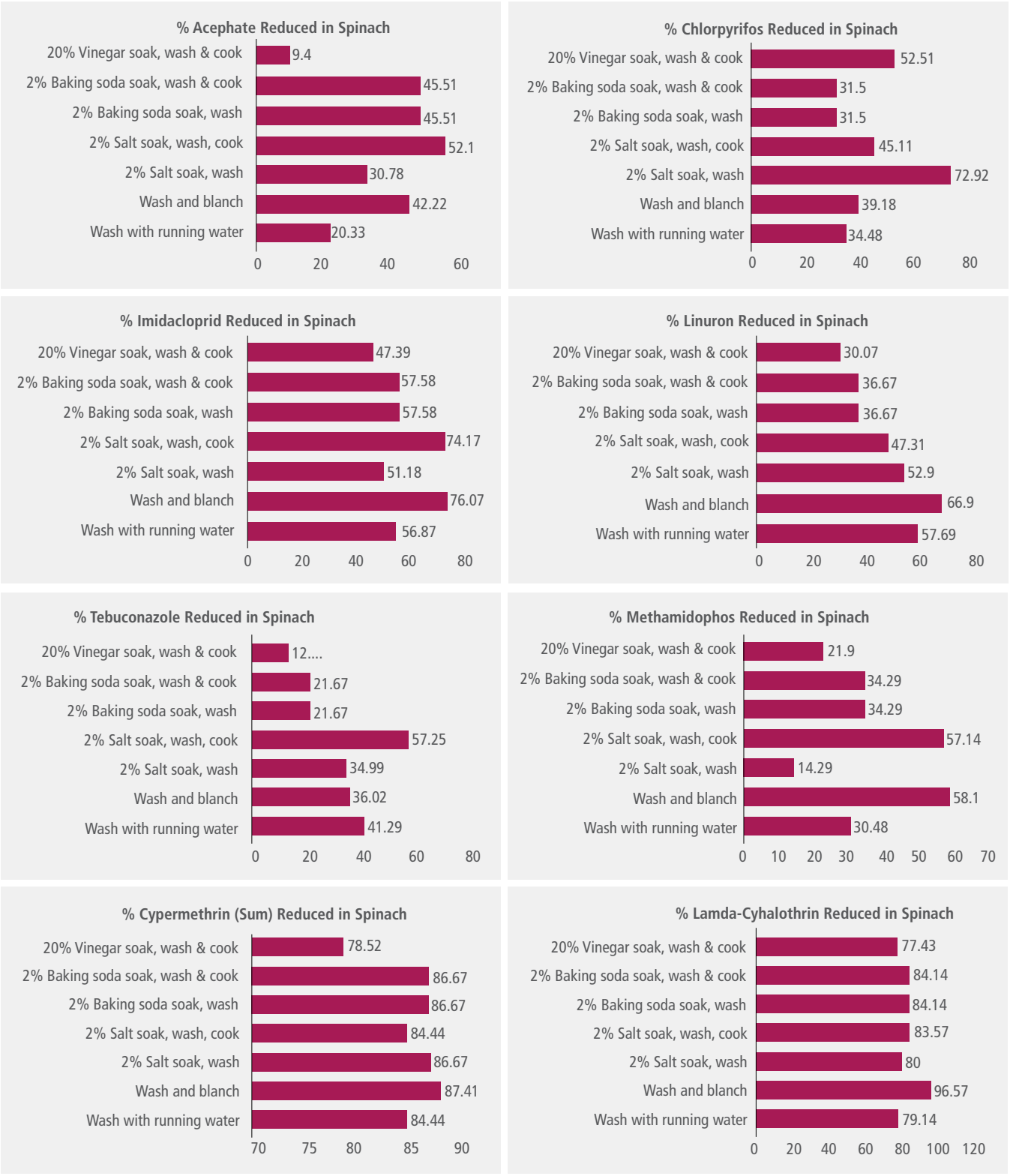


Figure 37: Percent reduction of the active ingredient in Spinach

4.6 Storage at Room Temperature and Refrigeration

Storage of Tomatoes at room temperature for seven days had a marked effect on pesticide residues of between 36.3% and 93.7%. Kale and Spinach were refrigerated for the same period to slow spoilage. The cold storage resulted in a reduction between 10% and 25% of pesticide residues, as shown in **Figure 13**.

**These food samples were not spiked, but baseline samples with pesticide residues were retested 7 days later.*

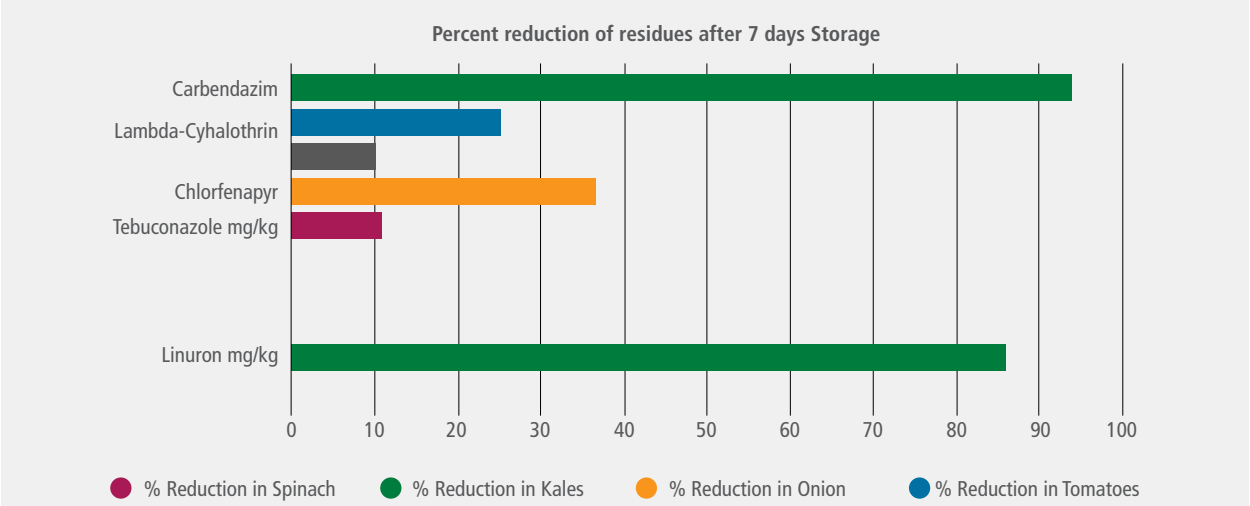


Figure 38: Re-testing after Storage of baseline positive samples for remaining pesticide residues

4.7 Incurred Residue Reduction

Tomatoes were found to contain Acephate and Chlorfenapyr residues at 0.04 mg/Kg and 0.07 mg/Kg, respectively, against the 0.01 mg/kg EU MRL. After applying the eight pesticide reduction methods, there was a 100% (0mg/Kg) reduction in Chlorfenapyr, and Carbendazim was reduced by 93.7% (0.011) after storage at room temperature for seven days.

Kale was found to contain 0.02mg/Kg Lambda-cyhalothrin residues at baseline analysis. Washing under running water followed by blanching for one minute reduced the residue by 74.9% (0.006mg/kg). Cypermethrin, which was detected at 1.1 mg/kg in a study by Karanja (2012), could be reduced by 89% to 0.1mg/kg by applying 2% salt soaking plus washing under running tap water.

Spinach samples at baseline had 0.14mg/kg Tebucanazole residues against the EU-MRL guideline of 0.02mg/Kg, Difenoconazole was at 0.7mg/kg residues against the acceptable EU-MRL of 0.08mg/kg, and Linorin residues were at 0.02mg/kg against 0.01mg/Kg EU-MRL guideline. Upon soaking for 15 minutes in 2% salt, washing under running water, and cooking for five minutes, 55.8% (0.078%) of Tebucanazole residues were reduced. Washing under running tap water followed by blanching reduced 53.9% (0.01%) of Linuron residues. **(Table 6; Figure 14).**

Active ingredient [EU-MRLs] mg/kg	Reduction Procedure	Incurred Residues, mg/kg	Reduced Residues, mg/kg	Applied Reduction [%]	Food Produce
Acephate [0.01]	2% baking soda soak + washing	0.07	0.01	72.97	Tomatoes
Tebuconazole [0.02]	2% salt soak, washing & Cooking	0.14	0.06	57.25	Spinach
Lambda-cyhalothrin [0.01]	Washing + Blanching	0.02	0.00	78.69	Kale
Linuron [0.01]	Washing + Blanching	0.03	0.01	66.9	Spinach
Chlorpyrifos [0.01]	2% salt soak, washing & Cooking	0.04	0.01	80.96	Tomatoes
Cypermethrin [0.1] (Karanja 2012)	2% salt soak & wash	1.1	0.10	89.35	Kale

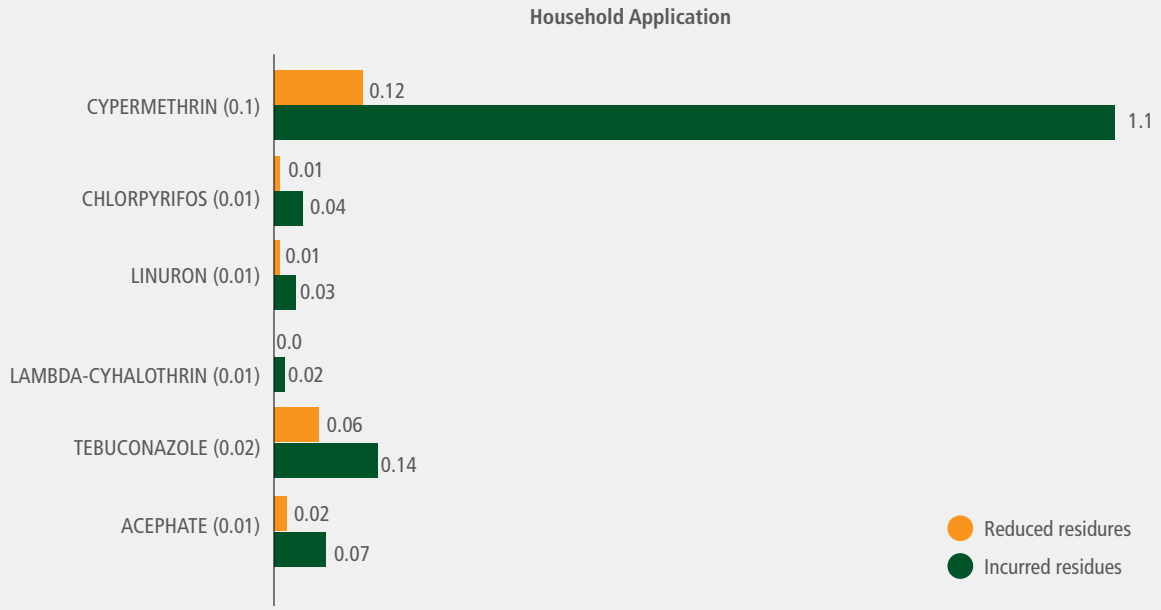


Figure 39: Incurred active ingredient residues, reduced to acceptable levels after treatment procedures

CHAPTER FIVE

5.0 DISCUSSION

5.1 Overview

This study evaluated the effectiveness of selected household food preparation methods in reducing pesticide residues in the four products. The findings demonstrate that common household preparation practices can substantially reduce pesticide residues, although their effectiveness depends on the characteristics of both the pesticide active ingredient and the vegetable.

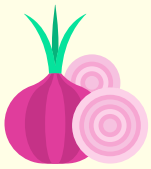
Overall, treatment methods that combined washing with soaking, blanching, or cooking consistently achieved greater pesticide residue reduction than washing alone. These findings support previous studies showing that multiple preparation steps are more effective because they remove both surface residues and residues weakly absorbed into plant tissues.

5.2 Pesticide residue reduction - Pre-treated samples

The concentrations of pesticide residues before treatment were above 0.1mg/kg, as recommended by OECD guidelines to allow for the determination of various processing factors (OECD, 2008). Except for Methamidophos, which was detected in pre-treated Tomatoes at 0.03mg/Kg, the others could be rounded up to achieve the 0.1mg/Kg.

Treated samples

Washing Onions under running tap water followed by blanching resulted in the best pesticide residue reduction, at an average of 99.7%. Unlike the other three food products, Onions were peeled before washing, which may have contributed to the effective removal of contaminants.



In practice, Onions would not be exposed to pesticides by spraying directly at the bulbs as was done in this study. That means the removal of pesticide residues would have been much more effective if the incurred residues had been traced through treatment.

Tomatoes come second, with a 69% average reduction achieved after soaking in 2% baking soda, washing under running tap water, and cooking. The best percentage reduction achieved after washing under running tap water in three out of the eight tested pesticides was 92.3%, 89.7%, and 63.6% for Cypermethrin, Lambda-cyhalothrin, and Tebuconazole, respectively. All Cypermethrin residues were removed after soaking in salty water, washing, and cooking.

When Tomatoes were kept at room temperature for seven days, 93.7% of Carbendazim, 85.7% of Chlorpyrifos, and 36.3% of Chlorfenapyr were removed. This provides a case for observance of Post-Harvest Intervals for farmers and an opportunity for consumers to buy and store Tomatoes for several days before eating them.

Cypermethrin is an emulsifiable concentrate that forms a suspension of tiny droplets in water; it is easily removed by washing. Tebuconazole, a broad-spectrum systemic fungicide, has very low solubility in water, at 0.36mg/ml. These characteristics would have influenced the observed increase in this study. Imidacloprid, which also had an increased residue concentration, is water-soluble at 610mg/l at 20OC °C. It remains stable in acidic to neutral pH, but its hydrolysis increases with increased temperature and alkaline pH. For Lambda-cyhalothrin, an emulsifiable concentrate that is nonvolatile with a low water solubility, residue levels increased after Tomatoes were soaked in 2% baking soda and washed under running tap water.

The highest average reduction in Spinach was 65.5%, after soaking in salty water, washing under running water, and cooking. The process without cooking resulted in an 86% reduction of Lambda-cyhalothrin, which is an emulsifiable concentrate that is poorly soluble in water. It is volatile and degrades in alkaline water with a half-life of seven days, significantly hydrolyzing at pH 9. It is a contact pesticide. For hydrophobic pesticides like Lambda-cyhalothrin, salinity causes a salting-out effect, which encourages precipitation or increased partitioning and hence removal from the food surface (Douglas ER, 2023). When Spinach was refrigerated for seven days, Tebuconazole was reduced by 10.7%. .

