CHEMICAL ELEMENTS IN RAPE (*Brassica napus L.*) A CASE STUDY OF SELECTED SMALL SCALE FARMS IN KABWE DISTRICT,CENTRAL PROVINCE, ZAMBIA

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CERTIFICATION [Submission for examination]

The undersigned hereby certify that they (he/she) have read and recommend the Research Report to be subjected to examination by Mulungushi University in (partial) fulfilment of the requirements for the award of the degree of Mulungushi University.

Prof /Dr.:………………………………………………………………………………........

(Supervisor 1)

Date:………………………………………………………………………………………..

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To my friends and colleagues, I really appreciate you all for being a pillar of support.

DEDICATION

I dedicate this work to my family.

DISCLAIMER

This research report describes the work carried out as part of programme of study at Mulungushi University .Therefore all views and opinions expressed herein remain the exclusive responsibility of the author and not necessarily those of Mulungushi University.

Abstract

A case study was carried out to investigate the concentration levels of chemical elements in different varieties of rape (*Brassica napus L.*) which were grown in five farms in Chowampanga, Kabwe district in Zambia. The purpose of the study was to monitor the levels of chemicals in locally grown vegetables in order to assist in achieving public health objectives of food safety and nutrition. The main objectives was to investigate the composition and concentration levels of chemical elements present in rape samples. In the farming season January to May 2018, 25 rape leaves were collected for plant tissue testing using Scanning Electron Microscopy. The results of the analysis showed the presence of 11chemical elements namely Nitrogen, Chlorine, Phosphorus, Sulphur, Aluminium, Calcium, Potassium, Magnesium, Silicon, Tellurium and Rubidium in most rape leaves. The concentration levels of chemical elements in the rape leaves were significantly different and characterised by higher levels of macro than micro nutrients and non-essential chemical elements, some which exceeded the Recommended Dietary Allowances. The rape leaves sampled from all the selected farms were therefore considered to be safe, valuable and important contributors to the diets of the people in Kabwe especially among the marginal income populations.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

CHAPTER ONE

INTRODUCTION

1.1 Background

Leafy vegetables are widely used for culinary purposes. They are used to improve the quality of soup and also for their dietary purposes (Sobukola et al., 2007). They are made up of chiefly cellulose, hemi-cellulose and pectin substances that give them their texture and firmness (Sobukola and Dairo, 2007). Fresh vegetables are of great importance in the diet because of the presence of vitamins and mineral elements. They are very important protective food and useful for the maintenance of health and the prevention and treatment of various disease (D' Mellow, 2003).

Vegetable plants contain both essential and toxic chemical elements over a wide range of concentrations (Radwan and Salama, 2006). Some elements are essential and their deficiency results in impairment of biological functions. Some are metals that are known to have essential function but may give rise to toxic manifestations when intakes are in excess (Friberg and Norberg, 1986).Unlike organic chemicals, metals elements are not biodegradable and therefore have potential for bioaccumulation (Gbaruko and Friday, 2007).Although chemicals elements can be eliminated from tissue by metabolic degradation, when present in excess, they may also become toxic.

In Kabwe district in central province of Zambia, rape (*Brassica napus* L) or leafy 'rape' is one of the most commonly consumed vegetables. The rape grown in small scale farms located at the periphery of the town and is sold to the public at various markets located near or within residential areas. However the chemical composition of the rape sold is often unknown to both the farmers and the consumers.

Dietitians and consumers may be encouraged to evaluate rape not only for its nutritional value, palatability and freshness but also for possible effects of the elements on human health. This is so because most chemical elements are toxic if consumed at sufficiently high levels for long periods of time. The difference between toxic intakes and optimal intakes to meet physiological needs for nutritional elements is great for some elements but is much smaller for others.

Epidemiologic data on the relationship between many of the nutritional chemical elements and the incidence of diseases such as cancer, cardiovascular disease, and hypertension are incomplete. Furthermore, most of the evidence is not related to dietary exposure. Most such studies have focused on heavy metals toxic effects on health (Apostoli, 2002).In this way information on foodborne diseases may be linked with food monitoring data, and lead to appropriate risk-based food control policies. This information includes annual incidence trends, identification of susceptible population groups, identification of hazardous foods, identification and tracking of causes of foodborne diseases, and the development of early warning systems for outbreaks and food contamination (FAO/WHO, 2003). The relevance of such approaches for health has been discussed by many scholars (Apostoli, 1999; 2002).

The government of Zambia being aware of the risks that poor quality vegetables may pose on human health, put in place measures to minimizing contamination in food substances (Odhiambo et al, 2004).These include putting in place laws, regulations and regulatory institutions such as Food and Drugs Act (Zambian Food and Drugs Act No. 13 of 1994) and Food and Drug Control Laboratory that has set maximum residual levels (MRLs) of contaminants in fruits and vegetables. Zambia Environmental Management Authority ZEMA in collaboration with the Food and Drug Control Laboratory, ZABS, and Local government authorities is supposed to regulate and monitor quality of vegetables grown on farms in Zambia before they are sold to consumers.

The chemical element levels in rape varieties grown in Kabwe had not been studied extensively. In Lusaka, Zambia, few similar related studies that have been conducted to determine the presence of residues in rape, lettuce tomato and cabbage (Inambo et al, 1997) in (Musukwa ,2016).Other studies were to determine the levels of heavy metals such as lead in vegetables.

Such gaps in knowledge suggested directions for research using a case study approach.Therefore this research on plant tissue analysis was undertaken to to determine composition and concentration levels of chemical elements present in rape grown in selected small scale farms in Kabwe district. The information generated can be used to help make diagnosis of the condition of the rape.This in turn helps to provide technical support for health risk evaluation as a strategy for prevention and reduction of food borne disasters.

1.2 Problem statement

There is inadequate information regarding the composition and concentration levels of chemical elements in rape grown in some small scale farms in Kabwe district of Zambia. This is due to irregular monitoring of the state of vegetable health.The monitoring of chemical element concentrations in vegetables against standards prescribed by WHO/FAO (2002) by both farmers and regulatory authorities is irregular. This could be due to reasons such as lack of clearly defined policies and programs on how and when the monitoring ought to be conducted as well as logistics constraints. As a result rape with chemical elements of unknown concentration levels are constantly supplied to markets. According to Itanna (2002),'' when people take up nutritional chemical elements below recommended daily allowance their health decrease, and when the uptake is also too high health problems may occur.''

1.3 General objective

The objective of the study was to investigate the type of chemical elements present in rape grown in Chowa Mpanga, Kabwe.

1.3.1 Specific objectives

Specific objectives of the study were to;

i. Investigate the composition of chemical elements in the rape samples.
ii. Investigate the concentration levels of chemical elements in rape samples.

1.3.2 Research questions

The research answered following questions.

i. What type of chemical elements were present in the rape samples?
ii. What were the concentration levels of chemical elements in rape samples?

1.4 Conceptual and Theoretical Framework

1.4.1 Conceptual Framework

The regular consumption of poor quality vegetables is linked to human health problems. These health problems can be in the form of communicable or non-communicable diseases.In this case study, the people who are most likely to be at risk of diseases caused by various chemical elements usually found in vegetables are those who buy their rape on a regular basis from local small scale farms in Chowampanga area in Kabwe district and also from the markets for example Kachulu Market in Kabwe.

Therefore if the inspectorate system of the Zambia Bureau of Standards and local municipal council is strengthened to be able to conduct monitoring of vegetables quality at the source and point of sale, the foodborne human health risks will be monitored and reduced as shown in the conceptual framework (Fig 1) below.

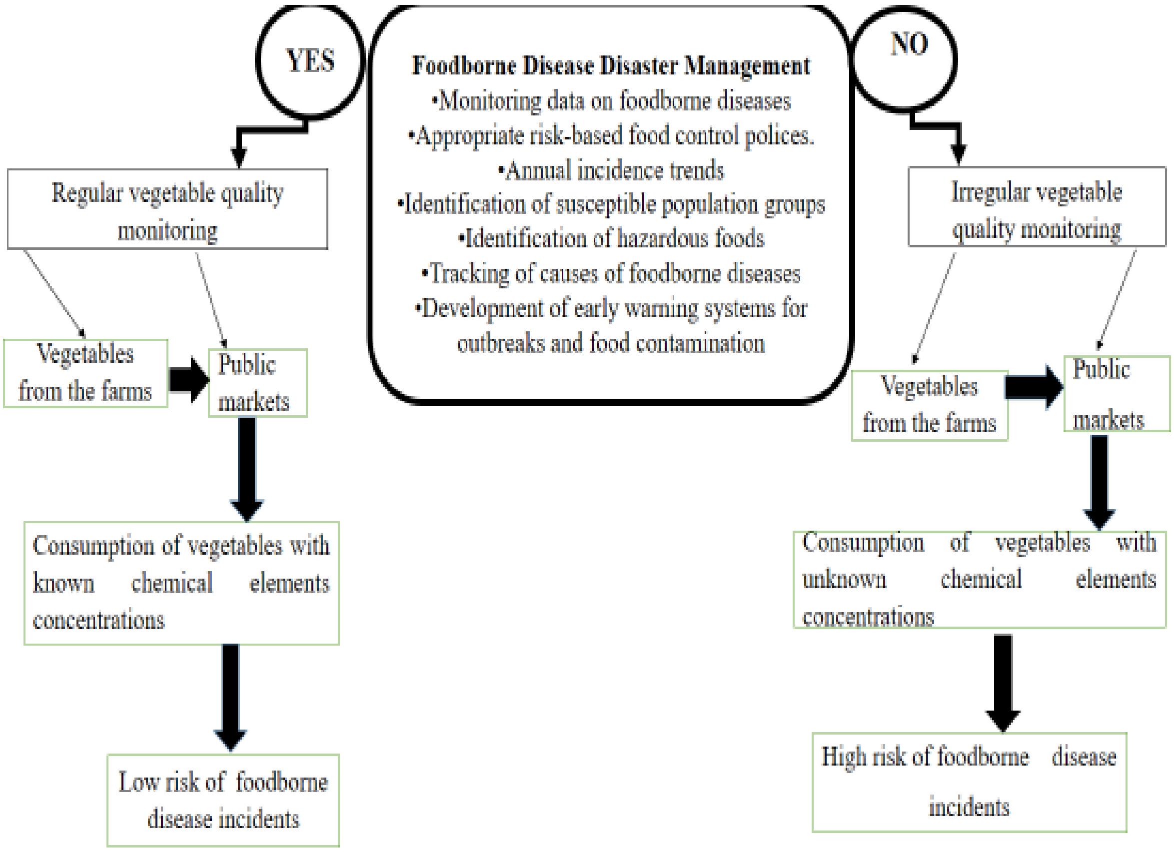


Fig 1. Conceptual framework (Chakabveyo, 2018)

The conceptual framework describes the importance of regular monitoring of quality of vegetable crops grown in small scale farms as a tool for successful prevention and mitigation of foodborne disease disasters.

1.4.2 Theoretical Framework

The dietary focus on chemical elements derives from an interest in supporting biochemical reactions of metabolism with required elemental components because appropriate intake of certain chemical elements have been demonstrated to be required to maintain optimal health. Globally, the incidence of disasters from foodborne diseases is increasing and it has never been more important for developing countries to implement and enforce a food control system based on the modern concept of risk assessment (FAO, 2003).

