PESTICIDE RESIDUES IN LOCALLY PRODUCED GRAPE WINE IN TANZANIA: A CASE STUDY OF DODOMA URBAN AND BAHI DISTRICTS

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EXTENDED ABSTRACT

The aim of this study was to assess the levels of pesticide residues in locally produced grape wine in Tanzania. Fifty samples of grape wine from different locations in Dodoma urban and Bahi district were analysed to determine the presence of 49 pesticides using the quick, easy, cheap, effective, rugged and safe (QuEChERS) multi-residue extraction, followed by gas chromatography-tandem mass spectrometry (GC-MS/MS). Twenty-two pesticides were detected among the 49 pesticides analysed. The selected 49 pesticides were based on their use in grape cultivation reported by grape farmers in the study location which include fungicides, insecticides and herbicides. The pesticides whose concentrations exceeded the maximum residue levels (MRL) were: pyroquilon 76%, ethofumasate 66%, chloroneb 92%, azobenzene 28% and cycloate 2% of the wine samples.

Of the samples analysed 18% contained one pesticide, 16% contained two different pesticides, 46% contained three different pesticides, 16% contained four different pesticides, among those that exceeded MRL (pyroquilon, ethofumesate, chloroneb, azobenzene and cycloate).

The results indicated the occurrence of pesticide residues in grape wine produced in Dodoma urban and Bahi districts, Tanzania. Most of the samples contained pesticide residues that exceeded MRL set by European standards for grape wine indicating that grape wine was not safe for human consumption and could lead to negative health effects to consumers.

In addition, study aimed at assessing awareness on ill-health effects of pesticide residues and best practices among grape wine stakeholders in Dodoma Urban and Bahi districts. A cross-sectional descriptive study was carried out between December 2019 and January 2020 in Dodoma Urban and Bahi districts, involving 40 farmers, 15 grape wine processors and 4 agricultural officers through interviews. Data were collected using semi-structured questionnaires and analysed using IBM SPSS ® version 25 (2017). Descriptive statistics were used to determine frequencies and percentages of social demographic, awareness and handling practices of pesticides. The results indicated that, grape farming was mostly practiced by people with low education level. It was also observed that pesticides handling practices were poor. Poor handling practices of pesticides were identified on poor disposal of empty containers, use of personal protective equipment whereby few respondents worn it and they usually worn one item of those PPE recommended and low knowledge about pesticides safety labels. Although respondents were aware that pesticides had negative health effects on human and environment, still their handling practices were unsatisfactory. This could be due to negligence and lack of education. Also, it was observed that there was no treatment performed by grape wine producers to reduce the pesticides load before wine processing and no tests were performed to ascertain the pesticides residues level in their raw materials. Awareness creation on good practices for pesticides application and food safety strengthening are recommended to protect public health against pesticides.

Keywords: Pesticide residues; grape wine; food safety, maximum residue levels (MRL), handling practices, health effect.

DECLARATION

I, Sifa Sosten Chamgenzi do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution for a degree award.

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DEDICATION

This dissertation is dedicated to my husband, Mr. Zeno Augustino Chaula for his support, encouragement and constant love and; to my lovely children Caroline and Callistus for their love and patience during my absence.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
CAC	Codex Alimentarius Commission
DDT	Dichlorodiphenyltrichloroethane
DEET	Diethyl-m-toluene
EFSA	European Food Safety Authority
EU	European Union
FAO	Food and Agricultural Organization
GAP	Good Agricultural Practices
GC-MSMS	Gas Chromatography Tandem Mass Spectrometry
IPM	Integrated Pest Management
LOD	Limit of Detection
LOQ	Limit of Quantification
$MgSO_4$	Magnesium Sulphate
MRL	Maximum Residue Levels
PAN	Pesticide Action Network
PPE	Personal Protective Equipment
PSA	Primary Secondary Amine
PTFE	Polytetrafluoroethylene
QuECHERS	Quick, Easy, Cheap, Rugged and Safe
RSD	Relative Standard Deviation
TBS	Tanzania Bureau of standards
TFDA	Tanzania Food and Drugs Authority
TMDA	Tanzania Medicine and Medical Devices Authority

TPRI	Tropical Pesticides Research Institute
WHO	World Health Organization

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Grapes (*Vitis vinifera*) belong to the family Vitaceae and are one of the world's most important economic fruit crops (Kocher and Nikhanj, 2019). This crop has many uses as it can be eaten raw and it is used as raw materials for the manufacture of wine, jam, juice, jelly, grape seed-extracts, raisins, vinegar and grape-seed oil (Kalimang'asi *et al.*, 2014; Grimalt and Dehouck, 2016).