Soaking in 20% vinegar, washing under running tap water, and cooking gave the highest reduction in Kale at an average of 62.3%. Cypermethrin was reduced by 92.3% after washing under running water, while blanching resulted in a 78% reduction. Soaking in salty water plus washing gave an 89.3% reduction of Cypermethrin in Kale. Refrigeration of Kale for seven days removed Lambda-cyhalothrin and Cypermethrin by 25% and 10.7%, respectively. Acephate and its metabolite, Methamidophos, increased after soaking in salt + washing, soaking in salt + cooking, soaking in baking soda, soaking in vinegar, washing, and cooking.

Acephate and its degraded metabolite, Methamidophos, are soluble in water and can be easily removed from the surfaces of vegetables. They are systemic insecticides and interact with the surfaces of vegetables differently, with the amounts absorbed by the plant degrading slowly (Mohapatra et al., 2022). Soaking vegetables in salt results in the disruption of the plant's cellular structure, leading to the release of previously adsorbed Acephate, thus increasing the concentration in the soaking solution. Salt also increases the solubility of the pesticide, thus leaching from the plant tissue (Rawat et al., 2024). The increased Acephate and Methamidophos observed in this study could have resulted from an erroneous assay of the soaking solution together with the Kale tissue.

On average, soaking in salty water, washing, and cooking gave the highest average residue reduction at 72.4%. This was followed by washing under running tap water and blanching at 70%, then soaking in baking soda, washing and cooking at 69.8%, while soaking in vinegar, washing, and cooking had 64.6% reduction.

Washing under running tap water had an average reduction of 61.3%. A majority of the insecticides or fungicides applied directly to crops undergo very limited movement or penetration of the cuticle; the location of the pesticide in terms of surface or systemic residue affects the removal processes. Washing will remove most of the surface residues, while those able to penetrate the food tissue may not be affected by the process (Sances et al., 1992). Water-soluble pesticides are reduced by washing, which improves when blanching, cooking, or boiling.

The time lapse for the pesticide residue on the farm produce inversely affects the amounts removable through washing, which could be due to the pesticide-plant tissue interactions (Geisman, 1975; Sarode and Lal, 1982; Sarode et al., 1982; Dikshit et al., 1969). As much as the pesticide is soluble in the wash, the same cannot easily penetrate the plant's waxy layers (Elkins, 1989) and will be easily

removed. The temperature of the wash has been shown to improve results. Blanching is more effective than cold wash, even with longer attached pesticides (Sances et al., 19; Geisman, 1975). Hot caustic wash is effective in the removal and degradation of hydrolysable pesticides (J. Agric. Sci, 1986).

Comminution of plant tissue by chopping or blending results in the release of enzymes and acids that may increase the rate of pesticide degradation (Howard and Yip, 1971). The cooking process of different food types varies. Removal of residues is affected by the cooking conditions, including temperature, time, moisture loss, and closed or open systems. Whereas the open system results in high volatilization of residues, closed systems are more effective in hydrolysis processes of degradation. Compounds with low volatility and that are stable to hydrolysis are less affected by cooking and will thus remain on the plant tissue or sometimes increase in concentration as a result of vaporization (Mestres and Mestres, 1992), which could explain the increased residues witnessed in this study. Residues remaining on the farm produce even after soaking in reducing solutions could also be attributed to the strong bonding between the pesticide and the waxy layer of the crop (Srivastara et al., 2021).

5.3 Summary of the explanations

5.3.1 Effect of Washing Under Running Tap Water

Washing vegetables under running tap water reduced pesticide residues in all four vegetables, although the extent of reduction varied among pesticide active ingredients. Washing is the simplest and most accessible household intervention and is effective in removing pesticide residues that remain on the surface of vegetables.

The effectiveness of washing is influenced by several factors, including the water solubility of the pesticide, the duration of washing, water flow, and the surface characteristics of the vegetable. Smooth-skinned vegetables generally allow easier removal of surface residues than leafy vegetables with rough or waxy surfaces, where pesticides may adhere more strongly.

Although washing alone produced measurable reductions, it was generally less effective than methods incorporating soaking, blanching, or cooking. This finding suggests that washing should be regarded as the minimum recommended practice rather than the only intervention for reducing pesticide residues.

5.3.2 Effect of Blanching and Cooking

Blanching and cooking further reduced pesticide residues beyond the reductions achieved through washing alone. Heat treatment promotes pesticide degradation, volatilization, and migration into cooking water, particularly for pesticides that are unstable at elevated temperatures or readily dissolve in water.

The degree of residue reduction differed among pesticides because thermal stability varies considerably between chemical classes. Water-soluble pesticides generally showed greater reductions during blanching and cooking than more lipophilic compounds that bind strongly to plant tissues.

These findings are consistent with previous studies demonstrating that thermal processing can substantially reduce pesticide residues in vegetables commonly consumed after cooking. However, cooking alone did not eliminate all residues, indicating that heat treatment should complement rather than replace thorough washing.

Heat treatment promotes pesticide degradation, volatilization, and migration into cooking water, particularly for pesticides that are unstable at elevated temperatures or readily dissolve in water.

5.3.3 Effect of Salt Solution Treatment

Soaking vegetables in a 2% sodium chloride solution before washing reduced pesticide residues more effectively than washing alone for several pesticide active ingredients. Salt solutions may facilitate the removal of loosely bound pesticide residues by altering osmotic conditions and improving detachment from vegetable surfaces. Salt also increases the solubility of the pesticide, thus leaching it from the plant tissue (Rawat et al., 2024).

Nevertheless, the effectiveness of salt treatment varied among pesticides and vegetables, suggesting that residue removal depends on interactions between pesticide chemistry and vegetable morphology.

Although salt soaking provided measurable benefits, it was generally less effective than sodium bicarbonate treatment, particularly for pesticides with strong adherence to plant surfaces.

5.3.4 Effect of Sodium Bicarbonate Treatment

Among the household preparation methods evaluated, soaking vegetables in a 2% sodium bicarbonate solution followed by washing consistently produced some of the greatest reductions in pesticide residues. The alkaline nature of sodium bicarbonate is thought to promote alkaline hydrolysis of certain pesticide active ingredients while simultaneously facilitating removal of residues from vegetable surfaces.

The treatment was particularly effective for tomatoes and several pesticides commonly detected in Kenyan vegetable production. These findings agree with previous international studies reporting enhanced pesticide removal using dilute sodium bicarbonate solutions compared with water alone. Because sodium bicarbonate is inexpensive, widely available, and easy to use, this method has considerable potential as a practical household intervention for reducing dietary exposure to pesticide residues.

5.3.5 Effect of Vinegar Treatment

Vinegar treatment followed by washing and cooking achieved substantial reductions in pesticide residues, particularly in kale and other leafy vegetables. The acidic environment created by vinegar may contribute to degradation of certain pesticide compounds while also assisting in the removal of residues attached to leaf surfaces. The effectiveness observed in leafy vegetables may also reflect improved penetration of the treatment solution between leaves where pesticide deposits frequently accumulate. Although vinegar treatment proved effective, its performance differed among pesticide active ingredients, reinforcing the importance of selecting preparation methods appropriate for both the vegetable and the pesticide involved.

5.3.6 Effect of Household Storage

Short-term household storage resulted in moderate reductions in pesticide residues for some active ingredients. These reductions are likely attributable to natural degradation processes occurring during storage, including volatilisation, hydrolysis, oxidation, and microbial activity. However, storage alone was considerably less effective than active preparation methods such as washing, soaking, blanching, or cooking. Furthermore, prolonged storage may adversely affect the freshness, nutritional quality, and marketability of vegetables. The findings therefore suggest that storage should not be relied upon as a primary strategy for reducing pesticide residues.

5.4 Differences Among Vegetables

The effectiveness of household preparation methods varied among the four vegetables studied. Tomatoes generally responded well to sodium bicarbonate treatment, while vinegar treatment was particularly effective for kale. Spinach showed substantial reductions following washing, blanching, and cooking, whereas onions exhibited comparatively lower initial residue levels and responded well to peeling and washing.

These differences can be explained by variation in vegetable morphology, including surface texture, wax content, leaf structure, and edible plant parts. Such characteristics influence both pesticide retention and the ease with which residues are removed during food preparation. The findings demonstrate that no single preparation method provides maximum residue reduction for every vegetable. Consequently, consumer recommendations should be tailored to specific vegetable types rather than adopting a universal approach.

5.5 Implications for Consumer Health

The findings have important implications for consumer food safety. Household food preparation methods can substantially reduce dietary exposure to pesticide residues and therefore serve as practical risk-reduction measures that are readily applicable in everyday domestic settings.

Nevertheless, even the most effective household treatments did not eliminate pesticide residues from all samples. Consequently, responsibility for food safety must remain shared across the food system. Farmers should prevent excessive residues through responsible pesticide use, while consumers should adopt effective

preparation practices to further minimise exposure. This integrated approach provides the greatest protection for public health.

5.6 Comparison with Previous Studies

The findings are consistent with international research demonstrating that washing, blanching, cooking, sodium bicarbonate treatment, and vinegar treatment reduce pesticide residues to varying degrees. Similar trends have been reported in studies conducted in China, Vietnam, India, and other countries where household food preparation has been investigated as a strategy for reducing dietary pesticide exposure.

The present study extends this body of knowledge by evaluating these methods using vegetables commonly consumed in Kenya and pesticides identified through national residue surveillance. Consequently, the findings provide locally relevant evidence that can support national food safety recommendations and consumer education programmes.

5.7 Study Strengths and Limitations

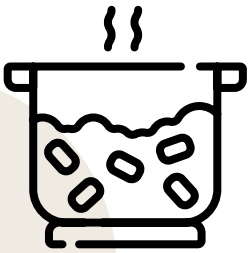
A major strength of this study is the controlled experimental design, which enabled direct comparison of multiple household preparation methods under standardized conditions. The use of accredited laboratory analytical methods further ensured accurate measurement of pesticide residue concentrations before and after treatment.

The study was limited to selected pesticides and four commonly consumed vegetables. Additional research involving a wider range of pesticide active ingredients, vegetables, fruits, cereals, and traditional household preparation practices would strengthen the evidence base for consumer recommendations.

The study also focused exclusively on pesticide residue reduction and did not assess potential changes in nutritional composition, sensory quality, or consumer acceptability associated with the different preparation methods. The treatment of the pesticides for uniformity was done under laboratory settings, and pesticide assimilation in the field is different.

5.8 Summary

This study demonstrates that household food preparation methods can significantly reduce pesticide residues in vegetables, although effectiveness varies according to pesticide chemistry and vegetable characteristics. Combining washing with soaking, blanching, or cooking consistently achieved greater residue reductions than washing alone.



Combining washing with soaking, blanching, or cooking consistently achieved greater residue reductions than washing alone.

Among the methods evaluated, sodium bicarbonate treatment showed particularly strong performance across several vegetables, while vinegar treatment was especially effective for leafy vegetables. These findings provide a scientific basis for evidence-based household food preparation recommendations and complement the farm-level interventions discussed in Part One.

Together, Parts One and Two demonstrate that reducing pesticide-related health risks requires coordinated action across the food value chain, from responsible pesticide use during production to effective food preparation practices in the home.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

The effectiveness of the evaluated methods varied according to the pesticide active ingredient, vegetable type, and preparation technique. Washing vegetables under running tap water reduced surface residues, but combining washing with soaking, blanching, or cooking consistently achieved greater reductions.

Among the evaluated methods, soaking vegetables in a 2% sodium bicarbonate solution followed by washing proved particularly effective for tomatoes, while vinegar treatment followed by washing and cooking produced the greatest reductions in kale. Blanching and cooking substantially reduced pesticide residues in spinach, whereas peeling and washing lowered residue levels in onions effectively.

The findings demonstrate that household preparation methods are valuable consumer-level interventions for reducing dietary exposure to pesticide residues. However, these methods cannot eliminate residues and should not be considered substitutes for responsible pesticide use during crop production.

The results reinforce the importance of adopting a comprehensive food safety approach that combines Good Agricultural Practices (GAP), Integrated Pest Management (IPM), effective pesticide regulation, routine residue monitoring, and evidence-based household food preparation practices.

6.2 Recommendations

6.2.1 Recommendations for Consumers

Consumers should adopt household preparation methods that have been demonstrated to reduce pesticide residues effectively. Based on the findings of this study, the following practices are recommended:

1. Proper washing of leafy vegetables and fruit vegetables under running water for a minimum of two minutes, depending on the size, while scrubbing with the fingers to remove dirt and as much pesticide residue as possible.
2. Trim and peel off all inedible parts of the produce before washing under running water, as in 1 above.
3. Most specifically, for the best results;
    a) Onions should be peeled, washed under running tap water for 30 seconds, and blanched for 60 seconds.
    b) Tomatoes should be trimmed, washed under running tap water for 30 seconds, soaked in 2% baking soda for 60 seconds, washed again under running tap water to remove the baking soda, and then cooked.
    c) Spinach and Kale should be trimmed to remove the inedible parts, washed under running tap water for 30 seconds, then blanched for 60 seconds.
    d) Farm produce should be stored after purchase/ harvest in a dry place at room temperature OR refrigerated for the longest possible time before consumption, as this practice was shown to drastically reduce some pesticide residues.

These simple practices can substantially reduce dietary exposure to pesticide residues while preserving the nutritional value of vegetables.

6.2.2 Recommendations for Farmers

Reducing pesticide residues should begin at the production stage. Farmers are encouraged to:

1. apply only pesticides registered for the intended crop;
2. follow manufacturers' recommended application rates;
3. observe prescribed pre-harvest intervals;
4. adopt Integrated Pest Management to minimise reliance on chemical pesticides;

5. maintain accurate pesticide application records; and
6. seek regular technical guidance from agricultural extension services.

Compliance with Good Agricultural Practices will reduce pesticide residues entering the food chain while improving productivity and market access.