Since the launch of the Sendai Framework 2015-2030 numerous global targets were set forth towards an integrated and anticipative disaster risk management. Some of the targets strongly emphasizes the consideration of small-scale and slow-evolution extensive disasters which, by being recurrent, lock communities in a vicious circle of impoverishment (FAO, 2017). Therefore the Sendai Framework is of great relevance when it comes to innovations in agriculture, food safety and nutrition (FSN).

The scope of the Sendai Framework got considerably extended to focus on threats of both natural and human origin, as well as on related environmental, technological and biological risks and threats. This innovation was important for the agriculture and FSN sector, because it includes the risks regarding the food chain under the same framework. For instance, vegetable pests or animal disease that could get to have a devastating effect on agriculture. Likewise, this element includes technological risks, which are a central element in the sector, particularly in terms of contamination of foods (food safety), and the degradation of natural resources due to inappropriate use of agrochemicals. (Ibid)

Chemicals used in the growing vegetables have raised concerns about environmental risks associated with the exposure of the elements through various routes such as residues in food and drinking water. Although such hazards range from short-term (e.g., skin and eye irritation, headaches, dizziness, and nausea) to chronic impacts for example cancer, asthma, and diabetes, their risks are difficult to elucidate due to the involvement of various factors such as period and level of exposure, type of chemicals (regarding toxicity and persistence), and the environmental characteristics of the affected areas. There are no groups in the human population that are completely unexposed to chemical contaminants in vegetables while most diseases are multi-causal to add considerable complexity to public health assessments (Ki-Hyun *et al,* 2016).

In addition to that, farmers in low income countries, although using much smaller quantities of chemicals such as inorganic fertilizers and pesticides than farmers in high income countries, are much more vulnerable to the risks arising from their use (WHO, 1990, Panuwet *et al*, 2008, Wesseling *et al*, 2001). The progress made by countries in minimizing the risks arising from chemical use is difficult to monitor, even for developed countries, as chemical products are toxicologically diverse, for example, in his compendium of pesticides (Tomlin,2009) listed 908 active ingredients. In addition, the level of risk also depends on the circumstances under which non-target organisms are exposed to chemicals.

An important element of a national food quality control system is its integration in a national food safety system so that essential effective linkages are established between food control agencies and the public health system including epidemiologists and microbiologists. In this way information on foodborne diseases may be linked with food monitoring data, and lead to appropriate risk-based food control policies. This information includes annual incidence trends, identification of susceptible population groups, identification of hazardous foods, identification and tracking of causes of foodborne diseases, and the development of early warning systems for outbreaks and food contamination (FAO/WHO, 2003).

It is therefore important to put emphasis on monitoring of vegetables quality through regular inspection and monitoring. The responsibilities of inspection services include, sampling food during harvest, processing, storage, transport or sale to establish compliance, to contribute data for risk assessments and to identify offenders. In addition to that, identifying food which is unfit for human consumption, or food which is otherwise deceptively sold to the consumer and taking the necessary remedial action (FAO/WHO, 2003).

In one study it was shown that many vegetable farmers in Zambia applied chemicals that are considered hazardous, indiscriminately used organophosphate and used over-dosage of organophosphate (Nyirenda *et al*, 2011).Vegetables especially rape, contaminated with toxic chemical elements may be being supplied to various markets in the country. It has been observed that there is limited documentation on monitoring and analysis of levels of chemical elements in vegetables sold in various markets in Kabwe.

1.5 Significance of the study

Rape is a major component of the diet of many Kabwe residents and any suspected health concerns arising in association with its consumption is an issue of great concern to both the consumers and medical fraternity.

Timely plant tissue testing is an important tool used to achieve a high degree of precision to diagnose suspected problems as well as to indicate the implications of less or excess elemental nutrients in rape on human health. Results from vegetable tissue testing can simply assist in learning more about soil, fertiliser and pesticide management efficiency as well as the environment.

The findings from the research will serve to protect the public against health hazards and frauds in the sale and use of foods as well as help increase customer confidence in the quality of vegetables produced locally. In addition to that, the results will also help farmers improve their farming methods.The policy makers can utilize some of the findings to improve on existing strategies in vegetables growing in Zambia.

1.6 Scope of the study

The study was investigating the composition and concentration levels of chemical elements present in rape leaf samples from selected small scale farms in Chowampanga area in Kabwe district only. These farms were selected on purpose because they regularly supplied vegetables to large markets such as Kachulu, Railways and Kamushanga within Kabwe. The study also focused on analysing rape leaves only because that is the part mostly used as a relish.

1.7 Limitations of the study

Due to logistics constraints, it was not be possible to collect samples from all small scale farms in Chowa Mpanga area in Kabwe because most farms were located between 1to 2 km apart. Also, considering the nature of the research, fewer samples were collected for laboratory analysis because of the high costs involved in scanning electron microscopy. Soil sampling in order to help establish links with the results of the state of the plant was not done.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter provides literature on the role of small scale vegetable farming in promoting food security. It also looks at various chemical elements in vegetable crops and their effects on human health as well as the role of government monitoring agencies in promoting food quality and safety. In addition to that, the importance of monitoring food safety as part of disaster management is emphasised.Lastly this chapter discussed other researches from around the globe, whose purpose was to investigate different characteristics of vegetable crops quality using modern techniques.

2.2 The role of small scale vegetable farming in promoting food security

Today, almost 50 percent of the world population lives in urban areas. The urbanization trend is expected to continue and even to accelerate, especially in Africa and Asia. This phenomenon has given birth to an increased demand for fresh fruits and vegetables which needs to be met by new production areas combined with more intensified crop management in order to raise the productivity per unit of land and water. It has been forecast that the uncontrolled growth of cities will lead to poverty and malnutrition for more than 600 million people by 2025.This has prompted the intensification of urban and peri-urban horticulture production systems to secure year-round supply of fresh horticultural produce to urban population (Veenhuizen and Danso, 2007).

Increasing the global food supply requires the intensification of agriculture, as there is little scope for expanding the current land area used globally (The World Bank, 2008). Intensifying agriculture involves the use of improved crop varieties and the more intensive or more efficient use of water and plant nutrients. Small-scale agriculture is the main source of food in the developing world, producing up to 80 percent of the food consumed in many developing countries, notably in sub-Saharan Africa and Asia. With poor rural households making up two-thirds of the global population earning less than $1.25 per day, smallholder agriculture is also an important source of income underpinning the livelihoods of vast numbers of poor people (Arias *et al*, 2013).

It is important to note that vegetable production contributes greatly to sustainable livelihoods in the sense that vegetable production needs only a small area of land, with minimal capital outlay and can provide access to a valuable food under subsistence conditions (Hilmi and

Nicholas, 2009).Usually smallholders intensively cultivate vegetables in gardens, and promoting vegetables in gardens can help smallholders in a number of ways such as providing a regular supply of vegetables at a low cost, providing a more varied diet for the farm family, providing income from the sale of vegetables, providing gender employment and gender participation in economic activities as well as providing employment for the disabled and the elderly. (Ibid)

However ensuring food security poses two challenges to smallholder farmers and society, especially against a background of climate change. The first is to grow and distribute enough healthy and affordable food. The second is to protect the fundamental natural resources on which productivity relies, namely soil, water, biodiversity and the atmosphere. Meeting both challenges requires sustainable intensification of crop production, a fact which many people and organizations now recognize and accept (FAO, 2013). This means that technical innovations are needed over how growers can work more productively with natural resources and optimize agricultural inputs like seeds, fertilizers, pesticides, fuel and machinery (Dyson, 2013).

Kabwe is a town in the Central Province of Zambia and agriculture in Kabwe is one of the key priority sectors that contribute to economic growth and poverty reduction, and small-scale farmers from areas such as Chowa, Katondo and Mukonchi play a vital role in promoting food security through growing of vegetables, yet they have to cope with numerous challenges ranging from farming inputs to market access.

2.3 Chemical elements in vegetables and their effects on human health

In most leafy vegetables there are chemical elements which are highly likely to be present. Examples include Nitrogen, Chlorine, Phosphorus, Sulphur, Aluminium, Calcium, Potassium and Magnesium. In this section the focus is on each element’s function in the human body as well as deficiency or toxic effects on human health.

Nitrogen (N):Nowadays, some vegetables may contain higher nitrate levels than before because of fertilisers that contain necessary elements for plant growth are used .The could be due to misuse of production technology ,usage of prohibited fertilizers, pesticides and chemicals as well as an increased level of fertiliser concentrations in the soil can all result in serious damage to health. Continous intake of foods with a high nitrate content may lead to an elevated risk of serious diseases, which is also a representative food safety problem. The effect is brought about as the body converts nitrates from the food eaten into nitrites. And these nitrites combine with compounds called amines, producing cancer-causing nitrosamines. Most studies linking nitrates to cancer are from animal studies (European Journal of Cancer Prevention 2011).

Phosphorus (P)**:** Phosphorus is most commonly found in nature as phosphate (PO). Most vegetables sources exhibit good phosphorus bioavailability. Inadequate phosphorus intake is expressed as hypophosphatemia. At a whole organism level, the effects of hypophosphatemia include anorexia, anaemia, muscle weakness, bone pain, rickets and osteomalacia, general debility, increased susceptibility to infection, paraesthesia's, ataxia, confusion, and even death (Lotz *et al.,* 1968). These severe manifestations are usually confined to situations in which ECF P falls below ~0.3 mmol/litre (0.9 mg/dl).Regular consumption of rape rich in phosphorus may assist in preventing the adverse effect of phosphorus deficiency which results in retarded growth and delayed sexual maturation because of its role in nucleic acid metabolism and protein synthesis (Barinas *et al.*, 1998).

Potassium (K): Potassium is a mineral (electrolyte) which is found in vegetables. In the human body almost 98% of potassium is found inside the cells. Small changes in the level of potassium that is present outside the cells can have severe effects on the heart, nerves, and muscles. Hyperkalaemia is a condition where there is too much potassium in the blood. The body needs a delicate balance of potassium to help the heart and other muscles work properly. But too much potassium in the blood can lead to dangerous, and possibly deadly, changes in heart rhythm as well as tiredness or weakness, a feeling of numbness or tingling, nausea or vomiting, trouble breathing, chest pain, palpitations or irregular heartbeats.

Chlorine (Cl): Foods very high in chlorine are the cabbage family of vegetables – cabbage, cauliflower, broccoli and Brussels sprouts. Most leafy greens such as rape also contain a bioavailable form of chlorine. Wilson (2014) indicated that,'' Chlorine is a light element and a very important one for fluid balance, production of hydrochloric acid (HCl) in the stomach, and the operation of the pituitary gland, as well. Deficiency symptoms are rare, as chlorine compounds are widely distributed in foods. However, chlorine in most forms is extremely toxic for the body. It can cause heart disease, cancer, and hypothyroidism. Other acute symptoms are heart palpitations, and nausea and vomiting.''

Sulphur(S)**:** Mostly the excellent source of sulphur include cruciferous and Allium vegetables. The rich vegetarian sources of sulphur exclude leaf vegetable such as rape hence the low levels observed in the rape samples studied. There is no recommended dietary allowance for sulphur. One of the side effect of excess sulphur is ulcerative colitis (Fredenburg, 2017).