Approximately 4744 tons of grapes were produced in Tanzania in the year 2018 while the largest producer of grapes in the world for the year 2018 was China with 13 494 811 tons (FAOSTAT, 2020). Wine provides various beneficial compounds on human health including antioxidants in the form of phenolic compounds, aromatic compounds, flavonoids, non-flavonoids, anthocyanins, ascorbic acid, tannins, stilbenes, resveratrol, and many other bioactive compounds (Kocher and Nikhanj, 2019). Nevertheless, wine may also contain compounds that have negative effects on human health such as pesticide residues, toxic metals, sulphites and mycotoxins (Cepo *et al.*, 2018).

The quality of wine depends on the quality of grapes and in order to obtain high-quality wines, quality grapes at the correct stage of ripeness and free from parasites have to be used (Caboni and Cabras, 2010). In addition, the quality of wine depends on the vinification process, geographical origin of the grapes and varietal composition of the grape must; therefore, grapes traceability is important in quality control and suppliers' information (Espineira and Santaclara, 2016).

Pesticides

Pesticides are substances or mixtures of substances that are mainly used in agriculture or in public health protection programs in order to protect plants from pests, weeds or diseases (Nicolopoulou-Stamati *et al.,* 2016). Pests and diseases are among the constraints in production of grapes, thus necessitating the use of pesticides that subsequently contaminate grape products and pose health hazards to consumers and also contaminate the environment (Tago *et al.,* 2014). The pesticide residues on grapes can be transferred to the must and this can influence the selection and development of yeast strains (Grimalt and Dehouck, 2016; Caboni and Cabras, 2010; Vaquero-Fernandez *et al.,* 2012) withstand fermentation and the wine making process and eventually be found in wine (Gonzalez-Rodriguez *et al.,* 2011). If good agricultural practices (GAP) such as correct fungicides dosage and/or pre- harvest safety interval are not used, the grapes might be contaminated with unacceptable levels of pesticides residues (Esteve-Turrillas *et al.,* 2016). Consequently, the quality and safety of the wine can be compromised. The maximum reside levels must thus be within legally permitted levels that are set on national and international standards based on Codex Alimentarius Commission (CAC) (Mutengwe *et al.,* 2016).

The most common fungal diseases affecting grape quality are downy and powdery mildew (*Plasmopara viticola* and *Uncinula necator*) and grey mold (*Botrytis cinerea*). On the other hand, the most dangerous insects are the grape moth (*Lobesia botrana*), vine mealybug (*Planococcus ficus*) and the citrus mealybugs (*Planococcus citri*) (Caboni and Cabras, 2010).

Uses of pesticides in Tanzania

Pests and diseases have been the limiting factors in the horticultural development in Tanzania (Mrema *et al.,* 2017). Historically, crops have been grown for subsistence by smallholder farmers who practice crop rotation and intercropping for preventing disease and harmful pest infestations in different agricultural activities (Han-ming *et al.,* 2019). However, recent developments have resulted in monoculture and thus an increased pest population. To cope with this situation, large amounts of pesticides and other agrochemicals are used to manage pests and ensure the production of more quantity of products (Mrema *et al.*, 2017).

Pesticide residues in grape wine

The incidence and concentrations of pesticide residues in harvested grapes depend on the pests and diseases of grapevine typical for each vine growing region, type of grape production (conventional, intergrated pest management (IPM), organic), pesticide concentrations at application, time period and climatic conditions from the last spraying until harvest (Cesnik *et al.,* 2008). The pesticide residues on grapes can be transferred to the must and this can influence wine fermentation. Moreover, yeasts can also influence the levels of the pesticides in the wine by reducing or adsorbing them on lees (Caboni and Cabras, 2010).

In wine making process there are two types of fermentation processes, the first type is due to yeast which transforms sugars to alcohol (alcoholic fermentation) and the second step is malolactic fermentation which converts malic acid to lactic acid using lactic acid bacteria such as *Oenococcus oeni, Lactobacillus hilgardii and Leuconostoc fragile* (Caboni and Cabras, 2010).