6.2.3 Recommendations for Regulatory Authorities

The Pest Control Products Board (PCPB), Kenya Plant Health Inspectorate Service (KEPHIS), Ministry of Agriculture and Livestock Development, Ministry of Health, and county governments should strengthen national food safety systems by:

1. expanding routine pesticide residue surveillance programmes;
2. enhancing enforcement of pesticide regulations;
3. strengthening post-registration monitoring of pesticide use;
4. improving farmer education and extension services;
5. increasing public awareness of food safety; and
6. supporting accredited laboratories to improve national analytical capacity.

These measures will enhance consumer protection and strengthen confidence in Kenyan agricultural produce.

6.2.4 Recommendations for Public Health Education

Public health agencies, educational institutions, and civil society organisations should develop coordinated consumer education programmes on practical household methods for reducing pesticide residues.

Education campaigns should promote:

1. proper washing techniques;
2. appropriate soaking solutions and contact times;
3. blanching and cooking practices;
4. safe handling and storage of vegetables; and
5. awareness that household preparation complements, but does not replace, safe pesticide use during production.

Such programmes will improve public awareness and contribute to healthier dietary practices.

6.2.5 Recommendations for Future Research

Future research should:

1. evaluate additional household preparation methods commonly used in Kenya;
2. investigate residue reduction in other fruits, vegetables, cereals, and legumes;
3. assess the effects of preparation methods on nutritional quality and sensory attributes;
4. conduct cumulative dietary exposure and risk assessments using Kenyan food consumption data; and
5. evaluate seasonal and regional variations in pesticide residues.

These studies will strengthen the scientific evidence needed to support national food safety policies and consumer guidance.

6.3 Overall Conclusions of the Report

This report provides a comprehensive assessment of pesticide residues in selected vegetables marketed in Kenya and evaluates practical household interventions for reducing consumer exposure.

Part One established that pesticide residues are frequently detected in vegetables marketed in Kenya, with some samples exceeding internationally recognized Maximum Residue Limits. These findings highlight the importance of strengthening pesticide stewardship, regulatory oversight, and routine residue surveillance.

Part Two demonstrated that common household preparation methods, including washing, blanching, soaking in sodium bicarbonate or vinegar solutions, and cooking, can significantly reduce pesticide residues before consumption. While no single method was universally effective, combining preparation techniques consistently achieved greater reductions than washing alone.

The findings emphasize that protecting consumers requires action throughout the food value chain. Safe pesticide uses by farmers, effective regulatory oversight, continuous residue monitoring, and informed household food preparation are complementary measures that together reduce dietary exposure to pesticide residues.

This study provides a scientific foundation for evidence-based food safety policies, strengthened pesticide management, and practical consumer guidance. Adoption of the recommendations presented in this report will contribute to improved public health, enhanced consumer confidence, and the sustainable development of Kenya's horticultural sector.

The findings emphasize that protecting consumers requires action throughout the food value chain. Safe pesticide uses by farmers, effective regulatory oversight, continuous residue monitoring, and informed household food preparation are complementary measures that together reduce dietary exposure to pesticide residues.

REFERENCES

1. (https://www.sciencedirect.com/science/article/pii/S2666154324000644). sciencedirect.com/science/article/pii/S2666154324000644
2. Bajwa U, Sandhu KS. Effect of handling and processing on pesticide residues in food- a review. J Food Sci Technol. 2014 Feb;51(2):201-20. doi: 10.1007/s13197-011-0499-5. Epub 2011 Aug 26. PMID: 24493878; PMCID: PMC3907644.
3. Chen, G. (2014). Encyclopedia of Toxicology, Third Edition
4. CPR (2025). Codex Pesticides Residues in Food Online Database
5. DBMR (2023) Data bridge Market research (2023). Tomatoes: A Global Market with Many Drivers https://www.databridgemarketresearch.com/reports/global-Tomatoes-market
6. Dikshit A.K., S.K. Handa and S. Verma, R.P. Farrow, E.R. Elkins, W.W. Rose, F.C. Lamb, J.W. Rall and W.A. Mercher, Residue Rev. B,73 (1969), J. Agric. Sci. 56,661 (1986)
7. Douglas E. Raynie. Enhancing Extractions by Salting Out, LCGC North America volume 41 number 7 (2023). www.chromatographyonline.com
8. Elkins E.R., J. Assoc. 0 ff. Anal. Chem a, 533-535 (1989)
9. EPA (2025). What is a Pesticide? https://www.epa.gov/minimum-risk-pesticides/what-pesticide
10. EPF (2021) Expert task force(2021) Scientific Report on Pesticides in the Kenyan Market file:///C:/Users/HP/Documents/Documents/Scientific%20Report%20on%20Pesticides%20in%20the%20Kenyan%20Market%20Report_Final.pdf
11. FAO (2023) (Food and Agriculture Organization of the United Nations-FAOSTAT
12. FAO (2024). Pesticide use and trade. 1990-2022 https://www.fao.org/statistics/highlights-archive/highlights-detail/pesticides-use-and-trade-1990-2022/en
13. FAO (2025) Pesticide Registration Toolkit
14. file:///C:/Users/HP/Documents/Documents/List%20of%20Registered%20Products%20%20Version%201_2018%20PPCB.pdf
15. Food and Agriculture Organisation of the United Nations- FAO-WHO. (2014). *Report_8_8-1* (Issue October).
16. Food and Agriculture Organisation of the United Nations, Pesticide registration toolkit, 2025. https://www.fao.org/pesticide-registration-toolkit/information-sources/pesticide-properties/en/
17. Geisman J.R., Residue Rev. S, 43-54 (1975)
18. Highly hazardous pesticides in Kenya. (2023).
19. Holland P. T., D. Hamilton, B. Ohlin, and M. W. Skidmore, Effects of storage and processing on pesticide residues. Pure & Appl. Chem., Vol. 66, No. 2, pp. 35-356, 1994. Printed in Great Britain. @ 1994 IUPAC
20. Hossain S, Hossain A, Rahman A, Islam M, Rahman A, Adyel TM. Health risk assessment of pesticide residues via dietary intake of market vegetables from Dhaka. Bangladesh. Foods. 2013;2:64-75. 25. KNBS. Kenya National Bureau
21. Howard S. and G. Yip, J. Assoc. Offic. Anal. 3, 1371-1372 (1971)
    a. https://www.fao.org/fao-who-codexalimentarius/codex-texts/dbs/pestres/en/
    b. https://www.fao.org/pesticide-registration-toolkit/information-sources/address-book/pesticide-registrars/en/
    c. https://www.fao.org/statistics/highlights-archive/highlights-detail/agricultural-production-statistics-2010-2023/en
    d. https://www.sciencedirect.com/science/article/abs/pii/S0261219405002267
22. Jankowska, M, Łozowicka, B & Kaczyński, P (2019). Comprehensive toxicological study over 160 processing factors of pesticides in selected fruit and vegetables after water, mechanical, and thermal processing treatments, and their application to human health risk assessment. *Science of Total Environment* Volume 652, 20 February 2019, Pages 1156-1167
23. Kang C(2014) A patient fatality following the ingestion of a small amount of Chlorfenapyr, National Institutes
24. Karanja, N. N., Njenga, M., Mutua, G., Lagerkvist, C., Kutto, E., & Okello, J. J. (2012). Concentrations of Heavy Metals and Pesticide Residues in Leafy Vegetables and Implications for Peri-urban Farming in Nairobi, Kenya. *Journal of Agriculture, Food Systems, and Community Development*, *3*(1), 255-267. https://doi.org/10.5304/jafscd.2012.031.003
25. Karanjaa, N. N.; Njengaa, M; Mutuaa, G, K; Lagerkvistb, C.J; Kuttoa, K & Okelloa, J.J (2012)Concentrations of heavy metals and pesticide residues in leafy vegetables and implications for peri-urban farming in Nairobi, Kenya *Journal of Agriculture, Food Systems, and Community Development (JAFSCD) ISSN:* 2152-0801 online www.AgDevJournal.com
26. KEPHIS. (2018). *The 2 nd Phytosanitary Conference Book of Abstract* (Issue June).
27. KOAN. (2020). *Pesticide use in Kirinyaga and Murang'a Counties: control strategies. Published by Kenya Organic Agriculture Network*. 1-32.
28. LC-MS/MS Liquid Chromatography Tandem Mass Spectrometry. https://www.eag.com
29. Mestres R. and G. Mestres, Rev. Environ. Con tam. Toxic. U, 1-25 (1992)
30. Momanyi, V. N; Keraka, M; Abong'o, D & Warutere, P.N (2021). Pesticide Residues on Tomatoes Grown and Consumed in Mwea Irrigation Scheme, Kirinyaga County, Kenya *Asian Journal of Agricultural and Horticultural Research 8(2): 1-11, 2021; Article no.AJAHR.67324*
31. Nakhungu VM (2021) Pesticide Residues on Tomatoes Grown and Consumed in Mwea Irrigation Scheme, Kirinyaga County, Kenya https://ir-library.ku.ac.ke/items/29df9e99-b473-4b59-b335-648f7b88df6c
32. National Center for Biotechnology Information (2025). PubChem Compound Summary for CID 3346, Fenthion. Retrieved February 4, 2025.
33. National Pesticide Information Center, NPIC, 2001; www.nipc.edu/
34. Ndirangu ZW (2025) Determinants of Pesticide Safety Adherence among Tomato Farmers in Kenya: Individual and Structural Factors for Sustainable Agriculture
35. Nguyen, T. T., Rosello, C., Bélanger, R., & Ratti, C. (2020). Fate of Residual Pesticides in Fruit and Vegetable Waste (FVW) Processing. *Foods*, *9*(10), 1468.
36. https://doi.org/10.3390/foods9101468
37. OECD. (2008). *OECD Guideline for the testing of chemicals. Magnitude of the Pesticide Residues in Processed Commodities. N° 508. 3 October*, 15.
38. PCPB (2024) Pest Control Products Registered for use in Kenya
39. PCPB. (2024). BASELINE STUDY ON PESTICIDE RESIDUES. In *PCPB* (Issue 2).
40. Pesticides atlas (2022): Kenya Edition. Facts and figures about toxic chemicals in foods https://ke.boell.org/en/2022/10/14/pesticides-atlas
41. Pesticide-use-in-Kenya-COMP. (2019). October.
42. Phopin, K.; Wanwimolruk, S.; Norkaew, C.; Buddhaprom, J.; Isarankura-Na-Ayudhya, C. Boiling, Blanching, and Stir-Frying Markedly Reduce Pesticide Residues in

Vegetables. Foods **2022**, 11, 1463. https://doi.org/10.3390/foods11101463

43. Rano, S, and Singh, M (2021). Strategy for the inspection of pesticide residues in food and agriculture. Sustainable Agriculture Reviews 47: pesticide occurrence, analysis. Springer https://www.sciencedirect.com/science/article/abs/pii/S088915752500643X
44. Rawat K, Srivastava A, Tandon S, Singh G. Validation and efficacy of various decontamination solutions in eliminating acephate residues from okra. Trends in Horticulture. 2024; 7(2): 4507. https://doi.org/10.24294/th.v7i2.4507
45. Recommended Methods of Sampling for the Determination of Pesticide Residues poor Compliance with MRLs *CAC/GL 33-1999*
46. Report Linker (2022-2026) Global Spinach Gross Production by Country Reportlinker.com
47. Report Linker (2022-2026) Kenya Tomato Industry Outlook. Reportlinker.com
48. Richfarm Kenya (2023) https://www.richfarmkenya.com/2023/01/Spinachis-popular-leafy-vegetable-and.html
49. Sait Engindeniz (2006). Economic analysis of pesticide use on processing Tomato growing: A case study for Turkey. Elsevier, Crop Protection Vol 25, Issue 6.
50. Sances F.V., N.C. Toscano and L.K. Gaston, Calif. A& Sept-Oct, 17-20 (1992)
51. Sarina Ahmadi, Salman Khazaei, Fereshteh Mehri, The concentration of pesticide residues in vegetables: A systematic review and meta-analyses, Journal of Agriculture and Food Research, Volume 15, 2024, 101027, ISSN 2666-1543, https://doi.org/10.1016/j.jafr.2024.101027.
52. Sarode S.V., R. Lal, A & An J. 52,135 (1982)
53. Sarode S.V., R. Lal, Indian J. AFric. Sci. 2, 173 (1982)
54. SGS Kenya Limited, Victoria Towers, Kilimanjaro Road, Nairobi https://www.sgs.com Health https://pmc.ncbi.nlm.nih.gov
55. Shashi Bhushan Vemuri, Cherukuri Sreenivasa Rao, Ravindranath Darsi, Harinatha Reddy A, Aruna M , Ramesh B , S. Swarupa. Methods for the Removal of Pesticide Residues in Tomato. Food Science and Technology 2(5): 64-68, 2014. DOI: 10.13189/ fst.2014.020502
56. Sherif, H.A., Manal, E.A., Gamila, A.K., and Hoda F (2014). Exposure to difenoconazole, diclofop-methyl alone and in combination, alters oxidative stress and biochemical parameters in albino rats. *International Journal of Clinical and Experimental Medicine*
57. Song, A L; Xusheng Y; Zixi, Y, Yueyuan, Z; Yufan, Wei; Jiahao, L; Canping, P & Gang, L(2025). Residue regulation and dissipation pattern of five typical pesticides on Spinach in a cool climate region. *Journal of Food Composition and Analysis* Volume 145, September 2025, 107828.
58. The Pest Control Products Bill (2022), Ministry of Agriculture and Livestock Development https://kilimo.go.ke/wp-content/uploads/2024/10/Pest-Control-Products-Bill-2022.pdf
59. Srivastava A, Singh GP, Srivastava PC (2021). Method validation for the determination of nine pesticides in okra and their mitigation using different solutions. PLoS ONE 16(12): e0260851. https://doi.org/10.1371/journal.pone.0260851
60. Su G, S Xie, L Jiang, G Du, P Li (2025)- A chemometric-assisted method for automatic, rapid, and non-targeted detection of multi-pesticides in plant-derived foods by gas chromatography-mass spectrometry. Food Chemistry, 2024 – Elsevier
61. United Nations- Environmental Protection Agency, 1998, www.epa.gov/
62. United Nations- Environmental Protection Agency, 2001, www.epa.gov/http://cfpub.epa.gov/ecotox/
63. Vidisha Tomer and Jaswinder Kaur Sangha. Vegetable processing at the household level: Effective tool against pesticide residue exposure. IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT) e-ISSN: 2319-2402, p-ISSN: 2319-2399. Volume 6, Issue 2 (2013), PP 43-53 www.Iosrjournals.Org
64. Wang, Z; Wang, Y; Dou, J ;Cong, H ;Sun, L & Wang (2024) Ecological risk assessment for typical organophosphorus pesticides in surface water of China based on a species sensitivity distribution model. Science of the Total Environment Volume 913, 25 February 2024, 169805
65. Waseem, K. I; Fareed, A; Rahim, M. A; Rehman, A. A &Rasul, H.F (2023) Industrial applications of Kale (Brassica oleracea var. sabellica) as a functional ingredient: a review. *International Journal of Food Properties*, Volume 26, Issue 1 (2023) Pages 489-501 |
66. WHO (2019): The WHO Recommended Classification of Pesticides by Hazard and Guidelines to classification file:///C:/Users/HP/Documents/Documents/guidelines%20on%20WHO%20classification%20of%20pesticides.pdf
67. Yang, S.-J.; Mun, S.; Kim, H.J.; Han, S.J.; Kim, D.W.; Cho, B.-S.; Kim, A.G.; Park, D.W. Effectiveness of Different Washing Strategies on Pesticide Residue Removal: The First Comparative Study on Leafy Vegetables. Foods **2022**, 11, 2916. https://doi.org/10.3390/foods11182916