Magnesium (Mg): Magnesium is widely distributed in green leafy vegetables, such as spinach, legumes, nuts, seeds, and whole grains, are good sources. Early signs of magnesium deficiency include loss of appetite, nausea, vomiting, fatigue, and weakness. As magnesium deficiency worsens, numbness, tingling, muscle contractions and cramps, seizures, personality changes, abnormal heart rhythms, and coronary spasms can occur. Severe magnesium deficiency can result in hypocalcaemia or hypokalaemia (low serum calcium or potassium levels, respectively) because mineral homeostasis is disrupted (Elin, 2010).Too much magnesium from food does not pose a health risk in healthy individuals because the kidneys eliminate excess amounts in the urine (Ross *et al*, 2012).

Aluminium (Al): Most of the intake of aluminium from food comes from the natural content of aluminium in fruit and vegetables. This is because plants absorb aluminium from the soil. Unlike vitamins, minerals, and trace elements, the body does not need aluminium. However aluminium is no innocent or benign participant. Aluminium accumulates in the kidneys, brain, lungs, liver and thyroid where it competes with calcium for absorption and can affect skeletal mineralization. High levels of aluminium in the body have been shown to have neurotoxic effects, effects on bone and possibly reproduction (Norsk, 2016). Some studies show that people exposed to high levels of aluminium may develop Alzheimer's disease, but other studies have not found this to be true.

Calcium (Ca): Mild hyperkalaemia may not produce any symptoms. However, symptoms of nausea, poor appetite, vomiting and constipation may be present with mild increases in blood calcium levels. Moderate high levels of hyperkalaemia may produce fatigue or excessive tiredness. Weil (2017).This can also cause muscle pain, mood disorders, abdominal pain and kidney stones. It may also increase risk for heart attack and stroke. Getting too much calcium can cause constipation. It might also interfere with the body's ability to absorb iron and zinc, but this effect is not well established Houillier (2005).

Silicon (Si): Silica is found in some vegetables and grains and is generally considered as a macro mineral. It is considered as one of the most crucial minerals in a human diet that is required for various proper structural physiology. Silica can have side effects and that is, it can lower blood sugar levels which can particularly be ddangerous, especially if one has diabetes Pramod (2017). A systematic literature search was conducted to review the studies about Si consumption and bone metabolism. Results showed a positive relationship between dietary Si intake and bone regeneration (Jugdaohsingh *et al.* 2007; Bu *et al.* 2016; Bone. 2004).There is no official recommended daily amount of silicon, but it is assumed that an adequate daily intake is 5 to 10 milligrams. In average diet is intake only 1-1.5 grams a day (Rodella *et al* 2014).

Tellurium (Te): Tellurium is a grayish-white solid with a shiny surface. It is chemically related to selenium and sulphur. Fortunately, tellurium compounds are encountered rarely by most people. So far tellurium in human tissues has no clinical deficiency syndrome. Scientist believe that some minerals found in our bodies and are there for a reason, we just don't know why at this time. The estimated daily intake of tellurium is about 100 ug and 0.1 to 0.5 mg/kg of body weight. However, the science community has not yet found a health benefit of tellurium (Shie, 1999).

Rubidium (Rh): Rubidium is present in the earth's crust, in seawater, and in the human body. Chemically, it is like potassium, and in some animals it can replace potassium in certain functions, though this does not seem to be the case in humans. Food sources of rubidium have not been researched very well as yet. Some fruits and vegetables have been found to contain about 35 ppm. Our body contains about 350 mg of rubidium which has not yet been shown to be essential. There is no known deficiency or toxicity for rubidium. There is no RDA for rubidium. The average dietary intake may be about 1.5 mg. daily (Staying Healthy with Nutrition, 2017).

2.4 The role of government monitoring agencies in promotion of food safety

The principal objectives of national food control systems are protecting public health by reducing the risk of foodborne illness, protecting consumers from unsanitary, unwholesome, mislabelled or adulterated food, and contributing to economic development by maintaining consumer confidence in the food system and providing a sound regulatory foundation for domestic and international trade in food (FAO/WHO, 2003).

Food control systems usually cover all food grown, processed and marketed within the country, including imported food. Such systems should have a statutory basis and be mandatory in nature. (Ibid).Many countries, especially developed countries, have set up regulatory procedures to control the production and use of chemicals.

In Zambia, the regulations, made under the Food and Drugs Act13 *of* 1994 (Annex 1) aim to protect the public against health hazards and fraud in the sale and use of food, drugs, cosmetics and medical devices.The Zambia Bureau of Standards (ZABS) is a regulatory body and certifying agent whose role includes inspecting all agricultural products sold. This body may require products from small scale farms and handling operations to undergo pre harvest or postharvest residue testing at their discretion. It has modern testing laboratories for testing and analysis of products to national and international standards as well as client specifications.

However, the Zambia Bureau of Standards is not in charge of enforcing all standards. Different sector specific regulators such as Zambia Environmental Management Agency (ZEMA) for chemicals and local government councils as authorities overseeing public health matters.

The Food and Drugs Control Laboratory (FDCL) at University Teaching Hospital (UTH) Zambia is a unit within the Ministry of Health in the directorate of Disease Surveillance Control and Research. The laboratory provides analytical services to the government, private sector, general public, donors and other partners. It operates in support of the ZABS to ensure public health concerns are addressed.

2.5 Monitoring food quality as a comprehensive approach to public health disaster management

Quality management aims to provide continuous improvements in the production process, to better serve the customer. There are two quality settings, according to Alan (2016),''Quality are those characteristics of the product to meet customer needs, promoting satisfaction with the product, another quality setting is related to the absence of defects. According to these concepts it is understood that the requirements demanded by customers determine the extent of liability of a product or service.''

In relation to food safety issues, in most countries there are public health agencies established. One of the major roles of public health agencies is to ensure safe products for consumers through analysis of residual agricultural chemicals and veterinary drugs in foods. The regular monitoring of chemicals in food is of great importance in the evaluation of food quality (Hamers et al, 2003).

While the components and priorities of a food quality control system will vary from country to country, most systems will typically comprise of relevant and enforceable food laws and regulations and this will impact on the effectiveness of all food quality control activities carried out in the country (FAO/WHO, 2003).

In Zambia, food and drugs laws have traditionally consisted of legal definitions of unsafe food, and the prescription of enforcement tools for removing unsafe food from commerce and punishing responsible parties after the fact. It has generally not provided food control agencies with a clear mandate and authority to prevent food safety problems. Even encouraging voluntary compliance in particular by means of quality assurance procedures has not been practiced much. The result has been food safety programmes that are reactive and enforcement-oriented rather than preventive and holistic in their approach to reducing the risk of foodborne illness.

In order to reduce the risks, effective food control systems as a disaster prevention tool are characterised by policy and operational coordination at the national level, with clearly defined core responsibilities which include the establishment of regulatory measures, monitoring system performance, facilitating continuous improvement, and providing overall policy guidance.

An increasingly important role for food quality control systems is the delivery of information, education and advice to stakeholders across the farm-to-table continuum. These activities include the provision of balanced factual information to consumers; the provision of information packages and educational programmes for key officials and workers in the food industry; development of train the-trainer programmes; and provision of reference literature to extension workers in the agriculture and health sectors (FAO/WHO, 2003).

But this cannot be achieved unless smallholder livelihoods in areas such as Kabwe district are strengthened by having access to integrated crop management protocols and professional education training on the safe and sustainable use of pesticide use.

2.6 Investigating different characteristics of vegetable crop quality

On quality monitoring of fresh fruits and vegetables Lakshmi *et al* (2013)indicated that, ‘‘Quality determines the shelf life as well as selling price of fresh fruit or vegetable and therefore, quality monitoring and testing of fresh commodities have paramount importance in their postharvest handling and supply chain management.’’ Most of the methods used to assess fruits and vegetables quality are destructive in nature. Nowadays, various mechanical, optical, electromagnetic, and dynamic non-destructive methods are gaining importance due to ease in operations, faster turn over and reliability. Some of the non-destructive techniques (ndt) are currently being used in laboratories, research institutions and food packaging and processing industries, whereas, some methods are still at developmental stage. Various non-destructive techniques with respect to their principle and applications such as impact test, electronic nose, time-resolved reflectance spectrometry, near infrared spectroscopy, nuclear magnetic resonance, x-ray, ultra sonic, acoustic impulse response method, electrical conductivity methods etc.

Methods of microscopically analysing plant cells or tissue are therefore mostly discussed in this review. This is so because sophisticated modern research tools for the evaluation of the plant tissues which are available, microscopy method is still one of the simplest and sometimes cheapest methods to use for establishing the correct identity of various materials.

Examples of such studies include research work in ‘monitoring nutrient distributions in higher plant tissues as an important task for plant physiology. A selection of potent methods are available by analysis of single-cell samples, giving information on nutrient ion content of cell vacuoles (Rygol *et al*, 1993; Fricke *et al*, 1996; Tomos and Leigh, 1999). Fluorescent-dye ratio imaging can monitor free ions at the cell and tissue levels, giving symplastic or apoplastic concentrations (Mühling and Läuchli, 2000; Halperin and Lynch, 2003). However, as for measurements with ion-selective microelectrodes, only a limited range of ions can be imaged, most commonly Ca or K ions in solution, but the total element contents, including bound species, are not detected. At the tissue level, distributions of nutrients can be best revealed by micro beam analysis techniques, but they have been severely limited because satisfactory sample preparation methods have not yet been developed or detection sensitivities are not adequate (Leigh, 2001).

In another related study by (Metzner, R *et al*, 2000) which involved imaging nutrient distributions in plant tissue using time-of-flight secondary ion mass spectrometry and scanning electron microscopy .This was a new approach to trace the transport routes of macronutrients in plants at the level of cells and tissues and to measure their elemental distributions. It was developed for investigating the dynamics and structure-function relationships of transport processes. Stem samples from *Phaseolus vulgaris* were used as a test system.

Other related research work was by Kumar *et al* (2000). The objective was to study detailed microscopic evaluation and physiochemical analysis of Dillenia indica (*D. indica*) leaf. Fresh leaf sample and dried power of the leaf were studied and the results were useful in quality, purity and sample identification.

In another study the objective was to investigate the content of essential elements in medicinal plants in the Kingdom of Saudi Arabia (KSA). Five different medical plants mahareeb

(*Cymbopogon schoenanthus*), sheeh (*Artemisia vulgaris*), harjal (*Cynanchum argel delile*), nabipoot *(Equisetum arvense*), and cafmariam (*Vitex agnus-castus*) were collected from Madina city in the KSA. Five elements Fe, Mn, Zn, Cu, and Se were determined by using inductively coupled plasma mass spectrometry (ICP-MS). The calculated intakes of essential elements for all plants did not exceed the daily intake set by the World Health Organization (WHO) and European Food Safety Authority (EFSA).It was concluded that these medicinal plants may be useful sources of essential elements, which are vital for health (Brima, 2018).

In the study by Koubová E *et.al* (2018), where the contents of thirty-six mineral and trace elements in teff (Eragrostis *tef L.*) grains were analysed. Dietary intakes were also calculated. Inductively coupled plasma mass spectrometry (ICP-MS) was used to assess mineral and trace element contents. Consequently, the appropriate Recommended Dietary Allowance (RDA) or adequate intake (AI), and provisional tolerable weekly intake (PTWI) or provisional tolerable monthly intake (PTMI) values for adults were determined according to the Food and Agriculture Organization/World Health Organization (FAO/WHO) and Institute of Medicine (IOM) regulations. The conclusion was that Teff was a significant contributor to RDAs and AIs and Teff grains can be recommended as a valuable and safe source of minerals and trace elements.