The presence of pesticides such as, fungicides in grape must, can drastically reduce yeast viability causing fermentation delay, wine cloudiness, and stuck fermentations (Scariot, *et al.,* 2016; Russo, 2019); Vaquero-Fernandez *et al.*, 2012). Studies have shown that after fermentation, pesticide residue levels in wine are always lower than those on the grapes and in the must, except for those pesticides that do not have a preferential partition between the liquid and solid phases (azoxystrobin, dimethoate, and pyrimethanil) and are present in wine at the same concentration as on the grapes (Cabras and Angioni, 2000). Study conducted by Caboni and Cabras, (2010) shows that in fermentative process, yeasts can cause the disappearance of pesticide residues by degradation or absorption at the end of the fermentation when yeasts are deposited as lees The study conducted by Roguiero (2014) indicate that deltametrin, permethrin and fenvalerate were completely degraded after fermentation with *Saccharomyces cerevisiae* that can be attributable to the yeast activity, while the fungicides benalaxyl, folpet, furalaxyl, metalaxyl, iprodione, procymidone, and ofurace remained unaffected.

Similarly malolactic fermentation using *Oenococcus oeni* resulted in significant reduction in chlorpyrifos and dicofol concentrations which were reduced by 70% and 30%, respectively, whereas, the concentrations of chlorothalonil and procymidone diminished only slightly (Bajwa and Sandhu, 2011).Some clarifying substances commonly used in wine (bentonite, charcoal, gelatin, polyvinylpolypyrrolidone, potassium caseinate, and colloidal silicon dioxide), charcoal allowed the complete elimination of most pesticides, especially at low levels, whereas the other clarifying substances were ineffective (Cabras and Angioni, 2000).

Effects of pesticide residues on health

Improper use of pesticides can cause food poisoning to humans accumulate as residues in food and environment and lead to occupational, environmental and food security risks (Oesterlund *et al.,* 2014). Exposure to pesticides has been associated with a wide spectrum of human health hazards, ranging from short-term impacts such as headaches and nausea to chronic diseases like cancer and endocrine disruption (Nakano *et al.,* 2016). Annually, there are dozens of million cases of food poisonings due to pesticides residues in food worldwide (Tago *et al.,* 2014). Many countries that import table grapes strive to restrict the levels of pesticide residues that the grapes could contain (Turgut *et al.,* 2009). Other disease conditions reported by pesticide sprayers including neurologic, sight, skin, and heart, respiratory, reproductive and sexual health were assessed and identified using a list of certain criteria of symptoms that the sprayer was able to identify (Rajabu *et al.,* 2017). Examples of health effect and associated with pesticides are indicated in Table1.1.

Table 1.1: Health effects and the associated pesticides

Health Effects	Pesticides
Endocrine disrupting	DDT, lindane, atrazine, carbaryl, parathion (Sarwar, 2015)
Reproductive disorder	acephate, acetochlor, aldicard, aldrin, atrazine,carbaryl, chlorothalonil, chlorfenviphos, chlorpyrifos,cypermethrin1, cyproconazole, DDT, Diazinon, dimethoate, endosulfan, Endrin, Fenvalerate, Heptachlor, hexaconazole, malathion, permethrin, tebuconazole (Mnif *et al.*, 2011)
Diabetes	DDT, DDE, oxychlordane, trans-nonachlor, hexachlorobenzene, and hexachlorocyclohexane (Kim *et al.*, 2017)
Cancer (colon cancer, Prostate cancer, Bladder cancer Brain turmor, Leukemia)	imazethapyr, a heterocyclic aromatic amine herbicide(Kim *et al.*, 2017) fonofos, terbufos, malathion, permethrin, aldrin,chlordecone, lindane, DDT, dieldrin, atrazin, methyl bromide, oxychlordane, mirex, hexachlorobenzene, diazinon, carbaryl (Alavanja *et al.*, 2013)
Nervous system disorders	Organophosphates and carbamates and some of the pyrethroids (Sarwar, 2016)
Respiratory problems (Asthma)	Paraquat, organochloride, organophosphate, Carbamate and Pyrethroid (Singh *et al.*, 2017)

Pesticides withdraw period

If pesticides are applied in accordance with basic good agricultural practices, by the time fresh produce reaches the markets or retail outlets, residue levels on crops should be well below legal levels (Esteve-Turrillas *et al.*, 2016; Cabras and Angioni, 2000). To avoid exceeding MRLs, farmers need to comply with prescribed application rates, as indicated on pesticide labels, including withholding periods before crops are harvested (Mutengwe *et al.*, 2016). However, farmers require knowledge on the right dosage, right ways of application and the suitable interval between harvesting and pesticide treatment. In most developing countries, farmers have low to moderate levels of knowledge about pesticides (Mwanja *et al.*, 2017).