APPENDICES

Appendix 1: Sample Collection Observation Checklist

Date of Data collection: [dd/mm/yyyy] _____

Name of Enumerator/ data collection personnel: _____

Name of the Market: **Wakulima [Nakuru]**

GPS coordinates of the Market _____ _____

Sample Type	Source [County]	Location of Origin	Sample Unique Identifier	Comments; (CAC/GL 33 – 1999)
Tomatoes [3]	Nakuru	Rongai	TNaW1	Table 1b (i), 1 primary sample per lot (Trader)
		Rumuruti	TNaW2	
		Marigat	TNaW4	
Onions [2]	Nakuru	Nyeri	ONaW2	Table 1b (i), 1 primary sample per lot
		Baringo	ONaW3	
Kale [6]	Nakuru [Bahati]	Bahati	KNaBW1	Table 1b (ii), 3 primary samples per lot [lot< 50 kg]
		Bahati	KNaBW2	
		Bahati	KNaBW3	
	Nakuru [Ol Kalao]	Ol Kalao	KNaOW1	
		Ol Kalao	KNaOW2	
		Ol Kalao	KNaOW3	
Spinach [4]	Nakuru [Bahati]	Bahati	SNaBW1	Table 1b (i), 2 primary samples per lot
		Bahati	SNaBW2	
	Nakuru [Ol Kalao]	Ol Kalao	SNaOW1	Table 1b (i), 2 primary samples per lot
		Ol Kalao	SNaOW2	
Total Samples			**15**	

Notes:

1. Obtain one (1) kilogram of each food produce from every trader (this constitutes one (1) primary sample) or otherwise as guided under comments when the sample is not homogeneous.
2. Every sample will be placed in a separate bag and given its unique identifier, as shown above.
3. Samples will be placed in a crate and transported to the PHPT lab as early as possible.
4. Ensure that you obtain the specified number of different food types from the specified sources [County].

Appendix 2: Sample Collection Observation Checklist

Date of Data collection: [dd/mm/yyyy] _____

Name of Enumerator/ data collection personnel:_____

Name of the Market: **Githurai**

GPS coordinates of the Market _____ _____

Sample Type	Source [County]	Sample Unique Identifier	Location of Origin	Comments; (CAC/GL 33 – 1999)
Tomatoes [5]	Kirinyaga	TKG1	Kirinyaga	Table 1b (i), 1 primary sample per lot
		TKG2	Kirinyaga	
	Nyeri	TNG1	Nyeri	Table 1b (ii), 3 primary samples per lot [lot< 50 kg]
		TNG2	Nyeri	
		TNG3	Nyeri	
Onions [4]	Pokot	OPG1	Pokot	Table 1b (i), 2 primary samples per lot
		OPG2	Pokot	
	Kajiado	OKaG1	Kajiando	Table 1b (i), 2 primary samples per lot
		OKaG2	Kajiando	
Kale [6]	Kiambu	KKiG1	Kiambu	Table 1b (i), 2 primary samples per lot
		KKiG2	Kiambu	
	Machakos	KMG1	Machakos	Table 1b (i), 2 primary samples per lot
		KMG2	Machakos	
	Nairobi	KNbG1	Ruai	Table 1b (i), 1 primary sample per lot
Spinach [5]	Kiambu	SKiG1	Kiambu	
	Machakos	SMG1	Machakos	Table 1b (i), 2 primary samples per lot
		SMG2	Machakos	
	Nairobi	SNbG1	Ruai	Table 1b (i), 2 primary samples per lot
		SNbG2	Ruai	
Total Samples		**17**		

Notes:

1. Obtain one (1) kilogram of each food produce from every trader (this constitutes one (1) primary sample) or otherwise as guided under comments when the sample is not homogeneous.
2. Every sample will be placed in a separate bag and given its unique identifier, as shown above.
3. Samples will be placed in a crate and transported to the PHPT lab as early as possible.
4. Ensure that you obtain the specified number of different food types from the specified sources [County].

SAMPLE COLLECTION OBSERVATION CHECKLIST

Date of Data collection: [dd/mm/yyyy] _____

Name of Enumerator/ data collection personnel:_____

Name of the Market: **Muthurwa**

GPS coordinates of the Market _____ _____

Sample Type	Source [County]	Sample Unique Identifier	Comments; (CAC/GL 33 – 1999)
Tomatoes [2]	Kajiado	TKaM1	Table 1b (i), 2 primary samples per lot
		TKaM2	
Onions [2]	Isiolo	OIM1	Table 1b (i), 2 primary samples per lot
		OIM2	
Kale [3]	Kiambu	KKiM1	Table 1b (ii), 3 primary samples per lot [lot< 50 kg]
		KKiM2	
		KKiM3	
Spinach [1]	Kiambu	SKiM1	Table 1b (i), 1 primary sample per lot
Total Samples		**8**	

Notes:

1. Obtain one (1) kilogram of each food produce from every trader (this constitutes one (1) primary sample) or otherwise as guided under comments when the sample is not homogeneous.
2. Every sample will be placed in a separate bag and given its unique identifier, as shown above.
3. Samples will be placed in a crate and transported to the PHPT lab as early as possible.
4. Ensure that you obtain the specified number of different food types from the specified sources [County].

SAMPLE COLLECTION OBSERVATION CHECKLIST

Date of Data collection: [dd/mm/yyyy] _____

Name of Enumerator/ data collection personnel: _____

Name of the Market: **Kangemi**

GPS coordinates of the Market _____ _____

Sample Type	Source [County]	Sample Unique Identifier	Comments; (CAC/GL 33 – 1999)
Tomatoes [4]	Kirinyaga	TKK1	Table 1b (i), 2 primary samples per lot
		TKK2	
	Kajiado	TKaK1	Table 1b (i), 2 primary samples per lot
		TKaK2	
Onions [1]	Kajiado	OKaK1	Table 1b (i), 1 primary sample per lot
Total Samples		**5**	

Notes:

1. Obtain one (1) kilogram of each food produce from every trader (this constitutes one (1) primary sample) or otherwise as guided under comments when sample is not homogeneous.
2. Every sample will be placed in a separate bag and given its unique identifier, as shown above.
3. Samples will be placed in a crate and transported to the PHPT lab as early as possible.
4. Ensure that you obtain the specified number of the different food types from the specified sources [County].

Appendix 3: Sample collection plan

Sample correction plan according to the EU directive (2002/EC/63) and Codex Alimentarius Standard (CAC/GL 33)

Food Produce	Traders	Region/ County	Sample Numbers	Market/ Sampled	Traders Sampled	Identification on sample bag
Tomatoes	13	Kirinyaga	4	Githurai	2	TKG1, TKG2
				Kangemi	2	TKK1, TKK2
		Nyeri	3	Githurai	3	TNG1, TNG2, TNG3
		Kajiado	3	Muthurua	1	TKaM2
				Kangemi	2	TKaK1, TKaK2,
		Nakuru	3	Wakulima	3	TNaW1, TNaW2, TNaW4
Onions	9	Pokot	2	Githurai	2	OPG1, OPG2
		Isiolo	2	Muthurua	2	OIM1, OIM2
		Kajiado	3	Githurai	2	OKaG1, OKaG1
				Kangemi	1	OKaK1
		Nakuru	2	Wakulima	2	ONaW2, ONaW3
Kale	14	Kiambu	4	Githurai	2	KKiG1, KKiG1
				Muthurua	2	KKiM2, KKiM3
		Machakos	2	Githurai	2	KMG1, KMG2
		Nairobi (Ruai)	2	Githurai	2	KNbG1, KNbG2
		Nakuru: (Bahati, & Ol Kalao)	6	Wakulima		
				Bahati	3	KNaBW1, KNaBW2, KNaBW3
				Ol kalao	3	KNaOW1, KNaOW2, KNaOW3
Spinach	9	Kiambu	2	Githurai	1	SKiG1
				Muthurua	1	SKiM1
		Machakos	2	Githurai	2	SMG1, SMG2
		Nairobi (Ruai)	1	Githurai	1	SNbG1
		Nakuru: (Bahati & Ol Kalao)	4	Wakulima		
				Bahati	2	SNaBW1, SNaBW2
				Ol kalao	2	SNaOW1, SNaOW2
Totals	**45**				**45**	

Notes:

a. Good laboratory procedures were strictly adhered to by the research team from UoN & KOAN under the guidance of the Principal Investigator.

b. One (1) kilogram of each food produce from every trader (this constitutes one (1) laboratory sample)

c. Every sample was placed in a separate bag and given its unique identifier, as shown in **Table 3.1.**

d. Samples were placed in a crate and transported to the PHPT lab as early as possible.

e. Sampling criteria at the market and county levels are demonstrated in **Appendix 1.**

1. The number of primary samples was determined according to the EU directive (2002/EC/63) and Codex Alimentarius Standard (CAC/GL 33). Samples were taken from traders who qualified for the study inclusion criteria.

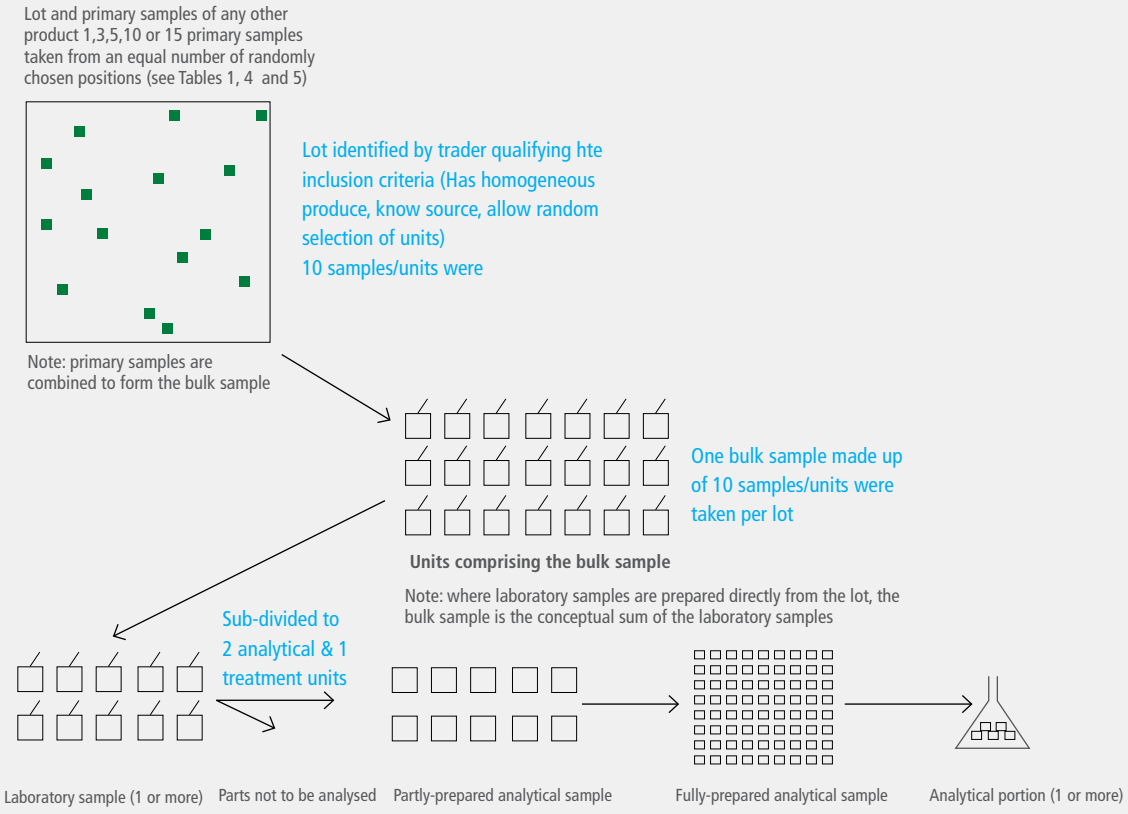
   a. Wholesalers or first-line retailers who had obtained their produce directly from the transporters,

   b. Trader with any/all four food produce (Tomatoes, Onions, Kale, Spinach)

   c. Trader able to identify the source of their produce in terms of county and have not mixed produce from different sources (Counties)

   d. Trader willing to allow the sampling officer to randomly pick the primary sample.

2. Since the selected markets had produce from different counties being sold by different traders, a lot was defined as a consignment from a named county placed on the trader's table. If more than one trader from the same county qualified for sampling, they were allocated lot numbers and primary samples taken as illustrated in the diagram below.