Other studies of plant tissue analysis include pharmacognostic studies of the leaves and stem of *Careya arborea Roxb* (Biomed Journal, 2012) development of quality control parameters for the standardization of *Limonia acidissima L.* leaf and stem. (Asian Pac J Trop Med, 2014); pharmacognostic evaluation of the leaf of succedanea (Himalaica. J. D, 2014); Leaf mesophyll conductance and leaf hydraulic conductance: an introduction to their measurement (Bot, 2013); Pharmacognostical evaluation of *Cardiospermum halicacabum L.* leaf and stem (Ancient Science of Life, 2013).

Another unpublished study was conducted in Lusaka, Zambia. (Musukwa, 2016)The selected areas for sampling were Chisamba, Ngwerere, Mwembeshi, Kenneth Kaunda Airport area, Kasisi, Chilanga and Mimosa based on widespread cultivation and readily availability of the vegetables under investigation. The presence of chemical residues in the vegetables were analysed using high performance liquid chromatography. The study found that out of the 38 vegetables (15 cabbages, 9 rape and 14 lettuce) the vegetable rape had the highest mean chemical residue levels while lettuce had the lowest. Generally this study agreed with studies conducted in the sub region and internationally which found that in general that the organophosphate residues in vegetables and fruits were higher than the Maximum Residual Levels (Elliion et al, 2000 and Taneja, 2005).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

This chapter outlines the materials and methods which were used in collecting data. It describes the research designs which was employed, the target population, sample size and sampling methods. It also describes data collection procedures, collection techniques and analysis.

3.2 Study area location and Description

The study was conducted in Chowa Mpanga area in Kabwe District of the Republic of Zambia. Kabwe district is located in Zambia at coordinates: 14°26′S 28°27′E at an elevation of 1,182 m as shown in Fig 2. below.

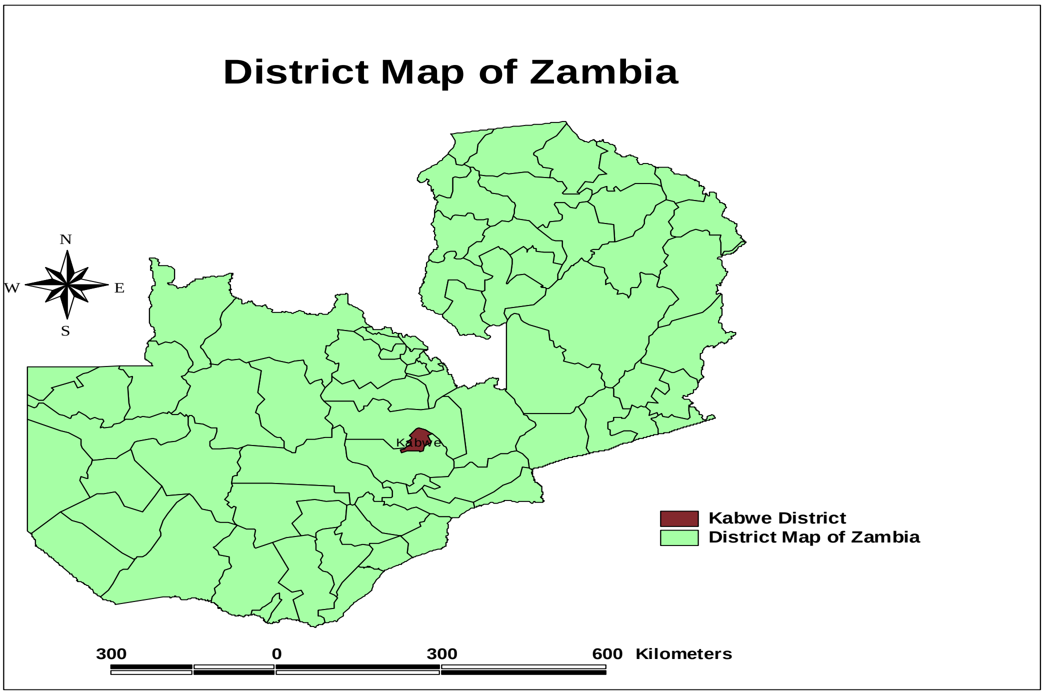


Fig 2. District map of Zambia showing the location of Kabwe.

According to Central Statistics Office (2012), Kabwe has a population estimated at 202,914 (2010 census). There are commercial farming areas as well as small scale farming units surrounding the city from a radius of about 1 to 25 km from the town center. The road and rail links provide ready access to the markets of the locals as well as Copperbelt and Lusaka

Purposive sampling was done .The selected sites for sample were collection small scale farms in Chowampanga located within a 1-20 km radius from Kabwe's Central Business District. These farms regularly supply their vegetables to Kachulu, Railways and Kamushanga markets.

3.3 Research design

The study was about investigating the composition and concentration levels of chemical elements present in rape leaf samples from five selected small scale farms in Chowampanga area in Kabwe district. These farms were selected on purpose because they regularly supplied vegetables to large markets such as Kachulu, Railways and Kamushanga within Kabwe. The study was done in order to compare the composition and concentration levels of chemical elements on the rape leaf surfaces as a means of periodic monitoring of the quality of vegetable crops grown in small scale farms in Kabwe as a tool for successful prevention of foodborne disease disasters.

Primary data was collected by conducting a baseline survey through interviews with famers, agro-dealers and medical health personnel. The quantitative data was collected through experimental analysis of rape leaf samples using a scanning electron microscope (SEM) Quanta^{TM} FEG-450 at Copperbelt University Chemical Engineering laboratory. SEM was selected because it was modern and could provide resolution between 1-20 nm and the desktop system could provide a resolution of 20 nm or more. The population size was all the rape grown at five selected farms in one farming season. (Approximately 1000 plants).Sample size was 50; 10 fresh, ready to eat rape leaves were randomly selected from each of the five farms. Secondary data was collected through literature review on negative effects of various chemical elements likely to be found in vegetables on human health. The study was done during the rape farming season (Jan/February-April/May) of 2018 as most rape varieties take between 35 to 106 days to reach full maturation.

3.4 Data collection procedure

Qualitative methods contributed to the development of quantitative instruments, in this case interviewing the farmers using schedules was done as the baseline survey prior to the quantitative method of collection and analysis of the rape leaves. The results from the interviews were meant to help interpret or explain the quantitative findings. The two methodologies were used in parallel to cross-validate and build upon each other's results. The data was collected in the following ways.

i. Vegetable farming practices by small scale farmers in Chowampanga, Kabwe

Interviews were carried out with the farmers in order to establish the type of rape grown, the length of each farming season and the times for fertilizer and pesticide application. In addition to that, data was gathered on the type of pesticides including the quantities that are used, the frequency of application. The researcher physically inspected the fields to see the varieties of rape grown. Further interviews were conducted with agro dealers and medical personnel in order to establish properties and effects of the common chemicals that are used by small scale vegetable farmers. An interview schedule was used. (Appendix 1)

ii. Rape sample collection

Three most commonly consumed rape varieties in Kabwe, Zambia were selected for analysis. The varieties were; Hobson, Nanga and English giant. The rape leaf samples were collected directly from the farms in Chowa Mpanga farms of Kabwe district, Zambia, The farms were coded as Farm AO1,Farm AO2,Farm AO3,Farm AO4 and Farm AO5 .The population was all the rape grown in all the beds at five selected farms in a farming season(approximately1000). A bunch of ten fresh, ready to eat rape leaves were collected from each farm. The total number of rape samples collected was 50.

A simple random sampling method was used to select the plants. This was done by choosing ready to eat plants from any part of the bed. This was so that all plants had an equal chance of being selected. The rape leaves were plucked by breaking them off from the lowest part of the stalk. At least ten leaves were plucked to make a bunch. The plucking of rape from different beds was so as to increase the probability of sampling different cultivation batches. .

During the sample collection, there was no washing prior to placing rape bunches into collection bags was required. The samples were put in separate polypropylene sealable bags, labelled with a unique sample identity and placed in a cooler box. A collection sheet was used, which provided information on the date, place and conditions of the vegetables. (Appendix 2). Rape samples were transported from the field to be examined in the laboratory in the Department of Chemical Engineering, Copperbelt University Kitwe- Zambia. Samples were placed in the refrigerator at 4° C and analysed within 4 days after collection.

iii. Sample preparation

Samples are often contaminated by pesticides, nutrient sprays, soil, or dust. Therefore data obtained from such leaf samples can be misleading. Decontamination of some dust or soil was accomplished by quickly rinsing the leaves in a dilute non-phosphate detergent solution (2%) followed by two distilled water rinses. Tap water was not used because it can be high in certain nutrients such as Ca, Fe, Mg, or S. Leaf samples were washed quickly to minimize the leaching of certain nutrients (especially K) from the leaves. It is important to note that contamination from chemical or nutrient sprays could not be effectively removed from the leaf surface.

Clean gloves were worn prior to handling each leaf sample. From each batch of leaves from a named farm, five (5) leaves were selected at random. In total twenty five (25) leaf specimen samples were prepared. Firstly each leaf was weighed on an analytical balance and then placed on a clean surface. Using a surgical blade and a scalpel, two round disks of leaf tissue each were cut from different parts of the same leaf. This was done so that the specimen samples were taken from different sections of the leaf. The specimen were weighed on an analytical balance. The total weight was 1 g each. Thereafter they were stained and mounted on slides using an adhesive and then put on a stage in the sample chamber of the SEM for scanning.

iv. Determining composition and concentration levels of chemical elements in rape leaf specimen.

The rape specimen samples were analysed using a scanning electron microscope (SEM) Quanta^{TM} FEG-450. The methods of sample preparation and operations instructions were provided by Quanta^{TM} FEG-450 Nano Science Instruments instructions manual (2018).The SEM as shown in Appendix 3 .The microscope has existed for almost 1000 years. Scientists in the 1930s began working with electron microscopes. M. Knoll and Manfred von Ardenne were two of the pioneers in this field. This technology has seen drastic improvement since those early days, and Charles Oatley of Cambridge University's Engineering Department developed the first SEM in 1948, and four years later, it was relatively cheap with greater magnifying power and producing three-dimensional images. Scanning electron microscopy (SEM) uses a finely focused beam of electrons in order to produce a high resolution image of a sample.

Chemical element refers to a substance which is a primary constituency of matter that cannot be chemically interconverted or broken down into simpler substances. Each element is distinguished by its atomic number.

The S E M had a limit of detection of 0.001mg/g. This means that any element concentration level less than 0.001mg/g was undetectable and was very negligible.The results of the analysis were displayed on the computer screen in form of a graph and table .An example of the graph of results is shown in (Appendix 3).

3.5 Analysis of results

Since the sample size was less than 30, no parametric test was done rather descriptive **s**tatistical analysis was performed on all plant samples using excel to establish the measures of central tendency, i.e. sample mean, median, mode, range and sample variance. Differences were determined to be statistically significant with 95% confidence levels.