Awareness of farmers, businessmen and consumers on pesticide residues

In European countries, consumers are anxious about the pesticide residues in their food and want to avoid them as much as possible (Kariathi *et al.*, 2017). However, due to the lack of awareness of farmers, the misuse of pesticides has become a serious problem in agricultural production (Hou and Wu, 2010). In Tanzania, small-scale farmers have little access to knowledge and therefore constrained by lack of appropriate knowledge on how to handle the different products and how to access the necessities and possibilities for safe use (Rajabu *et al.,* 2017).

1.2 Problem Statement and Study Justification

Pesticide residues on fresh produce resulting from the inappropriate use of pesticides are one of the most important food safety concerns in developing countries (Mutengwe *et al.*, 2016). There are numerous negative health effects that have been associated with chemical pesticides including dermatological, gastrointestinal, neurological, carcinogenic, respiratory, reproductive and endocrine disrupting effects (Nicolopoulou-Stamati *et al.*, 2016). Organophosphate and carbamate pesticides also cause adverse effects in the central nervous system and inhibition of the enzyme acetyl cholinesterase (Nakano *et al.,* 2016). According to Chandra *et al.* (2014), many researchers have investigated the pesticide residues in various fruits including banana, mango, apple, peach, watermelon, melon, grape, orange, lemon, pear, pineapple, strawberry, raspberry, kiwi fruit, beet, papaya and litchi and observed the occurrence of pesticide residues to be more than maximum residue levels (MRL) values recommended by European Union (EU), World Health Organization (WHO) and Food and Agricultural Organization (FAO) (Banerjee *et al.,* 2010); Boon *et al.,* 2008); Selim *et al.,* 2011). The Pesticide Action Network (Pan)-Europe (2008) reported that the majority of wine in European market contained residues of many pesticides and emphasized the need for continuous monitoring of residues in wine.

To date, there is no reported study which has been conducted to establish the pesticide residue levels in grape wine produced in Tanzania. Considering the risks associated with pesticides contamination of foods and beverages, there is need to establish the levels of pesticide residues in locally manufactured wine, particularly in the leading producer region, Dodoma, in order to determine its quality and safety. This study serve as a basis for awareness creation to farmers, consumers, processors and other stakeholders and enable the government to regulate the sector and advocate use of best practices and prevent economic losses.

1.3 Objectives

1.3.1 Main objective

The main objective of this study was to carry out surveillance on pesticide contamination and safety of grape wine produced in Tanzania.

1.3.2 Specific objectives

The specific objectives of the study were to:

i. determine the level of pesticides contamination in grape wine produced in Dodoma Urban and Bahi districts in Tanzania
ii. assess awareness on ill-health effects of pesticide residues and best practices among grape wine stakeholders in Tanzania.

The findings of this research work were reported in two manuscripts presented as Chapter Two and Three.

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CHAPTER TWO

Pesticide Residues in Locally Produced Grape Wine In Tanzania: A Case Study of Dodoma Urban and Bahi Districts

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CHAPTER THREE

Awareness on ill-health effects of pesticide residues and best practices among grape wine stakeholders in Tanzania: a case study of Dodoma Urban and Bahi Districts

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3.1 Abstract

The aim of this study was to assess the awareness on ill-health effects caused by pesticide residues and best practices among farmers, processors and agricultural officers in Dodoma Urban and Bahi Disticts, Tanzania. A cross-sectional descriptive study involving 40 farmers, 15 grape wine processors and 4 agricultural extension officers was carried out. Data was collected using semi-structured questionnaires and analysed using IBM SPSS ® version 25 (2017). Descriptive statistics were used to determine frequencies and percentages of social demographic, awareness and handling practices of pesticides. The results indicated that grape farming was mostly practiced by people with low education level. It was also observed that pesticides handling practices were poor. Poor handling practices of pesticides were identified through observations such as poor disposal of empty containers, none use of personal protective equipment and reading pesticides safety labels. Although respondents were aware that pesticides caused ill-health effects to humans and polluted the environment, they did not use best practices probably be due to negligence. Also, it was observed that no intervention was made by grape wine producers to determine or reduce the level of pesticides before processing grapes. Creation of awareness on health hazards and use of best practices in pesticides application along the grape value chain is crucial in order to protect public health.