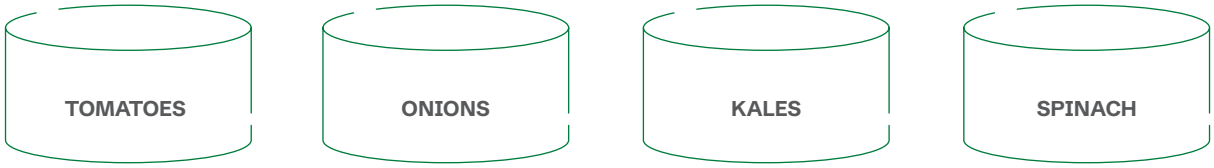
FROM: ANNEX II. B SCHEMATIC REPRESENTATION OF SAMPLING: PRODUCTS OTHER THAN MEAT AND POULTRY

[CAC/GL 33-1999]. Study Explanation in Blue.

Appendix 4: Diagrammatic Presentation of Treatments

WASHING WITH RUNNING WATER #1

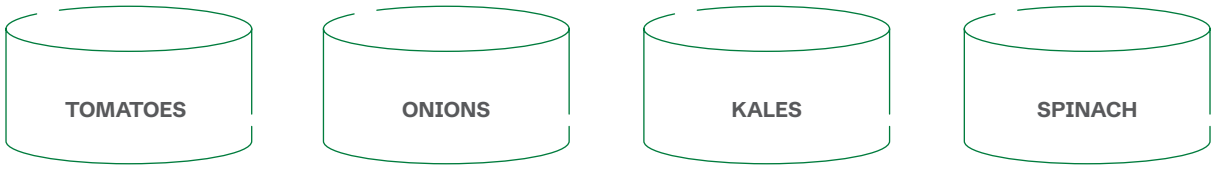
Flow rate of 170mls/s



600g	600g	600g	600g
051, 052	053, 054	055, 056	057, 058

- Peeled & Trimmed 600g of each food type with a clean knife
- Washed by hand, rubbing under running tap water at **170ml/s for 2 minutes**.
- Placed on clean filter/ blotting papers for drying.
- Packaged in well-labelled zip-lock bags and kept in a freezer awaiting dispatch.
- Dispatch to the testing lab in cool boxes with ice packs.

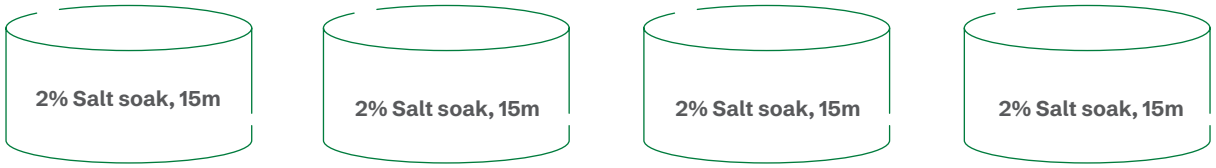
BLANCHING # 2



600g	600g	600g	600g
059, 060	061, 062	063, 064	065, 066

- Wash under running tap water as in #1.
- Place 600g of produce in boiling water for 60s.
- Remove and place on paper towels to dry.
- Put 300g in 2 zip-lock bags and label appropriately.
- Place in a freezer awaiting dispatch to the testing lab.

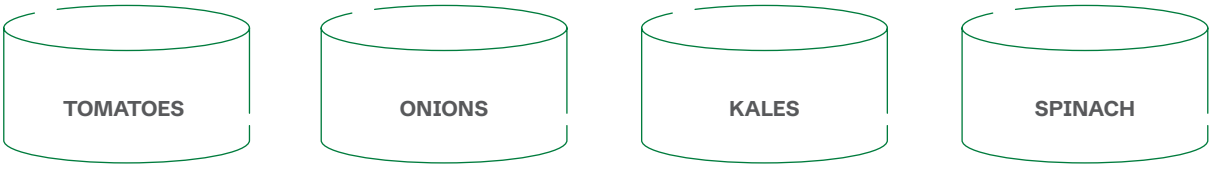
SALT SOAKING # 3 & 4



067, 068	069, 070	071, 072	073, 074

Soak for 15 minutes, chop into 1" pieces and then place in the appropriate cooking pot.

COOKING # 4



600g	600g	600g	600g
075, 076	077, 078	079, 080	081, 082

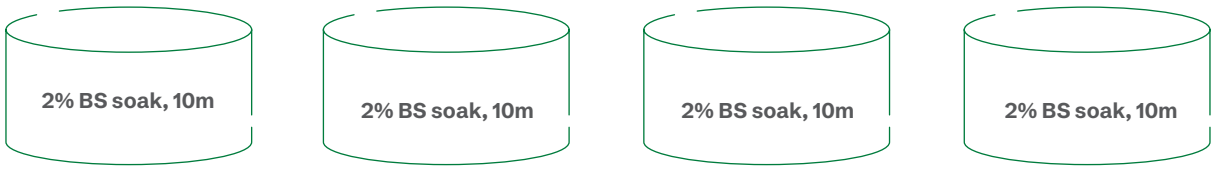
Tomatoes & Onions

- Heat 2 tablespoons of cooking oil in a pan on medium heat for 2 minutes.
- Place the 6 chopped Tomatoes OR 6 chopped Onions into the appropriate pan.
- Cook **Onions** for **five minutes** while stirring frequently with a clean wooden spoon.
- Saute **Tomatoes** for **three minutes** while tossing frequently.
- Remove from the pan and pour on a clean labelled foil to cool for 10 minutes.
- Place in a zip-lock bag with the lab. Number on it.
- Put in a freezer awaiting dispatch to the testing lab.

Kale & Spinach

- Place chopped Kale and Spinach in a cooking pot and cover.
- Cook while stirring occasionally with a clean wooden spoon
- **Kale**: cook for **five minutes.**
- **Spinach**: cook for **ten minutes**

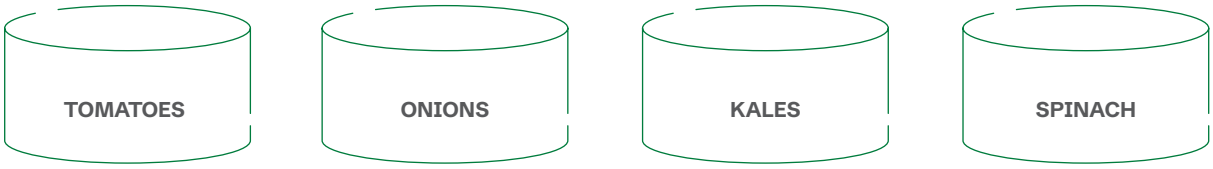
BAKING SODA # 5



Tomatoes, 600g	Onions, 600g	Kale, 600g	Spinach, 600g
083, 084	085,086	087, 088	089, 090

- Place 600g of each food type into the appropriate basin with 2 % backing soda.
- All the parts of the produce must be fully covered by the solution.
- Hold the produce in the solution for 15 minutes.
- Remove after 15 minutes and place on a clean paper towel to drain water.
- Place 300g of each produce in labelled zip-lock bags.
- Place the bags in a freezer awaiting dispatch to the testing lab.

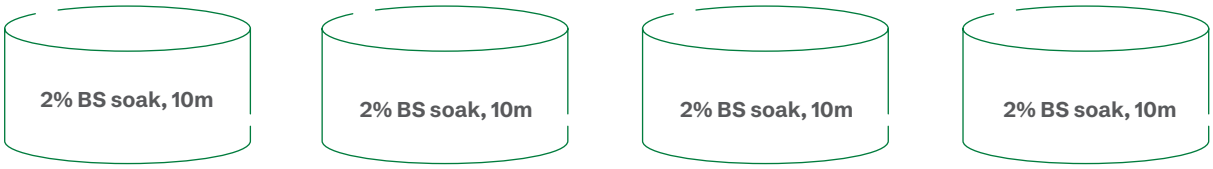
COOKING # 6



600g	600g	600g	600g
091, 092	093, 094	095, 096	097, 098

- Cook as in # 4 above

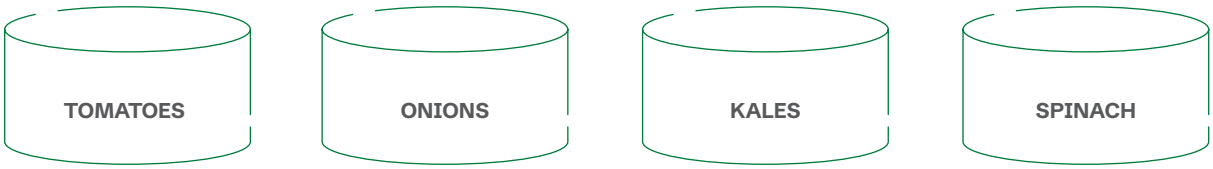
BAKING SODA # 7



Tomatoes, 600g	Onions, 600g	Kale, 600g	Spinach, 600g
099, 100	101,102	103, 104	105, 106

- Place 600g of each food type into the appropriate basin with 2 % backing soda.
- All the parts of the produce must be fully covered by the solution.
- Hold the produce in the solution for 15 minutes.
- Remove after 15 minutes and place on a clean paper towel to drain water.
- Place 300g of each produce in labelled zip-lock bags.
- Place the bags in a freezer awaiting dispatch to the testing lab.

COOKING # 7



600g	600g	600g	600g
099, 100	101, 102	103, 104	105, 106

Appendix 5: Baseline Results on Pesticide Residues in Four Food Types [Tomatoes, Spinach, Kale, and Onions] Sourced from Four Major Open Markets in Kenya.

N= 45	LAB NO:	Food Type	Source	Sample Batch No:	Pesticide Residues: Active Ingredients	Results Mg/ kg	EU-MRL Mg/ kg	CODEX-MRL Mg/ kg
1.	001	Tomatoes	Nakuru Rongai	TNAW1	Chlorfenapyr	0.04	0.01	0.4
					Carbendazim	0.08	0.3	0.5
2.	002	Tomatoes	Nakuru Rumuruti	TNAW2	Chlorfenapyr	0.02	0.01	0.4
					Carbendazim	0.03	0.3	0.5
3.	004	Tomatoes	Nakuru Marigat	TNAW4	Acephate	0.01	0.01	1
4.	006	Onions	Nyeri	ONAW2	None			
5.	007	Onions	Nakuru Baringo	ONAW3	None			
6.	008	Kale	Nakuru Bahati	KNABW1	None			
7.	009	Kale	Nakuru Bahati	KNABW2	None			
8.	010	Kale	Nakuru Bahati	KNABW3	None			
9.	011	Kale	Nakuru Ol Kalou	KNAOW1	None			
10.	012	Kale	Nakuru Ol Kalou	KNAOW1	Cypermethrin (Sum)	0.05	1	1
					λ -Cyhalothrin	0.02	0.01	-
11.	013	Kale	Nakuru Ol Kalou	KNAOW1	None			
12.	014	Spinach	Nakuru Bahati	SNABW1	Cypermethrin	0.01	1	1
					Azoxystrobin	0.01	3	5
					Difenoconazole	0.7	0.08	2
13.	015	Spinach	Nakuru Bahati	SNABW2	Linuron	0.02	0.01	
14.	016	Spinach	Nakuru Ol Kalou	SNA0W1	None			
15.	017	Spinach	Nakuru Ol Kalou	SNA0W2	None			
16.	018	Tomatoes	Kirinyaga	TKG1	None			
17.	019	Tomatoes	Kirinyaga	TKG2	Chlorpyrifos	0.02	0.01	1
18.	020	Tomatoes	Nyeri	TNG1	None			
19.	021	Tomatoes	Nyeri	TNG2	Chlorpyrifos	0.04	0.01	1
20.	022	Tomatoes	Nyeri	TNG3	None			
21.	023	Onions	Pokot	OPG1	Λ -Cyhalothrin	0.02	0.2	-
					Thiophanate	0.01	0.1	-
22.	024	Onions	Pokot	OPG2	None			
23.	025	Onions	Kajiado	OKAG1	None			
24.	026	Onions	Kajiado	OKAG2	None			
25.	027	Kale	Kiambu	KKIGI	None			
26.	028	Kale	Kiambu	KKIG2	None			
27.	029	Kale	Machakos	KMGI	None			
28.	030	Kale	Machakos	KMG2	None			

N= 45	LAB NO:	Food Type	Source	Sample Batch No:	Pesticide Residues: Active Ingredients	Results Mg/ kg	EU-MRL Mg/ kg	CODEX-MRL Mg/ kg
29.	031	Kale	Nairobi Ruai	KNBG1	None			
30.	032	Kale	Nairobi Ruai	KNBG2	None			
31.	033	Spinach	Kiambu	SKIGI	None			
32.	034	Spinach	Machakos	SMG1	Cypermethrin	0.03	0.7	1
					Carbendazim	0.7	0.1	-
33.	035	Spinach	Machakos	SMG2	Azoxystrobin	0.03	15	5
34.	036	Spinach	Nairobi Ruai	SNBG1	Tebuconazole	0.14	0.02	-
					Cypermethrin	0.02	0.7	1
35.	039	Tomatoes	Kajiado	TKAM2	Chlorfenapyr	0.19	0.01	0.4
					Acetamiprid	0.01	0.5	
36.	040	Onions	Isiolo	OIM1	Thiophanate	0.01	0.1	
37.	041	Onions	Isiolo	OIM2	None			
38.	043	Kale	Kiambu	KKIM2	None			
39.	044	Kale	Kiambu	KKIM3	None			
40.	045	Spinach	Kiambu	SKIMI	None			
41.	046	Tomatoes	Kirinyaga	TKK1	Chlorfenapyr	0.11	0.01	0.4
42.	047	Tomatoes	Kirinyaga	TKK2	Chlorfenapyr	0.05	0.01	0.4
					Acephate	0.07	0.01	1
					Pyridaben	0.02	0.15	
43.	048	Tomatoes	Kajiado	TKAK1	Chlorfenapyr	0.05	0.01	0.4
					Metalaxyl	0.05	0.3	
					Pyridaben	0.03	0.15	
44.	049	Tomatoes	Kajiado	TKAK2	Chlorfenapyr	0.03	0.01	0.4
					Imidacloprid	0.01	0.3	0.5
					Spirodiclofen	0.02	0.5	0.2
45.	050	Onions	Kajiado	OKAK1	None			