3.6 Ethical considerations

The study did not directly involve human subjects, clearance was sought from Mulungushi University Research Ethics Committee

CHAPTER FOUR

RESULTS

4.1 Introduction

The results showed the composition of 11 chemical elements(Nitrogen ,Phosphorus ,Potassium ,Sulphur ,Magnesium ,Chlorine ,Calcium ,Aluminium ,Silicon ,Tellurium and Rhodium) in the rape samples investigated . The mean concentration levels of the chemical elements in all rape leaf samples were in the following order from highest to the lowest P>N>K>Ca>Cl>Mg>Te>S>Al>Si>Rh. The results of chemical elements concentration levels amongst rape varieties and amongst the farms were compared and the levels showed to be greatly varied.

4.2 Composition of chemical elements in rape samples from different farms in Chowampanga, Kabwe, Zambia

11 chemical elements were found in rape leaf samples. From Fig 3 and Table 1 it can be seen that these elements fell into three categories of nutritional classes.50% were micronutrients 30% were micronutrients and 20% were non-essential elements.

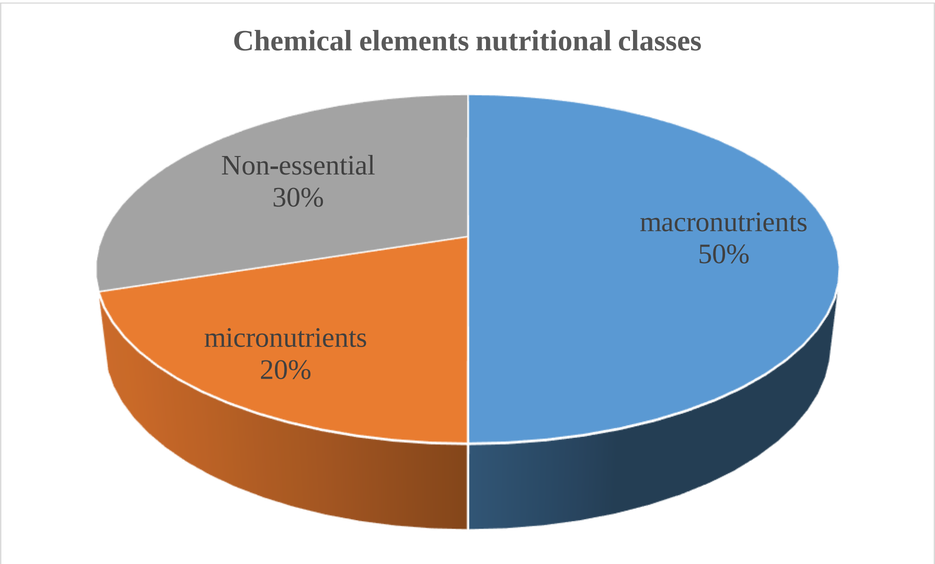


Fig 3. Chemical elements nutritional classes

Table 1. Composition of chemical elements found in rape leaf samples from Chowampanga farms in Kabwe district, Zambia.

Chemical Element	Ionic form absorbed by plant	Nutritional class
Nitrogen(N)	NH_4,NO_3	Macronutrient
Phosphorus(P)	PO_4^{3-},HPO_4^{2-},H_2PO	Macronutrient
Potassium(K)	K^+	Macronutrient
Chlorine(Cl)	Cl^-	micronutrient
Sulphur(S)	SO_4^{2-}	Micronutrient
Magnesium(Mg)	Mg^{2+}	Macronutrient
Aluminium(Al)	Al^{3+}	Non-essential trace element
Calcium (Ca)	Ca^{2+}	Macronutrient
Silicon(Si)	SiO_2	Micronutrient
Tellurium(Te)	Telluride	Non-essential metalloid
Rhodium(Rh)	free metal	Non-essential transition metal

4.2.1 Comparison of concentrations levels of chemical elements in rape leaves amongst farms

The mean concentration levels of the chemical elements in rape leaves from all the selected farms were in the following order from highest to the lowest P(0.884)>N(0.794)> K(0.748)>Ca (0,414) >Cl(0.274) >Al(0.236)>Mg(0.2366) >S(0.1524)> Te (0.1346)>Si(0.085)>Rh(0.031) .The chemical elements such as N ,P ,K ,Mg ,P ,S and Cl are usually expected to be found in rape leaves in moderate quantities however in this study in some rape leaf samples the chemical elements P, N, S, Cl, Ca, Si and Te were observed to be in higher than normal concentration levels as shown in Fig 4

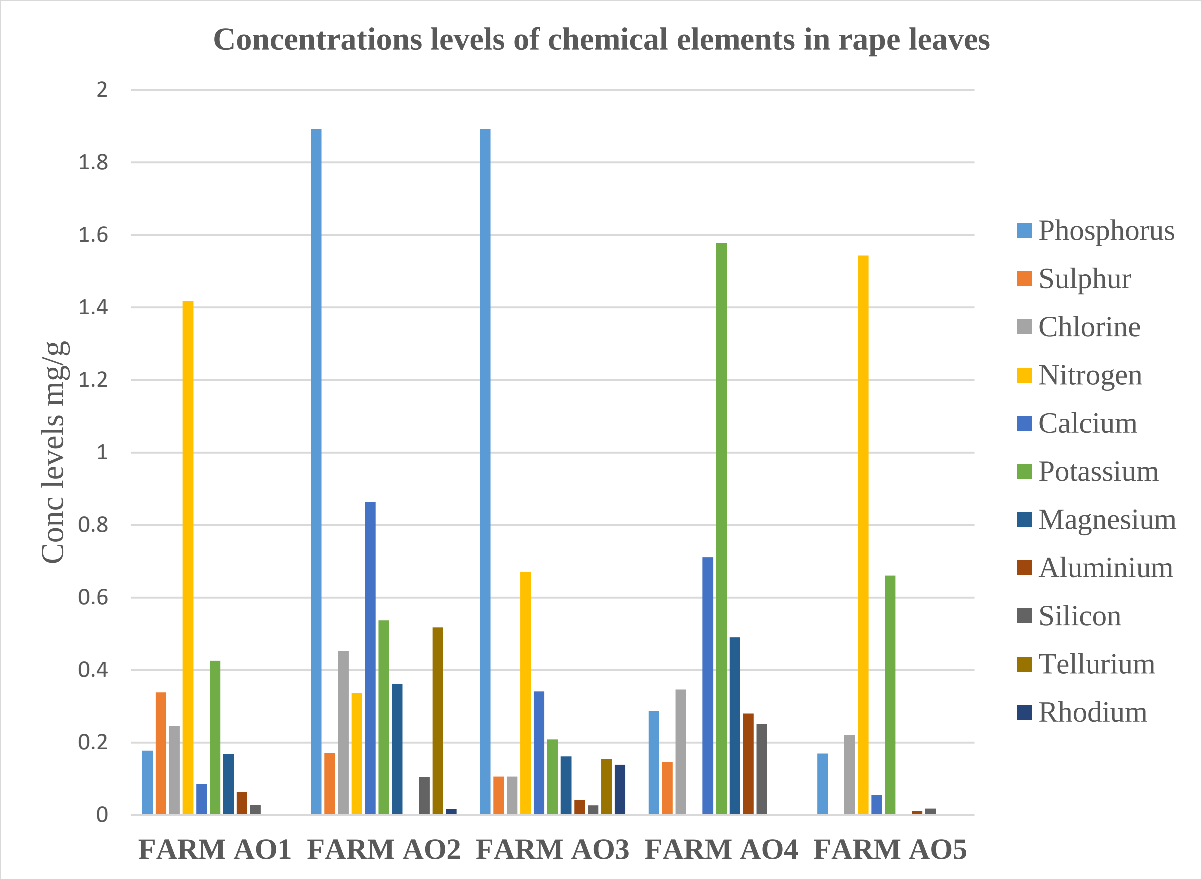


Fig 4. Mean concentrations of chemical elements in rape samples from Chowampanga farms in Kabwe District, Zambia 2018

KEY: AO1- Sampling area FARM AO1 AO2- Sampling area FARM AO2

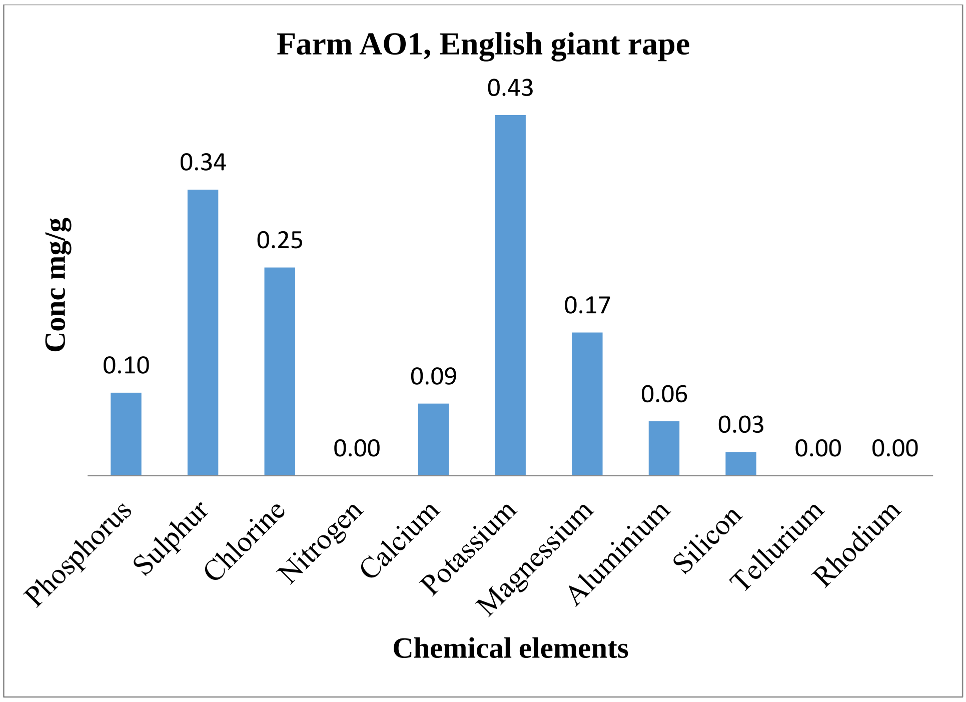
AO3- Sampling area FARM AO3 AO4- Sampling area FARM AO4

AO5- Sampling area FARM AO5

NB*Measured chemical element concentration levels by percentage weight [mg/g] indicates the relative amounts of each chemical element present in a rape leaf sample.