Keywords: Grape wine, pesticide residues, food safety, awareness

3.2 Introduction

The term pesticides can be defined as any substance or a mixture of substances intended for preventing, destroying, or controlling any pest including vectors of human or animal diseases, unwanted species of plants or animals (Gurung and Kunwar, 2017).

The applications of pesticides have shown success in increasing of crops and animals in Tanzania as they are used to protect crops and animals from different diseases since they kill pests that destroy crops and harm animals (Rajabu *et al.*, 2017; Oesterlund *et al.*, 2014). Regardless of the good intention of controlling pests and diseases, pesticides can also be toxic to humans thereby causing lethal effects to them (Gurung and Kunwar, 2017; Damalas and Eleftherohorinos, 2011). Farmers tend to apply pesticides excessively and irrationally because they lack knowledge about the health risks caused by pesticide residues and failure to follow the guidelines and standardized regulations on how much pesticide should be applied (Hou and Wu, 2010). This is the root of pesticide residue problems. In addition, farmers lack awareness on pesticides application and as a result the misuse of pesticides is a serious problem in agricultural production (Abhilash and Singh, 2009). Creation of awareness on safe use of pesticides is an important prerequisite for avoiding negative impacts on human health (Jallow *et al.*, 2017). Also, improper use and disposal of containers of pesticide and equipment storage, application of unregistered and non-approved pesticides and the use of excessive dosage are mainly caused by inadequate knowledge of the farmers (Mabe *et al.*, 2017).

The current report shows that in Tanzania, 68% of farmers were reported to have acute diseases after routine application of pesticides in the previous years (Rajabu *et al.*, 2017). The most common symptoms that were reported by the interviewees were dermal effects (34%), dizziness (31%), headache (31%), nausea (18%) and stomach ache

(Ngowi *et al.,* 2007). This is because the use of Personal Protective Equipment (PPE) remains optional to most farmers (Mabe *et al.*, 2017). Studies in developing countries of farmer's knowledge and practices have reported low to moderate levels of knowledge about pesticides, non-usage of PPE, unsafe pesticide storage at homes, poor disposal of empty pesticide containers, misuse of pesticides and relatively low knowledge about pesticide safety labels (Lekei *et al.,* 2014). That is why it is important that farmers comply with food safety requirements to protect themselves and the consumers, because the concerns over their health impacts are growing rapidly.

3.3 Materials and Methods

3.3.1 Study design

A cross sectional descriptive study was carried out between December 2019 and January 2020 in Dodoma Urban and Bahi districts in Dodoma region, Tanzania. This design aimed to capture and collect particular data regarding awareness on risks caused by pesticide residues and best practices among farmers/farm workers, processors and agricultural officers from the study population involved in grape wine production chain.

3.3.2 Study population

The study population engaged the people who were involved in grape wine production chain from farming to processing plants in Dodoma Urban and Bahi districts. This group was selected because it was involved in the production of grapes and grape wine. In addition, these people were more likely to make informed decisions and respond to the study questions precisely.

3.3.3 Sampling techniques and procedures

Probability sampling technique was employed (Adwok, 2015). This technique was appropriate for the study because it provided equal chance to all the study respondents in the population to be selected and thus eliminating the possibility of bias in our selection. It also provided a basis for the application of statistical theory of results. The study respondents (40 farmers) were randomly selected in their respective wards Hombolo Bwawani, Mtitaa, Mpunguzi and Mbabala through simple random sampling technique in which selection of individual farmer was based on their involvement in grape farming possession of not less than one acre of grape farm and involved in grape business.

Other information were collected from respondents in all processing plants involved in grape wine production. The samples of different batches of grape wine were collected from each respondent after conducting the interview. The interview was also conducted to Agricultural Officers in the study areas. There were only four Agricultural Officers all of whom were interviewed.