Appendix 6. Characteristics of spiked active ingredients

	Active ingredient	Solubility in water	Categories	Mode of action	Classification
1	Acephate	Water soluble	Organophosphate	Systemic & contact	Possible human carcinogen (Category C).
2	Methamidophos	Water soluble	Metabolite of acephate	Systemic & contact	WHO Toxicity Class 1b (Highly Hazardous)
3	Lambda-cyhalothrin	Emulsifiable Concentrate. nonvolatile	Synthetic pyrethroid insecticide	Contact	Type II pyrethroid insecticide
4	Alpha-cypermethrin	Emulsifiable Concentrate	Synthetic pyrethroid insecticide	Contact	Moderately hazardous (Class II) for acute oral toxicity
5	Imidacloprid	Water soluble	Systemic neonicotinoid insecticide	Systemic insecticide with contact and translaminar activity	WHO: Moderately toxic to mammals
6	Chlorpyrifos	Not mixed well with water	Synthetic organophosphate insecticide	Non-systemic insecticide usually lost through volatilization	WHO: Class II: moderately hazardous for acute effects
7	Tebuconazole	Emulsion Oil in Water	Systemic Fungicide for control of Rust	systemic fungicide	Class III slightly hazardous
8	Linuron	A suspension concentrate	Herbicide for control of annual grasses and broad-leaved weeds	Primarily a selective systemic herbicide with some contact activity	EFSA: Carcinogenic category 2 and as toxic for reproduction category 1B

Appendix 7: Active pesticide ingredients screened

Column 1 (Test)	LOQ	Column 2 (Test)	LOQ	Column 3 (Test)	LOQ	Column 4 (Test)	LOQ
Phenylphenol-2	0.01	Acetochlor	0.01	Aldicarb	0.01	Aminothrin	0.01
Alachlor	0.01	Aldrin	0.01	Aldrin	0.01	α, β, γ-HCH	0.01
Atrazine	0.01	Aminofos	0.01	Anthraquinone	0.01	Atraton	0.01
Atrazine-desethyl	0.01	Azinphos-ethyl	0.01	Azinphos-methyl	0.01	Azobenzene	0.01
Benfluralin	0.01	Beflubutamid	0.01	Bendiocarb	0.01	Benfluralin	0.01
β-HCH	0.01	HCH (sum)	0.01	α-HCH	0.01	β-HCH	0.01
Binapacryl	0.01	γ-HCH	0.01	Bifenox	0.01	Bifenthrin	0.01
Bromophos-ethyl	0.01	Biphenyl	0.01	Bromfenvinfos	0.01	Bromocyclen	0.01
Bromuconazole II	0.01	Bromophos-methyl	0.01	Bromopropylate	0.01	Bromuconazole I	0.01
Butralin	0.01	Butachlor	0.01	Butafenacil	0.01	Butamifos	0.01
Carbofuran	0.01	Captan	0.01	Captan	0.01	Carbosulfan	0.01
Chlordane-alpha	0.01	Carbophenothion	0.01	Chinomethionate	0.01	Chlorbenside	0.01
Chlorfenvinphos	0.01	Chlordane-gamma	0.01	Chlordane-oxy	0.01	Chlorfenvinphos	0.01
Chloroneb	0.01	Chlorbenzilate	0.01	Chlorfenson	0.01	Chloropicrin	0.01
Chlorothalonil	0.01	Chlorpyrifos-methyl	0.01	Chloroneb	0.01	Chlorothalonil	0.01
Cyanofenphos	0.01	Clomazone	0.01	Chlorthion	0.01	Cyfluthrin	0.01
Cyfluthrin (sum)	0.01	Cyanophos	0.01	Coumaphos	0.01	Cyhalothrin	0.01
Cypermethrin IV	0.01	Cyhalofop-butyl	0.01	Cypermethrin	0.01	Cypermethrin III	0.01
Cyproconazole	0.01	Cypermethrin (sum)	0.01	Cyphenothrin I	0.01	Cyphenothrin II	0.01
DDE-P,P	0.01	DDD-o,p	0.01	DDD-p,p	0.01	DDE-o,p	0.01
DEET	0.01	DDT (sum)	0.01	DDT-o,p	0.01	DDT-p,p	0.01
Dicofol	0.01	Deltamethrin	0.01	Demeton-S-methyl	0.01	Demeton-S-methyl sulfone	0.01
Dieldrin	0.01	Dichlofenthion	0.01	Dichloroaniline	0.01	Dichlorobenzophenone	0.01
Diphenylamine	0.01	Diclobutrazol	0.01	Diflufenican	0.01	Dichlorvos	0.01
Disulfoton	0.01	Dimethylvinphos	0.01	Dinotefuran	0.01	Dimethachlor	0.01
Endosulfan-alpha	0.01	Edifenphos	0.01	Disulfoton	0.01	Dinobuton	0.01
Endosulfan-beta	0.01	Endosulfan sulfate	0.01	Endrin	0.01	Disulfoton sulfone	0.01
EPN	0.01	EPTC	0.01	Etaconazole I	0.01	Endosulfan (sum)	0.01
Ethafluralin	0.01	Ethion	0.01	Ethofumesate	0.01	Endrin ketone	0.01
Fenvalerate	0.01	Fenitrothion	0.01	Famphur	0.01	Etaconazole II	0.01
Fipronil	0.01	Fenthion sulfoxide	0.01	Fenoxanil	0.01	Ethoprophos	0.01
Flumioxazin	0.01	Fipronil sulfone	0.01	Fensulfothion	0.01	Fenoxaprop-P-ethyl	0.01
Heptachlor	0.01	Fluchloralin	0.01	Flamprop-M-isopropyl	0.01	Fenvalerate I	0.01
Iprodione	0.01	Fluvalinate	0.01	Flucythrinate	0.01	Flamprop-methyl	0.01
Lambda-Cyhalothrin	0.01	Formothion	0.01	Flumetralin	0.01	Flucythrinate II	0.01
Metalaxyl-M	0.01	Heptachlor endo-epoxide	0.01	Flupirimidol	0.01	Fluotrimazole	0.01
Methoxychlor	0.01	Imazalil	0.01	Furmecyclox	0.01	Flutriafol	0.01
Mirex	0.01	Isoxathion	0.01	Heptachlor exo-epoxide	0.01	Haloxyfop-methyl	0.01
Oxyfluorfen	0.01	Leptophos	0.01	Iodofenphos	0.01	Hexachlorobenzene	0.01
Parathion	0.01	Metolachlor	0.01	Isocarbophos	0.01	Iprobenfos	0.01
Permethrin (sum)	0.01	Norflurazon	0.01	Malathion	0.01	Isodrin	0.01
Phenthoate	0.01	Pendimethalin	0.01	Metazachlor	0.01	Mevinphos	0.01
Phosmet	0.01	Prochloraz	0.01	Piperophos	0.01	Primiphos-ethyl	0.01
Pretilachlor	0.01	Propazine	0.01	Propyzamide	0.01	Profluralin	0.01
Prometon	0.01	Propargite	0.01	Proquinazid	0.01	Profenofos	0.01

Column 1 (Test)	LOQ	Column 2 (Test)	LOQ	Column 3 (Test)	LOQ	Column 4 (Test)	LOQ
Pyraclostrobin	0.01	Pyriproxyfen	0.01	Pyridaben	0.01	Prothioconazole	0.01
Pyrimethanil	0.01	Quinalphos	0.01	Quinoxyfen	0.01	Quintozene	0.01
Quintozene	0.01	Quizalofop-ethyl	0.01	Sebuthylazine	0.01	Silafluofen	0.01
Simazine	0.01	Sulfotep	0.01	Tebuconazole	0.01	Tau-fluvalinate	0.01
Tebufenozide	0.01	Tebufenpyrad	0.01	Terbuthylazine	0.01	Tefluthrin	0.01
Terbacil	0.01	Tetraconazole	0.01	Tetradifon	0.01	Terbutryn	0.01
Terbuthylazine	0.01	Tetrachlorvinphos	0.01	Thiacloprid	0.01	Thiamethoxam	0.01
Tetradifon	0.01	Tolylfluanid	0.01	Thionazin	0.01	Triadimefon	0.01
Tolclofos-methyl	0.01	Triadimenol	0.01	Tri-allate	0.01	Triadimenol	0.01
Trichlorfon	0.01	Trifluralin	0.01	Triazophos	0.01	Triflumizole	0.01
Vinclozolin	0.01			Triphenyl phosphate	0.01	Trifluralin	0.01
Phosmet	0.01	Prochloraz	0.01	Piperophos	0.01	Primiphos-ethyl	0.01
Pretilachlor	0.01	Propazine	0.01	Propyzamide	0.01	Profluralin	0.01
Prometon	0.01	Propargite	0.01	Proquinazid	0.01	Profenofos	0.01
Pyraclostrobin	0.01	Pyriproxyfen	0.01	Pyridaben	0.01	Prothioconazole	0.01
Pyrimethanil	0.01	Quinalphos	0.01	Quinoxyfen	0.01	Quintozene	0.01
Quintozene	0.01	Quizalofop-ethyl	0.01	Sebuthylazine	0.01	Silafluofen	0.01
Simazine	0.01	Sulfotep	0.01	Tebuconazole	0.01	Tau-fluvalinate	0.01
Tebufenozide	0.01	Tebufenpyrad	0.01	Terbuthylazine	0.01	Tefluthrin	0.01
Terbacil	0.01	Tetraconazole	0.01	Tetradifon	0.01	Terbutryn	0.01
Terbuthylazine	0.01	Tetrachlorvinphos	0.01	Thiacloprid	0.01	Thiamethoxam	0.01
Tetradifon	0.01	Tolylfluanid	0.01	Thionazin	0.01	Triadimefon	0.01
Tolclofos-methyl	0.01	Triadimenol	0.01	Tri-allate	0.01	Triadimenol	0.01
Trichlorfon	0.01	Trifluralin	0.01	Triazophos	0.01	Triflumizole	0.01
Vinclozolin	0.01			Triphenyl phosphate	0.01	Trifluralin	0.01
Acephate	0.01	Acetamiprid	0.01	Aldicarb	0.01	Aldicarb-sulfoxide	0.01
Ametryn	0.01	Aminocarb	0.01	Amitraz	0.01	Atrazine	0.01
Azaconazole	0.01	Azoxystrobin	0.01	Benalaxyl	0.01	Bendiocarb	0.01
Benfuracarb	0.01	Benodanil	0.01	Bensulfuron-methyl	0.01	Bentazone	0.01
Bifenazate	0.01	Bitertanol	0.01	Boscalid	0.01	Bromacil	0.01
Bupirimate	0.01	Buprofezin	0.01	Butarcaboxim	0.01	Buturon	0.01
Carbaryl	0.01	Carbendazim	0.01	Carbentamide	0.01	Carbofuran	0.01
Carboxin	0.01	Chlomequate-chloride	0.01	Chlorbromuron	0.01	Chlorbufam	0.01
Chlorfluazuron	0.01	Chloridazon	0.01	Chlorpropham	0.01	Chlorpyrifos	0.01
Chlorsulfuron	0.01	Chlorthiophos	0.01	Cinosulfuron	0.01	Climbazole	0.01
Clofentezine	0.01	Clomazone	0.01	Clopyralid	0.01	Clothianidin	0.01
Cyazofamid	0.01	Cycloxidim	0.01	Cyflufenamid	0.01	Cymoxanil	0.01
Cyprodinil	0.01	Cyromazine	0.01	Dazomet	0.01	Desmetryn	0.01
Diafenthiuron	0.01	Diazinon	0.01	Dicamba	0.01	Dichlofluanid	0.01
Dichlorvos	0.01	Dicrotophos	0.01	Diethofencarb	0.01	Difenoconazole	0.01
Diflubenzuron	0.01	Dimethenamid	0.01	Dimethoate	0.01	Dimethomorph (sum)	0.01
Dimoxystrobin	0.01	Diniconazole	0.01	Dinocap	0.01	Dinotefuran	0.01
Dipropetryn	0.01	Disulfoton-sulfoxide	0.01	Dithianon	0.01	Diuron	0.01
Dodine	0.01	Epoxiconazole	0.01	Ethiofemcarb sulfoxide	0.01	Ethiofencarb	0.01
Ethirimol	0.01	Ethofumesate	0.01	Etofenprox	0.01	Etoxazole	0.01
Famoxadone	0.01	Fenamidone	0.01	Fenarimol	0.01	Fenazaquin	0.01
Fenbuconazole	0.01	Fenhexamid	0.01	Fenobucarb	0.01	Fenoxycarb	0.01