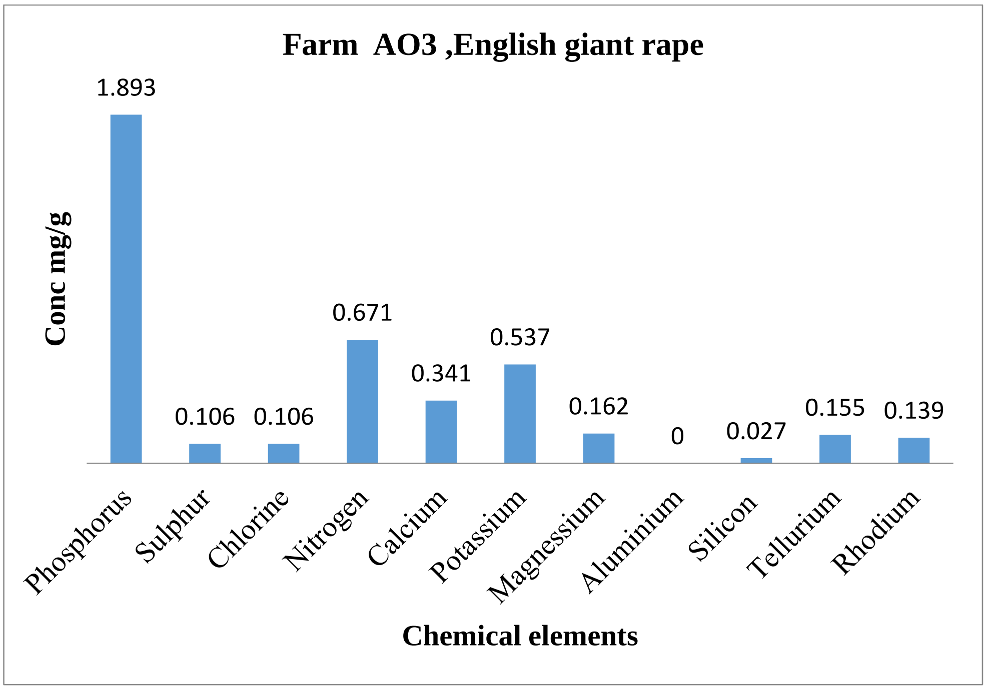
4.2.2 Comparison of concentrations levels (CLs) of chemical elements in different rape varieties

The concentration levels of chemical elements varied amongst the rape varieties. For instance ,it was found that the same type of rape varieties e.g. English giant rape but grown on different farms(AO1 and AO3) had different values as shown in Fig 5 a and b as well as Fig c and d



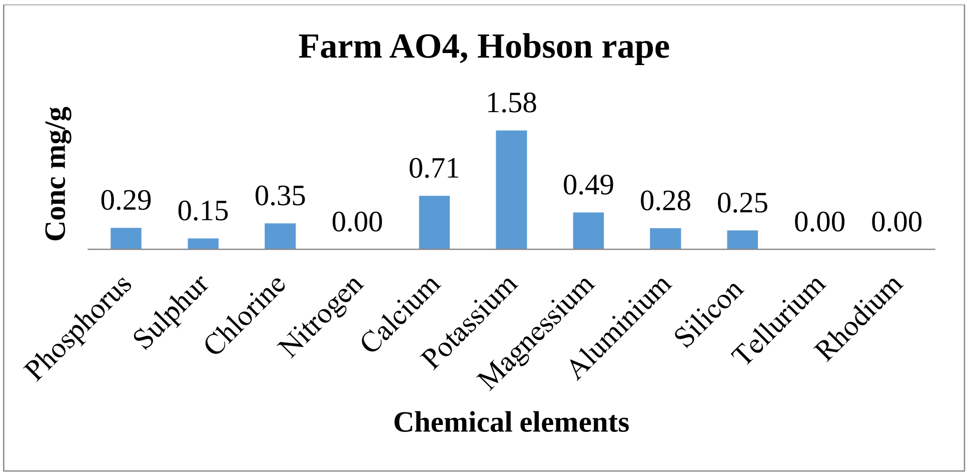
Farm AO1, English giant rape
Conc mg/g
0.10
0.34
0.25
0.00
0.09
0.43
0.17
0.06
0.03
0.00
0.00
Phosphorus
Sulphur
Chlorine
Nitrogen
Calcium
Potassium
Magnessium
Aluminium
Silicon
Tellurium
Rhodium
Chemical elements

(a)

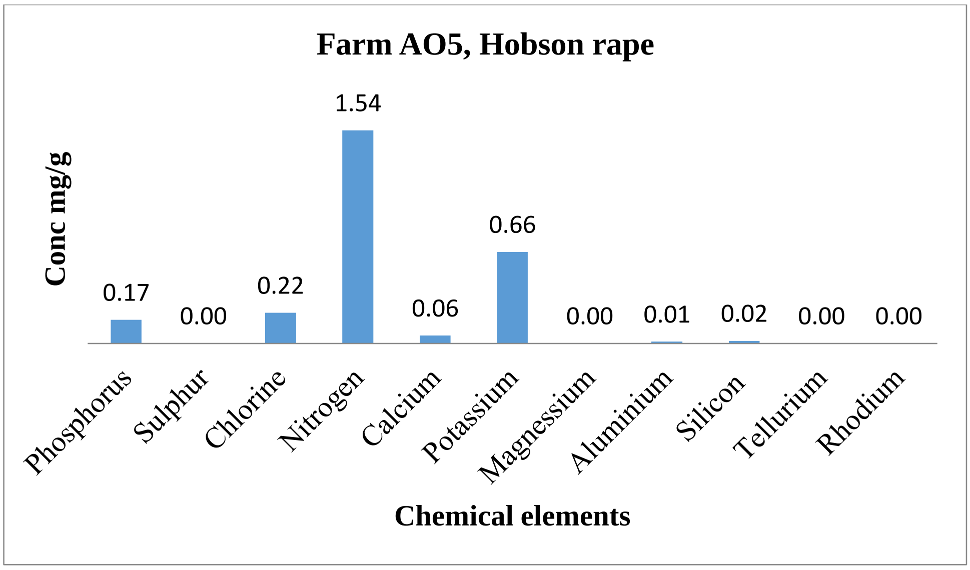


Farm AO3 ,English giant rape
Conc mg/g
1.893
0.106
0.106
0.671
0.341
0.537
0.162
0
0.027
0.155
0.139
Phosphorus
Sulphur
Chlorine
Nitrogen
Calcium
Potassium
Magnessium
Aluminium
Silicon
Tellurium
Rhodium
Chemical elements

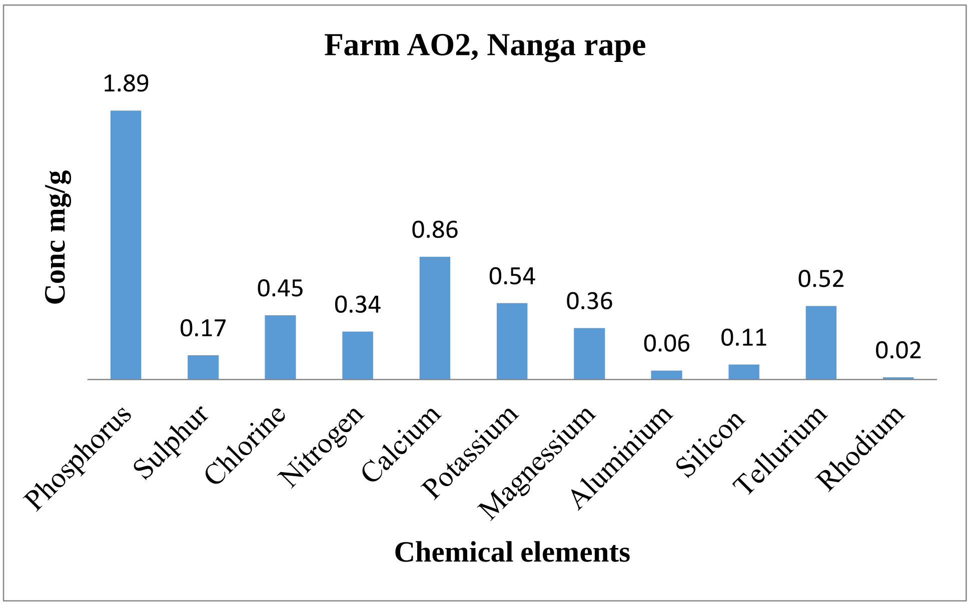
(b)


Farm AO4, Hobson rape
Conc mg/g
0.29
0.15
0.35
0.00
0.71
1.58
0.49
0.28
0.25
0.00
0.00
Phosphorus
Sulphur
Chlorine
Nitrogen
Calcium
Potassium
Magnessium
Aluminium
Silicon
Tellurium
Rhodium
Chemical elements

(c)


Farm AO5, Hobson rape
Conc mg/g
0.17
0.00
0.22
1.54
0.06
0.66
0.00
0.01
0.02
0.00
0.00
Phosphorus
Sulphur
Chlorine
Nitrogen
Calcium
Potassium
Magnessium
Aluminium
Silicon
Tellurium
Rhodium
Chemical elements

(d)


Farm AO2, Nanga rape
Conc mg/g
1.89
0.17
0.45
0.34
0.86
0.54
0.36
0.06
0.11
0.52
0.02
Phosphorus
Sulphur
Chlorine
Nitrogen
Calcium
Potassium
Magnessium
Aluminium
Silicon
Tellurium
Rhodium
Chemical elements

(e)

CHAPTER FIVE

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

The chapter discusses the meaning of results from rape leaves analysis and their implications on foodborne diseases disaster prevention. In this case the description of chemical elements composition in leaves, their nutritional classification and concentration levels were explained. The chapter also gives the research conclusion and recommendations.

5.2 Discussion

5.2.1 Composition and classification of chemical elements in rape leaves

The plant tissue analysis results revealed the presence of about eleven chemical elements. The element levels by weight composition varied in the leaves among themselves and from different sampling areas. (Lab5-Plant nutrition, 2017) indicated that,” All living organisms require certain elements for their survival known as macronutrients, because they are needed in larger amounts. Plants absorb these elements through air and water, they are not usually applied as fertilizers. Micronutrients are also needed in very minute quantities and they are called essential elements.’’ It was also indicated that plant tissues also contain other elements such as Na, Si and Rb amongst others which are not needed for the normal growth and development. It is important to note that there is no "most important element" since all are required for life, growth and reproduction.

The rape leaves from all the sampling sites did not have the same type of nutrients. Three out of five farms had rape leaves with significantly higher than the other two in terms of more macro and micro nutrients and fewer non-essential elements (e.g. Tellurium and Rhodium which might pose to toxic as they are not beneficial to both the plant and the humans).This could have been so because different rape varieties respond differently to their environment. The differences in the nutrient composition of the vegetable plant might be due to soil compositions and the rate of uptake of minerals by individual plant (Anjorin *et al.,* 2010; Asaolu and Asaolu, 2010).

Regardless of measures taken by regulators and food producers to protect consumers from natural food toxins, consumption of small levels of these materials is unavoidable. Although the risk for toxicity due to consumption of food toxins is fairly low, there is always the possibility of toxicity due to contamination, overconsumption, allergy or an unpredictable idiosyncratic response (Laurie *et al*, 2010).

5.2.2 Concentration levels of chemical elements in rape leaves

Quality determines the shelf life as well as selling price of fresh fruit or vegetable and therefore, quality monitoring and testing of fresh commodities have paramount importance in their postharvest handling and supply chain management (Lakshmi *et al*, 2013).In this study it could be suggested that the effect of chemical elements concentration levels would be significant only when the dosage in the rape leaves was considerably high. Therefore the long term sustainability of nutrition in the rape crops depended on the quality of the produce.

The average concentration level of each chemical element observed in samples for each farm was calculated and were evaluated for their contribution to RDAs. The appropriate Recommended Dietary Allowance (RDA) or adequate intake (AI), and provisional tolerable weekly intake (PTWI) or provisional tolerable monthly intake (PTMI) values for adults were determined according to the Food and Agriculture Organization/World Health Organization (FAO/WHO) and Institute of Medicine (IOM) regulations. The chemical elements present in concentration levels which were below the RDAs levels indicated deficiencies in the rape leaves. The nutrient elements which were present in high concentrations indicated an excess of nutrients.