3.3.4 Data collection tools

The data were collected using quantitative methods. An interview administered questionnaire (with closed and open ended questions) was used to study respondents who consented to participate. The questionnaire administered to farmers had twenty three questions that attempted to capture information on the use of pesticides, handling and awareness on negative health effects caused by pesticides. The questionnaire for processors had questions that attempted to capture information on awareness on pesticides, criteria used for receiving raw materials and pre-processing techniques used to reduce pesticide levels.

3.3.5 Statistical analysis

The data was analysed using Statistical Package for Social Sciences (IBM SPSS® Version 25 (2017). The data was coded appropriately and fed into SPSS version 25 to determine the frequencies. The analysis involved descriptive statistics to describe socio-demographic, awareness and handling practices, in frequency tables.

3.4 Results and Discussion

The demographic characteristics of farmers and wine processors on awareness, handling practices and factors associated with pesticides residues in grape wine from the respondents were investigated.

3.4.1 Farmers characteristics

3.4.1.1 Demographic characteristics of farmers

The age and level of education were determined using well defined ordinal scale categories. Table 3.1 shows that the highest percentage of farmers (42.5%) belonged to 40-49 age group, followed by above 50 age group (37.5%) and the remaining 20% were in 30-39 age group. The study indicated that 92.5% of the farmers were male and only 7.5% of them were women. Also the study on pesticide usage and pesticide safety awareness among farmers in Commewijne in Suriname conducted by Malgie *et al.* (2015) indicated that 90% of the farmers were male and only 10% of them were women. In grape production most of farmers were males due to the high investment start-up capital required that most women farmers cannot afford.

In principle, education helps farmers to understand the regulations guiding the use of chemicals in the farms thereby exposing them less to the dangers of inappropriate use of the chemicals (Mabe *et al.*, 2017). This study revealed that 82.5% of the farmers attended primary education, 10.0% attended secondary school, and only 5.0% attended college education, while 2.5% of the respondents did not attend formal education. Thus, the study area was dominated by farmers with a relatively low level of education. This is because the study conducted in rural areas where education is not a priority, after primary education completion most of people they engage in farming and also the educated people usually they live in town and most of them they do not like to engage in farming activities.

This study indicated that 77.5% of the farmers depended on grapes only as a cash crop whereas 20.0% of the farmers depended on both grapes and tomatoes and 2.5% of the farmers depended on grapes, tomatoes and sunflower. The grapes were usually harvested in two seasons per year and depended on the pruning period done at the time when the grapes are sold at a high price. In addition, the study indicated that 60.0% of the respondents harvested their grapes in February and September, 37.7% harvested in March and November and 2.6% harvested in February and October. Farmers reported that grapes harvested in February and March were severely attacked by pests and most succumbed to diseases due to rainfall, and this entailed over application of pesticides in comparison with those harvested during the relatively drier weather in August-October. The overview of demographic characteristics of surveyed farmers as indicated in Table 3.1.

Table 3.1: Demographic characteristics of grape farmers in Dodoma Urban and Bahi districts

Variable	Description	Frequency (N=40)	Percentage
Ward	Hombolo Bwawani	10	25.0
	Mtitaa	10	25.0
	Mpunguzi	10	25.0
	Mbabala	10	25.0
Sex	Male	37	92.5
	Female	3	7.5
Age categories	30-39	8	20.0
	40-49	17	42.5
	50 and above	15	37.5
Level of education	Did not complete primary education	1	2.5
	Completed primary education	33	82.5
	Completed secondary education	4	10.0
	Completed College	2	5.0
Main cash crop cultivated	Grapes	31	77.5
	Grapes and tomatoes	8	20.0
	Grapes, tomatoes and sunflower	1	2.55
Harvesting Month	February and October	1	2.5
	February and August	24	60.0
	March and November	15	37.5

3.4.1.2 Use and handling of pesticides

Table 3.2 indicates that the most frequently occurring grape pests and diseases problems were Downy mildew, Powderly mildew and Late bright. The following were the pesticides used by farmers to prevent pests and diseases: Linkimil, Xantho, Ridomil, Master Kinga and anvil in which they reported that, were purchased from agricultural inputs shops. Eighty five percent of the farmers were able to recognize the pest and diseases which affected grape plants. Also most of the farmers were able to mention the pesticides usually used in their farms to control pest and diseases by mentioning the brand names such as Linkimil, Ridomiln, Xantho, Anvil and Master Kinga which contains the following chemical pesticides Linkimil, Master Kinga and Ridomil (Metalaxy and Mancozeb), Xantho and Anvil (Hexaconazole).