Column 1 (Test)	LOQ	Column 2 (Test)	LOQ	Column 3 (Test)	LOQ	Column 4 (Test)	LOQ
Fenipliconil	0.01	Fenpropathrin	0.01	Fenpropimorph	0.01	Fenpyroximate	0.01
Fenthion (sum)	0.01	Fipronil desulfiyn	0.01	Florasulam	0.01	Fluazinum	0.01
Fluazuron	0.01	Flubenzimine	0.01	Fludioxonil	0.01	Flufenacet	0.01
Flufenoxuron	0.01	Fluometuron	0.01	Fluopicolide	0.01	Fluoroglycofene	0.01
Fluoxastrobin	0.01	Fluquinconazole	0.01	Flusilazole	0.01	Flutriafol	0.01
Foramsulfuron	0.01	Fosthiazate	0.01	Furalaxyl	0.01	Furathiocarb	0.01
Heptenophos	0.01	Hexaflumuron	0.01	Hexazinone	0.01	Hexythiazox	0.01
Hydramethylnon	0.01	Hymexazol	0.01	Imazalil	0.01	Imazaquin	0.01
Imazosulfuron	0.01	Imibenconazole	0.01	Imidacloprid	0.01	Indoxacarb	0.01
Iprovalicarb	0.01	Isocarbamide	0.01	Isoprocarb	0.01	Isoprothiolane	0.01
Isoproturon	0.01	Isoxaben	0.01	Isoxaffutole	0.01	kresoxim-methyl	0.01
Lenacil	0.01	Linuron	0.01	Lufenuron	0.01	Mancozeb	0.01
MCPA	0.01	Mecarbam	0.01	Mepiquat chloride	0.01	Mesotrione	0.01
Metaflumizone	0.01	Metalaxyl and metalaxyl-M	0.01	Metconazole	0.01	Methacrifos	0.01
Methamidophos	0.01	Methiocarb (sum of sulfoxide al	0.01	Methomyl (sum of methomyl ar	0.01	Methoprotryne	0.01
Metobrumuron	0.01	Metolcarb	0.01	Metribuzin	0.01	Monocrotophos	0.01
Monuron	0.01	Myclobutanyl	0.01	Napropamide	0.01	Nitenpyram	0.01
Nitralin	0.01	Novaluron	0.01	Nuarimol	0.01	Omethoate	0.01
Oxadixyl	0.01	Oxamyl	0.01	Parathion-methyl	0.01	Penconazol	0.01
Pencycuron	0.01	Phosalone	0.01	Phosphamidon	0.01	Picoxystrobin	0.01
Pinoxaden	0.01	Piperonyl-butoxide	0.01	Pirimicarb (sum)	0.01	Profenofos	0.01
Promecarb	0.01	Prometryn	0.01	Propamocarb	0.01	Propanil	0.01
Propazine	0.01	Propham	0.01	Propiconazole	0.01	Propoxur	0.01
Propyzamide	0.01	Proquinazid	0.01	Prosulfocarb	0.01	Pymetrozine	0.01
Pyraclostrobin	0.01	Pyridaben	0.01	Pyrimethanil	0.01	Pyriproxyfen	0.01
Rimusulfuron	0.01	Rotenone	0.01	Silthiofam	0.01	Simetryn	0.01
Spinosad	0.01	Spirodiclofen	0.01	Spiromesifen	0.01	Spiroxamine	0.01
Tebuconazole	0.01	Tebufenozide	0.01	Tebufenpyrad	0.01	Teflubenzuron	0.01
Terbutryn	0.01	Tetraconazole	0.01	Tetradifon	0.01	Thiabendazole	0.01
Thiacloprid	0.01	Thiamethoxam	0.01	Thiamethoxam and Clothianidir	0.01	Thiobencarb	0.01
Thiodicarb	0.01	Thiophanate-methyl	0.01	Thiram	0.01	Topramezone	0.01
Tri-Allate	0.01	Triadimefon	0.01	Triasulfuron	0.01	Triazamate	0.01
Tridemorph	0.01	Trifloxystrobin	0.01	Triflumizole	0.01	Triflumuron	0.01
Triticonazole	0.01	Uniconazole	0.01	Vamidothion	0.01	Zoxamide	0.01

Appendix 8: Detailed reduction results of 8 pesticide residues in the 4 foodstuffs.

Lab No.	Sample [ID]	Food Type	Weight	Acephate mg/kg	Chlorpyrifos mg/kg	Imidacloprid mg/kg	Linuron mg/kg	Methamidophoe mg/kg	Tebuconazole mg/kg	Cypermethrin (Sum)	Lamda-Cyhalothrin
SPRAY, HOLD @RT 40 HRS,TREAT & TEST											
1. Wash under running water, dry & Test											
51	1AT1	Tomato	300G	0.12	1.64	0.05	1.89	0.02	0.14	0	0.05
52	1AT2	Tomato	300G	0.12	1.93	0.04	1.76	0.02	0.14	0.01	0.03
		Before	Average	0.14	2.3	0.04	2.96	0.02	0.39	0.06	0.06
		After	Average	0.12	1.79	0.05	1.83	0.02	0.14	0.01	0.04
			sd	0	0.21	0.01	0.09	0	0	0.01	0.01
		% Reduction		35.14	34.01	0	32.16	33.33	63.64	92.31	89.74
53	1BO1	Onion	300G	0.09	0	0	0.07	0	0	0	0
54	1BO2	Onion	300G	0.11	0	0	0.05	0	0	0	0
		After	Average	0.1	0	0	0.06	0	0		
			sd	0.01	0	0	0.01	0	0		
		% Reduction		96.47	100	100	99.28	100	100		
55	1CK1	Kale	300G	8.1	11.59	1.83	16.4	0.4	4.76	0.26	1.58
56	1CK2	Kale	300G	6.06	10.9	1.31	13.8	0.28	3.58	0.14	0.85
		After	Average	7.08	11.25	1.57	15.1	0.34	4.17	0.2	1.22
			sd	1.44	0.49	0.37	1.84	0.08	0.83	0.08	0.52
		% Reduction		33.96	41.65	49.52	46.15	23.6	27.67	76.33	70.58
57	1DS1	Spinach	300G	4.55	8.68	0.93	9.92	0.38	2.11	0.13	0.8
58	1DS2	Spinach	300G	5.13	10.87	0.89	8.54	0.35	1.9	0.08	0.66
		After	Average	4.84	9.78	0.91	9.23	0.37	2.01	0.11	0.73
			sd	0.41	1.55	0.03	0.98	0.02	0.15	0.04	0.1
		% Reduction		20.33	34.48	56.87	57.69	30.48	41.29	84.44	79.14
2. Wash, Blanch, Dry & Test											
59	2AT1	Tomato	300G	0.19	1.51	0.03	1.45	0.03	0.16	0	0.02
60	2AT2	Tomato	300G	0.12	2.49	0.03	1.29	0.01	0.15	0.02	0
		After	Average	0.16	2	0.03	1.37	0.02	0.16	0.01	0.01
			sd	0.05	0.69	0	0.11	0.01	0.01	0.01	0.01
		% Reduction		16.22	26.06	33.33	49.07	33.33	59.74	84.62	97.44
61	2BO1	Onion	300G	0.01	0	0	0	0	0	0	0
62	2BO2	Onion	300G	0.07	0	0	0.02	0	0	0	0
		After	Average	0.04	0	0	0.01	0	0		
			sd	0.04	0	0	0.01	0	0		
		% Reduction		98.59	100	100	99.88	100	100		
63	2CK1	Kale	300G	5.6	11.26	0.8	12.73	0.25	4.22	0.14	0.67
64	2CK2	Kale	300G	4.32	8.97	0.6	10.47	0.2	3.67	0.23	1.09
		After	Average	4.96	10.12	0.7	11.6	0.23	3.95	0.19	0.88
			sd	0.91	1.62	0.14	1.6	0.04	0.39	0.06	0.3
		% Reduction		53.73	47.51	77.49	58.63	49.44	31.57	78.11	78.69

65	2DS1	Spinach	300G	3.55	9.39	0.51	7.27	0.23	2.26	0.03	0.16
66	2DS2	Spinach	300G	3.47	8.76	0.5	7.17	0.21	2.11	0.14	0.08
		After	Average	3.51	9.08	0.51	7.22	0.22	2.19	0.09	0.12
			sd	0.06	0.45	0.01	0.07	0.01	0.11	0.08	0.06
		% Reduction		42.22	39.18	76.07	66.9	58.1	36.02	87.41	96.57
3. 2% Salt Soak, Wash, Dry & Test											
67	3AT1	Tomato	300G	0.14	2.84	0.04	3.29	0.01	0.39	0	0.07
68	3AT2	Tomato	300G	0.2	2.21	0.07	2.73	0.02	0.28	0.01	0.08
		After	Average	0.17	2.53	0.06	3.01	0.02	0.34	0.01	0.08
			sd	0.04	0.45	0.02	0.4	0.01	0.08	0.01	0.01
		% Reduction		8.11	6.65	-22.22	-11.9	50	12.99	92.31	80.77
69	3BO1	Onion	300G	0.07	0.02	0	0.08	0	0		
70	3B02	Onion	300G	0.2	0.02	0	0.08	0.01	0.01		
		After	Average	0.14	0.02	0	0.08	0.01	0.01		
			sd	0.09	0	0	0	0.01	0.01		
		% Reduction		95.24	99.42	100	99.04	90.91	99.57		
71	3CK1	Kale	300G	15.53	8.55	2.27	18.86	0.48	5.99	0.04	1.94
72	3CK2	Kale	300G	14.27	5.3	1.98	15.69	0.44	4.57	0.14	0.93
		After	Average	14.9	6.93	2.13	17.28	0.46	5.28	0.09	1.44
			sd	0.89	2.3	0.21	2.24	0.03	1	0.07	0.71
		% Reduction		-38.99	64.06	31.67	38.39	-3.37	8.41	89.35	65.25
73	3DS1	Spinach	300G	4.62	4.64	0.86	9.5	0.42	2.04	0.11	0.72
74	3DS2	Spinach	300G	3.79	3.44	1.2	11.05	0.48	2.4	0.07	0.68
		After	Average	4.21	4.04	1.03	10.28	0.45	2.22	0.09	0.7
			sd	0.59	0.85	0.24	1.1	0.04	0.25	0.03	0.03
		% Reduction		30.78	72.92	51.18	52.9	14.29	34.99	86.67	80
4.2% Salt Soak, Wash, Cook, Dry & Test											
75	4AT1	Tomato	300G	0.15	0.65	0.04	2.09	0.02	0.21	0	0.03
76	4AT2	Tomato	300G	0.22	0.38	0.04	2.28	0.02	0.21	0	0.01
		After	Average	0.19	0.52	0.04	2.19	0.02	0.21	0	0.02
			sd	0.05	0.19	0	0.13	0	0	0	0.01
		% Reduction		0	80.96	11.11	18.77	33.33	45.45	100	94.87
77	4BO1	Onion	300G	0.06	0.06	0	0.14	0	0	0	0
78	4BO2	Onion	300G	0.05	0.03	0	0.27	0	0	0	0
		After	Average	0.06	0.05	0	0.21	0	0	0	0
			sd	0.01	0.02	0	0.09	0	0	0	0
		% Reduction		98.06	98.69	100	97.55	100	100	100	100
79	4CK1	Kale	300G	6	7.08	1.39	18.04	0.5	3.79	0.17	0.92
80	4CK2	Kale	300G	5.37	7.16	1.18	16.64	0.45	3.83	0.25	1.34
		After	Average	5.69	7.12	1.29	17.34	0.48	3.81	0.21	1.13
			sd	0.45	0.06	0.15	0.99	0.04	0.03	0.06	0.3
		% Reduction		46.97	63.05	58.68	38.16	-6.74	33.91	75.15	72.64
81	4DS1	Spinach	300G	2.89	8.13	0.54	11.79	0.23	1.58	0.12	0.66
82	4DS2	Spinach	300G	2.93	8.25	0.55	11.2	0.22	1.34	0.09	0.49
		After	Average	2.91	8.19	0.55	11.5	0.23	1.46	0.11	0.58
			sd	0.03	0.08	0.01	0.42	0.01	0.17	0.02	0.12
		% Reduction		52.1	45.11	74.17	47.31	57.14	57.25	84.44	83.57

5. 2% Baking Soda Soak, Wash, Dry & Test											
83	5AT1	Tomato	300G	0.08	3.54	0.02	3.17	0.01	0.44	0.18	0.83
84	5AT2	Tomato	300G	0.02	2.44	0.05	2.84	0.02	0.42	0.09	0.55
		After	Average	0.05	2.99	0.04	3.01	0.02	0.43	0.14	0.69
			sd	0.04	0.78	0.02	0.23	0.01	0.01	0.06	0.2
		% Reduction		72.97	-10.54	22.22	-11.71	50	-11.69	-38.46	-41.1
85	5BO1	Onion	300G	0.02	0	0	0.03	0	0	0	0
86	5BO2	Onion	300G	0.33	0	0	0.02	0		0	0
		After	Average	0.18	0	0	0.03	0	0	0	0
			sd	0.22	0	0	0.01	0	#DIV/0!	0	0
		% Reduction		93.83	100	100	99.7	100	100	100	100
87	5CK1	Kale	300G	8.81	5.76	1.98	15.33	0.46	4.48	0.74	3.5
88	5CK2	Kale	300G	11.01	10.22	2.55	18.59	0.51	5.63	0.96	4.15
		After	Average	9.91	7.99	2.27	16.96	0.49	5.06	0.85	3.83
			sd	1.56	3.15	0.4	2.31	0.04	0.81	0.16	0.46
		% Reduction		7.56	58.54	27.17	39.51	-8.99	12.32	-0.59	7.38
89	5DS1	Spinach	300G	4.24	8.06	0.99	10.47	0.37	2.39	0.41	2.54
90	5DS2	Spinach	300G	6.91	9.25	1.6	15.54	0.56	3.03	0.53	3.24
		After	Average	5.58	8.66	1.3	13.01	0.47	2.71	0.47	2.89
			sd	1.89	0.84	0.43	3.59	0.13	0.45	0.08	0.49
		% Reduction		8.23	41.99	38.63	40.39	11.43	20.64	30.37	17.43
6. 2% Baking Soda, Wash, Dry, Cook & Test											
91	6AT1	Tomato	300G	0.15	2.03	0.43	2.5	0.01	0.24	0.02	0.09
92	6AT2	Tomato	300G	0.03	0.03	0	0.12	0	0	0.03	0.14
		After	Average	0.09	1.03	0.22	1.31	0.01	0.12	0.03	0.12
			sd	0.08	1.41	0.3	1.68	0.01	0.17	0.01	0.04
		% Reduction		51.35	61.92	0	51.3	83.33	68.83	61.54	70.51
93	6BO1	Onion	300G	0.03	0.07	0	0.23	0	0	0	0
94	6BO2	Onion	300G	0.03	0.07	0	0.21	0	0	0	0
		After	Average	0.03	0.07	0	0.22	0	0	0	0
			sd	0	0	0	0.01	0	0	0	0
		% Reduction		98.94	97.97	100	97.37	100	100	100	100
95	6CK1	Kale	300G	7.18	6.61	1.15	13.67	0.45	2.68	0.35	1.21
96	6CK2	Kale	300G	4.97	6.22	1.07	14.04	0.42	2.75	0.27	1.13
		After	Average	6.08	6.42	1.11	13.86	0.44	2.72	0.31	1.17
			sd	1.56	0.28	0.06	0.26	0.02	0.05	0.06	0.06
		% Reduction		43.33	66.71	64.31	50.59	2.25	52.91	63.31	71.67
97	6DS1	Spinach	300G	4.06	10.18	0.87	13.81	0.33	2.79	0.11	0.67
98	6DS2	Spinach	300G	2.56	10.26	0.92	13.82	0.36	2.56	0.07	0.44
		After	Average	3.31	10.22	0.9	13.82	0.35	2.68	0.09	0.56
			sd	1.06	0.06	0.04	0.01	0.02	0.16	0.03	0.16
		% Reduction		45.51	31.5	57.58	36.67	34.29	21.67	86.67	84.14
7. 20% Vinegar Soak, Wash, Cook & Test											
99	7AT1	Tomato	300G	0.3	1.2	0.04	2.71	0.02	0.33	0.03	0.13
100	7AT2	Tomato	300G	0.31	0.84	0.04	2.01	0.02	0.2	0.02	0.11
		After	Average	0.31	1.02	0.04	2.36	0.02	0.27	0.03	0.12
			sd	0.01	0.25	0	0.49	0	0.09	0.01	0.01

		% Reduction		-64.86	62.29	11.11	12.27	33.33	31.17	61.54	69.23
101	7BO1	Onion	300G	0.09	0.05	0.01	0.35	0	0.03	0	0
102	7BO2	Onion	300G	0.07	0.05	0.01	0.32	0	0.02	0	0
		After	Average	0.08	0.05	0.01	0.34	0	0.03	0	0
			sd	0.01	0	0	0.02	0	0.01	0	0
		% Reduction		97.18	98.55	98.79	96	100	97.83	100	100
103	7CK1	Kale	300G	6.14	6.39	1.21	14.89	0.5	2.96	0.33	1.45
104	7CK2	Kale	300G	6.22	5.6	1.25	15.34	0.49	3.22	0.25	1.12
		After	Average	6.18	6	1.23	15.12	0.5	3.09	0.29	1.29
			sd	0.06	0.56	0.03	0.32	0.01	0.18	0.06	0.23
		% Reduction		42.35	68.89	60.45	46.09	-11.24	46.4	65.68	68.89
105	7DS1	Spinach	300G	6.22	6.7	1.25	15.34	0.49	3.22	0.17	0.89
106	7DS2	Spinach	300G	4.78	7.47	0.97	15.17	0.33	2.77	0.12	0.69
		After	Average	5.5	7.09	1.11	15.26	0.41	3	0.15	0.79
			sd	1.02	0.54	0.2	0.12	0.11	0.32	0.04	0.14
		% Reduction		9.47	52.51	47.39	30.07	21.9	12.3	78.52	77.43

Appendix 9: Technical Information of the Spiked Pesticides

Acephate, 970g/Kg; Orthere 97% pellet;

Acephate is an organophosphate insecticide.