Two out of five (Farm AO1 and AO2) farms had rape leaves (per 100g) with fewer chemical elements which had concentration levels above RDAs. Three out of five farms (AO3,AO5and AO4) had more than five chemical elements at levels above RDAs.Comparing the concentration of chemical elements obtained in this work with the Recommended Dietary Allowances (RDAs) values, the results indicated that the rape from all the farms were still suitable for human consumption especially on a once in a while basis based on the efficiency of the human body's metabolic rate, but if more than 100g of rape leaves were to be consumed on a frequent basis e.g. every day, the likelihood of health risks from elements such as Si, Te, Rh ,N,P and K would be increased.

In some situations, the dividing line between deficient and adequate values was not as clear as the graph would indicate. For example, 0.09 and 0.1 mg/kg might not be different from each other. For these "grey zone" values, one must use a common-sense approach to the interpretation.

The baseline survey revealed the conditions in which the rape from the selected farms were grown in. When growing Hobson rape at Farm AO5, the pesticide Profenophos (C11H15BrClO3P5) was applied and no fertiliser was applied. On the other hand the pesticide Dichlovos (C22H19Cl2NO3) and compound D (N, P, K) fertiliser were applied on Hobson rape from Farm A04. The use of these chemicals did not seem to have had an influence on the concentrations levels of chemical elements such as N, P, S and Cl which were the elements with high concentration levels in these farms. One can suggest that maybe compound D (N, P, K) fertiliser residues in the soil could have been the contributor of high Potassium in the rape leaves. However there is no evidence to support this suggestion because no soil sampling was done to ascertain the chemical composition of soil the rape was grown in.

The pesticide Quinalphos (C12H15N2O3P5) was applied to English giant rape at Farm AO1. Methomidophos (C2H8NO2PS) pesticide was applied to English giant rape at Farm AO3. In both farms fertiliser was not applied. From the results of the baseline survey there was no evidence to help establish whether the use of the pesticides could have had an influence on the concentrations levels of macronutrients such as Nitrogen and Phosphorus which were in higher concentration levels in English giant rape at Farm AO1 than in English giant rape at Farm AO3 Therefore further investigations were needed.

5.3 Conclusion

The findings of the study show that the rape leaves from all the farms were a rich source of nutrients, minerals and beneficial trace elements. The results indicated that the vegetables studied could make significant contribution to the recommended dietary allowances as the leaves were not a source of health risks despite having chemical elements such as Nitrogen, Potassium, Rhodium, Tellurium and Silicon in higher concentration levels. In addition, because the cultivation of rape varieties investigated in this study did not seem to be affected by the various conditions they were grown in, large scale production of these vegetables should be encouraged in order to make it available to all.

5.4 Recommendations

The following is an outline of recommendation that would help promote periodic monitoring of vegetable produced in small scale farms in order to have a database on the quality of vegetables that are supplied to the public in Kabwe district and in Zambia at large.

i. The findings have indicated that the vegetables studied could make significant contribution to the recommended dietary allowances for the nutrients. However there is need to investigate the proximate composition of different types of leafy vegetables other than rape grown in Chowampanga farms in order to have a complete picture of their nutritional value. Also a comparative analysis on boiled versus unboiled vegetables can be done. This can give a better indication of the actual chemicals present in leaves at the point of consumption.
ii. Introduce non-destructive methods/techniques (NDT) as these are useful in the evaluation of physical properties of both unprocessed and processed fruits and vegetables and correlate with the desired quality. Non-destructive methods can be used in fields, in laboratories for sampling purpose because they are rapid, precise, reduces the processing time, reduces cost, save energy, improve the shelf life and quality. Hence, they are advantageous over destructive methods such as SEM.
iii. Based on the results it goes to show that the study was carried out in an area where soil sampling was not done. Therefore simultaneous to plant analysis there is need to investigate the proximate composition of the soils in which the vegetables are grown. This will be done in order to have a complete picture of the soils' contribution to the vegetables' chemical elements composition.
iv. The responsible government wing should be actively involved in improving existing strategies in monitoring quality of vegetables grown in Zambia. This can be done through identification of relevant legislative needs, monitoring the efficiency and effectiveness of law enforcement and vegetable quality surveillance activities as well as exercise statutory powers to coordinate, monitor and audit local monitoring agencies least they default or are negligent in their duties.
v. The national and district regulatory bodies should provide a coordinated mechanism for uniform implementation of food control activities by operating under the principle of protecting the health status of the consuming public, and providing information and advice that enables consumers to make informed choices. The farmers and the inhabitants of the study areas should be educated on the dangers of chemical usage in order to reduce environmental pollution

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APPENDICES

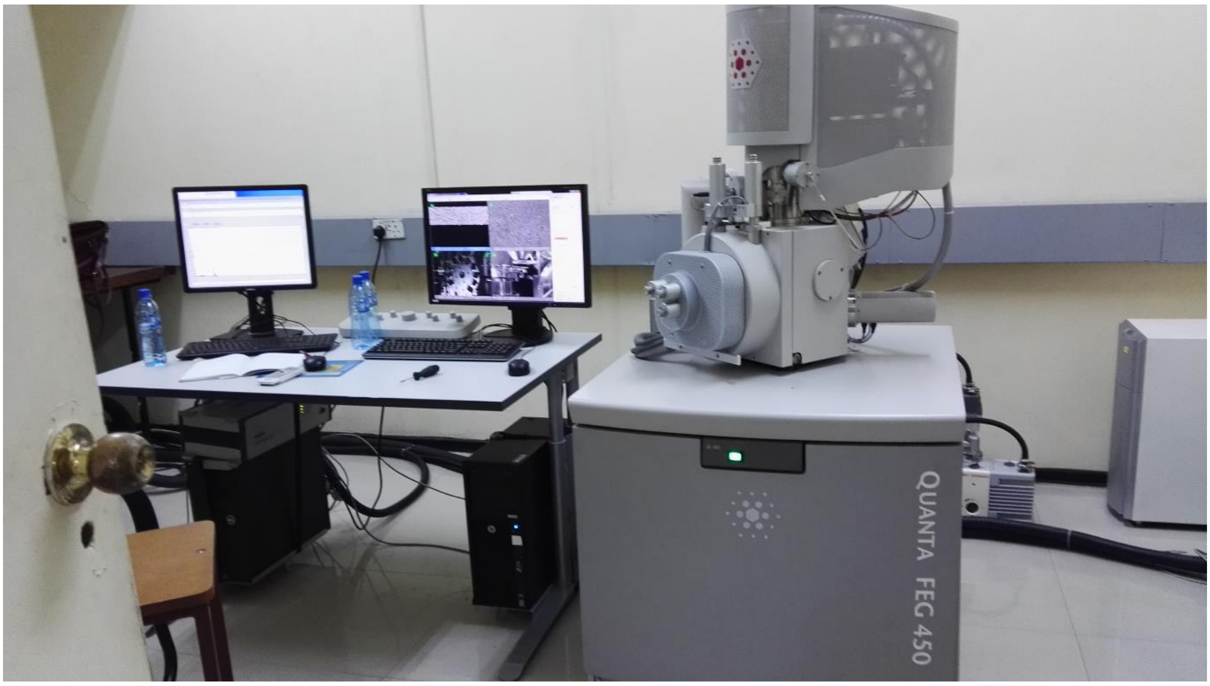
Appendix 1 Interview schedule

INTERVIEW SCHEDULE To be done by the researcher /research assistant. ***Please fill in in the appropriate column .Indicate with a tick where applicable.***		
i.	Farm Name (coded*)	
ii.	What type of rape variety is grown?	
iii.	What is the plant population?	Between 100-300 ☐ Between 300-500 ☐ Between 500-1000 ☐ 1000 or more ☐
iv.	How long is a farming season for rape?	
v.	Did you apply any pesticides to the rape?	
vi.	What type of pesticides were applied?	
vii.	When were the pesticides applied?	
viii.	How often are pesticides applied?	
ix.	What quantities of pesticides were applied?	
x.	How long is the waiting period after pesticide application?	
xi.	What properties are on the pesticide containers?(*interviewer to inspect)*	
xii.	What are the generic names of the common pesticides used?(*Agrodelear to give information)*	

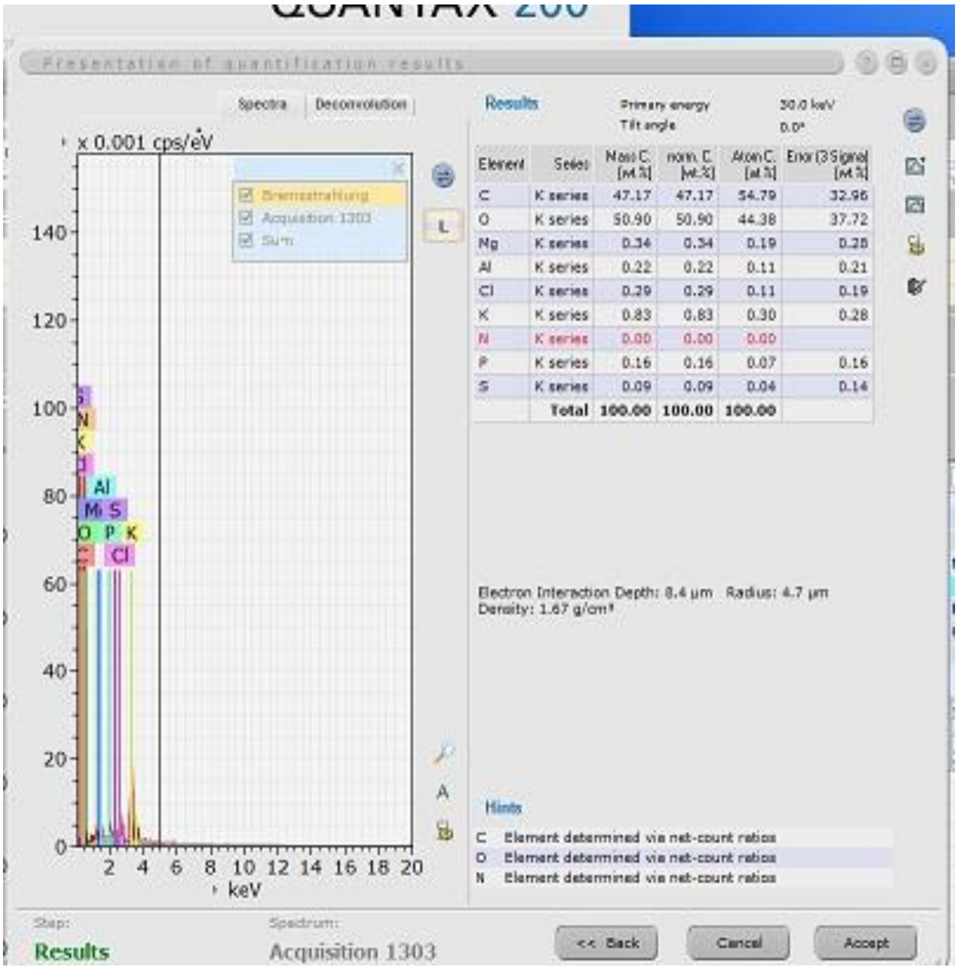
Appendix 2 Vegetable data collection sheet