For alternative ways of protecting grapes from pests and diseases other than the use of pesticides, 95% farmers indicated that they did not have alternative ways; 2.5 % reported that they used ashes and 2.5% they used neem leaves powder. Ninety five percent of the farmers responded that it was difficult to use alternative ways especially using ashes or neem leaves powder in a large farm plot of about 5 acres.

Training on proper use and handling of pesticides; 50% of the farmers reported that they had been trained and 50% did not receive any training on pesticides use and handling. Another study on pesticide awareness and management practices in Tanzania conducted by Felix and Sharp (2016) indicated 56.38% farmers have heard some general information about pesticides recently within a year, while 21.28% farmers have heard some general information about pesticides more than ten years ago. According to Rajabu *et al.* (2017), awareness on safety use of pesticides is an important prerequisite for avoiding negative health effects on human, hence specific knowledge and access to equipment and financial means are required to follow the recommendations for personal protection.

This study revealed that 90% of the respondents read the labels on the pesticides containers before use and followed the instructions for use and handling and 10.0% did not read the instructions. The study conducted by Nguyen *et al.* (2018) on pesticide knowledge, practice and attitude in Uganda observed that if these instructions were followed by farmers they might have assisted them to avoid pesticide under- or over-application, understand the pesticide toxicity potential, and adhere to pre-harvest interval restrictions. Farmers did not follow the instructions for use because of lack of understanding of the information written on the label. Thus, they usually relied on the information from the experienced farmers on how to use pesticides. Most of the farmers complained that pesticide labels are too abstruse and too technical for them to understand. This ultimately increased the risks of occurrence of pesticide residues. This is also the case in most other developing countries as, about 70% of farmers encounter difficulties in reading instruction manuals leading to the misuse of highly toxic pesticides (Hou and Wu, 2010).

Another focus of this study was to examine the practices and impact of personal protective equipment during application of pesticides. This study observed that 27.5% wore some of the PPEs although not as a complete set while 72. 5% did not wear PPEs. Following this observation 72.5% reported that they wore their normal clothes and less than two of five personal protective equipment that is gloves, overalls/long sleeve shirt, respiratory masks and eye protection glasses. Similar findings on non use of personal protective equipment amongst farmers was reported by Oesterlund *et al.* (2014), Mabe *et al.* (2017), Felix and Sharp, (2016), Malgie *et al.* (2015), and Gesesew *et al.* (2016). Reasons for not wearing the personal protective equipment included the prohibitive cost, unavailability of personal protective equipment and discomfort when PPEs are used. Similar observation was reported by Rajabu *et al.* (2017). In this study, 2.5% of the respondents wore gloves only, 27.5% wore respiratory masks only, 10.0% wore shoes/boots only, 2.5% wore long sleeve shirt only, 20.0% wore gloves, long sleeve shirt, and eye glasses and 37.5% wear respiratory mask and boots.

The respondents also disposed empty pesticides containers and the remaining pesticides. Table 3.2 indicates that 30.0% disposed by burying or land fill, 32.5 % burnt, 30.0% just threw them on the farm and 7.5% burnt and then buried in the farm. These disposal methods were also reported by Felix and Sharp, (2016) and Malgie *et al.* (2015). The practice of burying was not safe as it increased possibility of pesticides contamination in the environment, food and underground water (Felix and Sharp, 2016). Disposal by burning is not safe because the burning of empty pesticide containers or pesticide treated biomass oxidizes nitrogen, sulphur, chlorine and phosphorous fragments to toxic gases that when inhaled might kill humans, ecosystem and biodiversity (Rajabu *et al.*, 2017). Therefore, there is need for the government and stakeholders to establish a good system for collection and proper disposal of empty containers and expired pesticides.

There were several other agricultural production activities in which pesticides were used. Forty percent of farmers used pesticides in maize farms, 5.0% farmers used pesticides in tomatoes production and 22.5% farmers used pesticides in maize and tomatoes and 32.5% farmers did not use them in any other crop other than grapes. Application of the pesticides in grape cultivation indicated that 100% of all respondents apply pesticides throughout the production period from pruning time to early fruit development. Others applied pesticides once a week, and this activity was usually done by hired farm labourers. Most of the farmers hired farm labourers for spraying pesticides in farms followed by the farmers themselves and family members. Similar results were also reported by Shetty *et al.* (2010).