In Kenya, registered for the control of thrips and false codling moths in roses and fall armyworm in maize (NOT FOR USE ON VEGETABLES).REI:6 hours Maize: Canada MRL:0.5mg/kg PHI-21days WHO Class II Moderately hazardous; Yellow[2]

Acephate is a general-use insecticide that can be used on food crops, agricultural seed, and non-bearing plants, Institutions and commercial buildings, including public health facilities, sod, golf course turf, ant mounds, and horticultural nursery plants[1].

Acephate is a systemic insecticide used to control sucking and biting insects by direct contact or ingestion. Technical grade Acephate is a white or transparent solid.[1] Acephate has a strong odour similar to mercaptan, which smells like sulphur. Molecular weight[1]: 183.16 g/mol

Solubility (water)[1,3]: 79 - 83.5 g/100 mL.

Concentration used: 48.5g/20lts.

In soil, plants, and insects, Acephate is converted to Methamidophos.

Methamidophoe

Methamidophos is a more potent organophosphate than Acephate.[4]

Insects metabolize acephate into methamidophos by hydrolysis, whereas mammals metabolize acephate more readily into des- O-methylacephate, accounting for Acephate's relatively high selectivity against insects.

The acute reference dose (aRfD) is 0.005 mg/kg/day, and the cRfD is 0.0012 mg/kg/day.[1]

1. *Reregistration Elegibility Decision (RED) Acephate*; EPA 738-R-01-013; U.S. Environmental Protection Agency, Office of Preventio n, Pesticides and Toxic Substances, Office of Pesticide Programs, U.S. Government Printing Office: Washington, DC, 2006; pp 1-87.
2. PCPB. https://www.pcpb.go.ke/crops/
3. Davy, M.; Eckel, W. P.; Hammer, C. *Risks of Acephate Use to the Federally Listed California Red Legged Frog (Rana aurora draytonii)*; U.S. Environmental Protection Agency, Office of Pesticide Programs, Environmental Fate and Effects Division: Washington, DC, 2007; p 122.
4. Reigart, J. R.; Roberts, J. R. Organophosphate Insecticides. *Recognition and Management of Pesticide Poisonings*, 5th ed.; U.S. Environmental Protection Agency, Office of Prevention, Pesticides and Toxic Substances, Office of Pesticide Programs; U.S. Government Printing Office: Washington, DC, 1999; pp 34-47.

Imidacloprid, 200g/L; Emerald, 200SL

PCPB registered use: Insecticide to control aphids, whiteflies, thrips, beanfly, on French beans and flowers[1]. Imidacloprid is a neonicotinoid insecticide.[2]

Neonicotinoid insecticides are synthetic derivatives of nicotine, an alkaloid compound found in the leaves of many plants, in addition to tobacco.[3, 4, 5]

Imidacloprid is made up of colourless crystals with a slight but characteristic odour.[2]

Henry's constant[2]: $1.7x10^{-10}$ $Pa \cdot m^3/mol$

Molecular weight[2]: 255.7 g/mol

Solubility (water)[2]: 0.61 g/L (610 mg/L) at 20 °C.

Imidacloprid is used to control sucking insects, some chewing insects, including termites, soil insects, and fleas on pets. In addition to its topical use on pets, Imidacloprid may be applied to structures, crops, soil, and as a seed treatment.[2,6]

Uses for individual products containing Imidacloprid vary widely. Imidacloprid is designed to be effective by contact or ingestion.[2] It is a systemic insecticide that translocates rapidly through plant tissues following application.[2,6] Imidacloprid is broken down in water by photolysis.[7]

Imidacloprid is stable to hydrolysis in acidic or neutral conditions, but hydrolysis increases with increasing alkaline pH and temperature.[8]

Researchers determined that hydrolysis of Imidacloprid produced the metabolite 1-[(6-chloro- 3-pridinyl) methyl]-2-imidazolidone.[8] This may be further broken down via oxidative cleavage of the N-C bond between the pyridine and imidazolidine rings, and the resulting compounds may be broken down into $C0_2$, $N0^-$, and Cl^-.[7]

1. PCPB. https://www.pcpb.go.ke/crops/
2. Tomlin, C. D. S. *The Pesticide Manual, A World Compendium*, 14th ed.; British Crop Protection Council: Surrey, England, 2006; pp 598-599.
3. Costa, L. G. Toxic Effects of Pesticides. *Casarett and Doull's Toxicology: The Basic Science of Poisons*, 7th ed.; Klaassen, C. D., Ed.; McGraw-Hill: New York, NY, 2008; pp 907, 922-930.
4. Copping, L. G. *The Biopesticide Manual*, 2nd ed.; British Crop Protection Council: Surrey, England, 2001; pp 202-203.
5. Ware, G. W.; Whitacre, D. M. *The Pesticide Book*; MeisterPro Information Resources: Willoughby, OH, 2004; pp 70-71.
6. Fossen, M. *Environmental Fate of Imidacloprid*; California Department of Pesticide Regulation, Environmental Monitoring: Sacramento, CA, 2006.
7. Liu, W.; Zheng, W.; Ma, Y.; Liu, K. Sorption and Degradation of Imidacloprid in Soil and Water. *J. Environ. Sci. Health B* 2006, 41, 623-634.
8. Zheng, W.; Liu, W. Kinetics and mechanism of the hydrolysis of Imidacloprid. *Pestic. Sci.* 1999, 55, 482-485.

Tebuconazole, 250g/L; Folicur EW 250

PCPB registered use: Fungicide for control of Rust, Angular leaf spot, Anthracnose on French beans; Early blight in Tomatoes; Tomatoes MRL: 0.1mg/Kg PHI: 7days.

Emulsion Oil in Water

Chlorpyrifos, 480g/L; Sulban 48EC

Chlorpyrifos is a synthetic organophosphate insecticide that is a white crystal-like solid with a mild rotten egg odour.

It does not mix well with water, so it is usually mixed with oily liquids before it is applied to crops or animals. It may also be applied to crops in a capsule form.[1]

PCPB registered use: Insecticide for the control of antestia bugs in coffee, thrips, aphids & whiteflies on roses; aphids, scaly insects & termites on tea.

NOT FOR FOLIAR USE ON FRUITS AND VEGETABLES[2].

Solubility: In water, 0.39 mg/L at 19.5 °C /OECD 105 method/

Henry's Law constant = 3.55X10-5 atm cu-m/mol at 25 °C.

Molecular weight: 350.6 g/mol. Chlorpyrifos is a non-systemic insecticide designed to be effective by direct contact, ingestion, and inhalation.[3]

The mean half-lives are 2.8 days in oranges and 3.7 to 6.7 days in grapefruit. Much of the applied chlorpyrifos is usually lost from volatilization, and very little is translocated throughout the plant.[4] Chlorpyrifos taken up by plant tissues is primarily metabolized to TCP, which is then stored as glycoside conjugates.[2,4]. Studies report that Chlorpyrifos residues remain on plant surfaces for 10 to 14 days after application.[5]

1. *Reregistration Eligibility Decision (RED) for Chlorpyrifos*; U.S. Environmental Protection Agency, Office of Prevention, Pesticides and Toxic Substances, Office of Pesticide Programs, U.S. Government Printing Office: Washington, DC: 2006.
2. https://www.pcpb.go.ke/crops/
3. Tomlin, C. D. S. *The Pesticide Manual, A World Compendium*, 14th ed.; British Crop Protection Council: Alton, Hampshire, UK, 2006; p 186-187.
4. Roberts, T. R.; Hutson, D. H. *Metabolic Pathways of Agrochemicals - Part 2: Insecticides and Fungicides*; The Royal Society of Chemistry: Cambridge, UK, 1999; pp 235-242.
5. Kamrin, M. A. *Pesticide Profiles Toxicity, Environmental Impact, and Fate*; Lewis Publishers: Boca Raton, FL, 1997; pp 147- 152.

Linuron, 500g/Kg; Linagan 50 WP

Linuron is moderately soluble in water (8.10E+01mg/L)[1], It is a suspension concentrate. Some Linuron will volatilize or become a vapour. Linuron does not break down very well in water. This property is associated with long-term persistence if the chemical reaches groundwater.[3]

PCPB registered use: Pre-emergence herbicide for control of annual grasses and broad-leaved weeds in carrots, French beans, baby corns, Onions and chives. EU MRL: 0.2mg/kg PHI: 42 days. WHO Class II Moderately hazardous Yellow colour Band. [4]

4. https://www.pcpb.go.ke/crops/

Alpha-Cypermethrin, 200g/L; Degree max 200EC

Designed to be effective longer than pyrethrins[1].

Cypermethrin kills insects that eat or come into contact with it[2].

It is an emulsifiable Concentrate Insecticide for the control of thrips, whiteflies, aphids, and caterpillars on roses, thrips, whiteflies, aphids, caterpillars, and Leaf miners in French beans and Tomatoes; Diamondback moth, aphids, cutworms in cabbage; thrips, aphids, Whiteflies, and Leaf miners in pepper; thrips in Onions.

Tomatoes: CODEX MRL-0.2mg/kg PHI-7 days (https://www.pcpb.go.ke/crops/)

Cypermethrin is a pyrethroid insecticide. It was first synthesized in 1974[1]. Cypermethrin is a synthetic chemical similar to the pyrethrins in pyrethrum extract (which comes from the chrysanthemum plant).

Cypermethrin works by quickly affecting the insect's central nervous system.

PCPB registered use: Insecticide for the control of aphids, thrips, Leaf miners, whiteflies, and caterpillars in French beans; aphids, thrips, whiteflies, and caterpillars in roses. REI: 12 Hrs EU MRLs: Alpha-Cypermethrin-0.7mg/kg, Acetamiprid- 0.6mg/kg PHI: 7 days WHO Class II Moderately Hazardous Yellow colour Band.[3]

1. World Health Organization. (1989). Environmental Health Criteria. Cypermethrin. (Vol. 82). Geneva: United Nations Environmental Programme, the International Labour Organization, and the World Health Organization. 2. Tomlin, C. (Ed.). (1994). A World Compendium.
2. The Pesticide Manual. Incorporating the agrochemicals handbook. (10th ed.). Bungay, Suffolk, U.K.: Crop Protection Publications. 3. PCPB, https://www.pcpb.go.ke/crops/

Lambda-Cyhalothrin, 17.5g/L; Duduthrin 1.75 EC

Emulsifiable Concentrate[1]

PCPB registered use: A contact insecticide for the control of Diamondback moth and aphids in cabbage and Kale; sucking and chewing insects in beans and Tomatoes; aphids, thrips, and whiteflies in roses; aphids in wheat and barley; maize stalk borer and armyworms in maize.

Tomatoes: PHI of 7days EU MRLs: Tomato- 0.07mg/kg[2]

Lambda-cyhalothrin is a pyrethroid insecticide[1]. Pyrethroids are synthetic chemicals that are structurally similar to the natural insecticides pyrethrins. Scientists developed pyrethroid insecticides to have enhanced biological activity and desired physical and chemical properties relative to pyrethrins[3]. Lambda-cyhalothrin is a colourless to beige solid that has a mild odor. It has a low water solubility (5 x 10-3 mg/L) and is nonvolatile with a vapor pressure of 1.5 x 10-9 mm Hg at 20 oC [3, 4].

1. Pesticide Fact Sheet Number 171: KARATE (PP321); U.S. Environmental Protection Agency, Office of Pesticide Programs,
2. U.S. Government Printing Office: Washington, DC, 1988.
3. PCPB, https://www.pcpb.go.ke/crops/
4. World Health Organization. Cyhalothrin, Environmental Health Criteria, 99; Geneva, Switzerland, 1990.
5. A World Compendium: The Pesticide Manual, 11th ed.; Tomlin, C. D. S., Ed.; British Crop Protection Council: Farnham, Surrey, UK, 1997; pp 300-302

Other detected Pesticides

Thiophanate-methyl 500g/kg

Fungicide for control of Powdery mildew and Botrytis on Roses; angular leaf spot on French beans; for the control of leaf rust in coffee. EU MRL-0.1mg/kg PHI-45 days REI: 12 hours French beans: EU MRL- 0.1mg/kg PHI- 14 days WHO Class II Moderately hazardous, Yellow colour Band.

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