VEGETABLE SAMPLE COLLECTION FORM To be entered by the researcher/research assistants			
i.	**Site where rape is grown:**		
ii.	**Type of rape grown:**		
iii.	**Number of samples collected:**		
iv.	**Physical condition of rape:**		
v.	**Types of pesticides used:**		
vi.	**Date of planting**		
vii.	**Date of pesticide application**		
viii.	**Date of sample collection**		
Name of collector:……………………………………………….. **Signature of collector:………………………………………………** **Date:………………………………………….**			

Appendix 3 Quanta™ FEG-450 scanning electron microscope used in plant tissue analysis



Appendix 4 Sample graph showing concentrations of chemical elements shown by SEM



Appendix 5 Concentration levels of chemical elements in rape leaves from Farm AO1

LEAF SAMPLES		CONCENTRATION OF CHEMICAL ELEMENTS											
FARM A01	C	O	P	S	Cl	N	Ca	K	Mg	Al	Si	Te	Rd
Sample 01	34.63	64.65	0.13	0.6	0.12	0	0	0	0	0	0	0	0
Sample O2	36.8	59.61	0.04	0.06	0.23	0	0	0	0	0	0	0	0
Sample O3	54.29	43.2	0.13	0.29	0.34	0	0	0.56	0	0	0.14	0	0
Sample O4	54.29	43.2	0.13	0.29	0.34	0	0.55	0.13	0.3	0.2	0.14	0	0
Sample O5	47.17	44.38	0.16	0.9	0.29	0	0	0.83	0.34	0.22	0	0	0
Sample O6	47.17	50.9	0.16	0.9	0.29	0	0	0.83	0.34	0.22	0	0	0
Sample O7	39.91	59.37	0.07	0.04	0.09	0	0	0.52	0	0	0	0	0
Sample O8	53.3	45.13	0.08	0.18	0.3	0	0.3	0.39	0.31	0	0	0	0
Sample O9	36.8	59.61	0.04	0.06	0.23	0	0	0.5	0.2	0	0	0	0
Sample 10	36.8	59.61	0.04	0.06	0.23	0	0	0.5	0.2	0	0	0	0

Appendix 6 Concentration levels of chemical elements in rape leaves from Farm AO2

LEAF SAMPLES		CONCENTRATION OF CHEMICAL ELEMENTS											
FARM A02	**C**	**O**	**P**	**S**	**Cl**	**N**	**Ca**	**K**	**Mg**	**Al**	**Si**	**Te**	**Rd**
Sample 01	36.71	62.45	0.02	0.01	0.18	0.32	0.14	0.02	0	0	0	0	0
Sample O2	53.37	42.25	0.14	0.28	0.71	0	0.81	1.09	0.47	0	0	0	0
Sample O3	41.65	56.29	0.1	0.18	0.29	0.3	0.34	0.47	0.37	0	0.19	0.69	0.16
Sample O4	57.15	38.37	18	0.32	1.1	0	0.71	0.18	0.46	0	0	0.52	0
Sample O5	35.38	64.02	0	0.01	0.11	0	0.13	0	0	0	0	0	0
Sample O6	31.98	66.04	0.19	0	0	1.46	0	0.34	0	0	0	0	0
Sample O7	53.37	42.25	0.14	0.28	0.71	0	0.81	1.09	0.47	0	0.19	0.69	0
Sample O8	53.37	42.25	0.14	0.28	0.71	0	0.81	1.09	0.47	0	0.19	0.69	0
Sample O9	53.37	42.25	0.14	0.28	0.71	0	0.81	1.09	0.47	0	0.19	0.69	0
Sample 10	36.75	54.72	0.06	0.07	0	1.29	4.08	0	0.55	0	0.29	1.9	0

Appendix 7 Concentration levels of chemical elements in rape leaves from Farm AO3

LEAF SAMPLES		CONCENTRATION OF CHEMICAL ELEMENTS											
FARM A03	**C**	**O**	**P**	**S**	**Cl**	**N**	**Ca**	**K**	**Mg**	**Al**	**Si**	**Te**	**Rd**
Sample 01	33.85	64.51	0.04	0.03	0.03	1.31	0	0.21	0	0	0	0	0
Sample O2	27.63	71.72	0.02	0.03	0.18	0	0.11	0.1	0.22	0	0	0	0
Sample O3	30.21	68.75	0	0.07	0.21	0.14	0.15	0.13	0.21	0.13	0	0	0
Sample O4	36.78	61.06	0.01	0.01	0.19	1.78	0	0.01	0	0	0	0	0
Sample O5	43.42	55.39	0.02	0.03	0.35	0.33	0.27	0.18	0	0	0	0	0
Sample O6	44.04	51.63	0.33	0.29	0.5	0.81	0.82	0.33	0.14	0.13	0.1	0.66	0
Sample O7	51.9	41.14	0.21	0.35	1.08	1.48	1.14	0.52	0.39	0	0.17	0.89	0.75
Sample O8	0.23	64.09		0.08	0.43	0	0.23	0.32	0.24	0	0	0	0.32
Sample O9	34.95	63.75	0.02	0.01	0.16	0.86	0.25	0	0	0	0	0	0
Sample 10	37.65	59.97	0.14	0.16	0.45	0	0.44	0.29	0.42	0.16	0	0	0.32

Appendix 8 Concentration levels of chemical elements in rape leaves from Farm AO4

LEAF SAMPLES		CONCENTRATION OF CHEMICAL ELEMENTS											
FARM A04	**C**	**O**	**P**	**S**	**Cl**	**N**	**Ca**	**K**	**Mg**	**Al**	**Si**	**Te**	**Rd**
Sample 01	47.4	49.14	0.47	0.21	0	0	0.52	1.07	0.34	0.72	0.13	0	0
Sample O2	55.41	40.44	0.6	0	0.24	0	0.38	2.02	0.61	0	0	0	0
Sample O3	55.41	40.44	0.6	0.28	0.24	0	0.38	2.02	0.61	0	0	0	0
Sample O4	57.9	38.63	0.2	0.15	0.32	0	0.76	1.2	0.37	0.33	0.14	0	0
Sample O5	57.9	38.63	0.2	0.15	0.32	0	0.76	1.2	0.37	0.33	0.14	0	0
Sample O6	58.86	37.84	0.15	0.14	0.4	0	0.68	1.35	0.45	0.14	0	0	0
Sample O7	53.13	42.31	0.17	0.14	0.44	0	0.89	1.61	0.5	0.3	0.51	0	0
Sample O8	53.13	42.31	0.17	0.14	0.44	0	0.89	1.61	0.5	0.3	0.51	0	0
Sample O9	50.75	43.74	0.14	0.12	0.62	0	0.95	2.09	0.65	0.38	0.57	0	0
Sample 10	53	42	0.17	0.14	0.44	0	0.9	1.61	0.5	0.3	0.51	0	0

Appendix 9 Concentration levels of chemical elements in rape leaves from Farm AO5

LEAF SAMPLES		CONCENTRATION OF CHEMICAL ELEMENTS											
FARM A05	**C**	**O**	**P**	**S**	**Cl**	**N**	**Ca**	**K**	**Mg**	**Al**	**Si**	**Te**	**Rd**
Sample 1	31.11	68.04	0.08	0	0	0.3	0.21	0.16	0	0	0.09	0	0
Sample 2	31.11	68.04	0.08	0	0	0.3	0.21	0.16	0	0	0.09	0	0
Sample 3	32.48	66.4	0.19	0	0.1	0.35	0.14	0.34	0	0	0	0	0
Sample 4	59.41	35.61	0.42	0	0.79	1.37	0	0.42	0	0.12	0	0	0
Sample 5	39.51	57.83	0.16	0	0.16	1.95	0	0.38	0	0	0	0	0
Sample 6	39.51	57.83	0.16	0	0.16	1.95	0	0.38	0	0	0	0	0
Sample 7	53.29	42.46	0.19	0	0.39	3.01	0	0.66	0	0	0	0	0
Sample 8	30.22	68.32	0.07	0	0.06	1.24	0	0.1	0	0	0	0	0
Sample 9	53.29	42.46	0.19	0	0.39	3.01	0	0.66	0	0	0	0	0
Sample 10	39.51	57.83	0.16	0	0.16	1.95	0	0.38	0	0	0	0	0

Appendix 6 Mean concentrations of chemical elements in rape leaf samples from Chowampanga farms of Kabwe district in Zambia (2018)

	mass Concentration [wt.%] mg/g				
Elements	**FARM AO1**	**FARM AO2**	**FARM AO3**	**FARM AO4**	**FARM AO5**
Phosphorus	0.178	1.893	1.89	0.287	0.17
Sulphur	0.338	0.171	0.11	0.147	0
Chlorine	0.246	0.452	0.11	0.346	0.221
Nitrogen	1.417	0.337	0.67	0	1.543
Calcium	0.085	0.864	0.34	0.711	0.056
Potassium	0.426	0.537	0.21	1.578	0.661
Magnesium	0.169	0.362	0.16	0.49	0
Aluminium	0.064	0	0.04	0.28	0.012
Silicon	0.042	0.057	0.21	0.103	0.023
Tellurium	0	3.45	0.28	0.107	0
Rubidium	0	0.61	0.11	0.023	0

Appendix 7 Mean concentrations of chemical elements in rape leaf samples among Chowampanga farms of Kabwe district in Zambia (2018)

	P	**S**	**Cl**	**N**	**Ca**	**K**	**Mg**	**Al**	**Si**	**Te**	**Rh**
Mean	0.8842	0.1524	0.2742	0.7938	0.4114	108.0406	0.2366	0.084	0.0858	0.1346	0.031
Standard Error	0.412359	0.054864	0.058602	0.300399	0.163158	107.24	0.085455	0.050723	0.04419	0.10044	0.027177
Median	0.287	0.147	0.246	0.671	0.341	0.662	0.169	0.064	0.028	0	0
Mode	1.893	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0.064	#N/A	0	0
Standard Deviation	0.922063	0.12268	0.131039	0.671713	0.364832	239.796	0.191083	0.11342	0.098811	0.22459	0.06077
Sample Variation	0.850201	0.01505	0.017171	0.451198	0.133102	57502.14	0.036513	0.012864	0.009764	0.050441	0.003693
Kurtosis	-3.31807	1.551458	-0.22069	-2.42671	-2.54259	4.999927	-0.91549	3.729111	2.348056	3.099708	4.727998
Skewness	0.597294	0.622891	0.196164	0.091248	0.339725	2.236048	0.255262	1.869846	1.644396	1.804108	2.166593
Range	1.723	0.338	0.346	1.543	0.808	536.574	0.49	0.28	0.233	0.518	0.139
Minimum	0.17	0	0.106	0	0.056	0.426	0	0	0.018	0	0
Maximum	1.893	0.338	0.452	1.543	0.864	537	0.49	0.28	0.251	0.518	0.139
Sum	4.421	0.762	1.371	3.969	2.057	540.203	1.183	0.42	0.429	0.673	0.155
Count	5	5	5	5	5	5	5	5	5	5	5
Confidence Levels (95.0%)	1.144893	0.152327	0.162706	0.834041	0.452999	297.7461	0.237261	0.140829	0.122691	0.278866	0.075456