Table 3.2: Use and handling practices of pesticides

Variable	Description	Frequency (N=40)	Percentage
What are the common pest and diseases	Downy mildew	1	2.5
	Powderly and Downy mildew	34	85.0
	Powderly and Downy midlew and Late bright	5	12.5
	Linkimil and Xantho	14	35.0
Pesticides used	Linkimil, xantho nd Ridomil	25	62.5
	Linkimil, Master Kinga, Anvil and Xantho	1	2.5
Purchase of pesticides	Chemist/Agricultural inputs shop	40	100
Have you changed pesticides	Yes	3	7.5
	No	37	92.5
Reading the pesticides label	Yes	36	90.0
	No	4	
			10.0
Wearing personal protective equipments when applying pesticides	Yes	11	27.5
	No	29	72.5
If not why	Too expensive	8	20.0
	Not available	3	7.5
	Uncomfortable		
Which personal protective equipments worn	Gloves	1	2.5
	Respiratory mask	11	27.5
	Shoos/boots	4	10.0
	Long sleeves, gloves, eye glasses	8	20.0
	Respiratory mask and boots	15	37.5
Ways of disposing empty containers	Burying	12	30.0
	Burning	13	32.5
	Throwing in the farm	12	30.0
	Burning and burying	3	7.5
Other agricultural activities in which pesticides are used	Maize	16	40.0
	Tomatoes	2	5.0
	Maize and Tomatoes	9	22.5
	None	13	32.5
Observing withholding period	After pruning to early fruit development	40	100.0
	Yes	39	97.5
	No	1	2.5

Table 3.2 shows that 97.5% of the respondents observed the withholding period because when the fruit started ripening pesticide were not applied. That is usually about 40 days before harvesting, while 2.5% of farmers did not practice this. Moreover, this study indicated that most of the farmers in Dodoma Urban and Bahi districts did not know how to use and handle pesticides properly. This is similar to other reports where small-scale farmers were observed to have some knowledge on the names and effects of the pesticides used but lacked knowledge on toxicity and proper pesticide mixing practices (Kiwango *et al.,* 2018).

3.4.1.3 Safety of pesticides

Results in Table 3.3 indicate that 67.5% of the farmers did not report cases of illness during use and handling of pesticides, while 32.5% reported cases of illness associated with use and handling pesticides. The most common symptoms that were reported by farmers were; problems in eyes (67.5%), skin irritation (5.0%), headache (12.5%) and headache and flue (15%) in Table 3.3. The symptoms associated with acute exposure to pesticide residues in human include coughing, nausea, vomiting, abdominal pain, headache, diarrhoea and loss of vision (Ngowi *et al.,* 2007; Oesterlund *et al.,* 2014; Kiwango *et al.,* 2018). Chronic exposure to pesticide residues is associated with endocrine disruption, neurotoxicity, cytogenetic damage and effects in the reproductive and immunological system (Kim *et al.,* 2017).

Another observation was that 97.6% (Table 3.3) of the respondents had no information on any case of poisoned person due to use and handling of pesticides but 2.5% reported cases of poisoned by pesticides. This could be due to underreporting the poisoning by pesticides. The farmers who suffer mild poisoning might not regard the symptoms as sufficiently important to seek medical, or might have become habituated to symptoms as normal for farming practice (Lekei *et al.*, 2016). About 92.5% of the respondents reported that they did not notice any environmental changes after use of pesticides, while 7.5% noticed environmental changes after use of the pesticides and observed drying of some plants.

Table 3.3: Awareness of ill-health effects caused by pesticide residues in Dodoma Urban and Bahi districts

Variable	Description	Frequency (N=40)	Percentage
Any reported cases of illness due to use and handling of pesticides	Yes	13	32.5
	No	27	67.5
What were the symptoms	Problem in eyes	27	67.5
	Skin irritation	2	5.0
	Headache	5	12.5
	Headache and flue	6	15.0
Has anyone poisoned by pesticide	Yes	1	2.5
	No	39	97.5
Have you noticed any environmental changes after use of pesticides	Yes	3	7.5
	No	27	92.5
Remarks on how should pesticides use be improved in Tanzania	Training on proper use and handling	23	57.5
	Improve enforcements of law too traders of pesticides to get proper products.	12	30.0
	Training and enforcements should be emphasized	3	7.5
	No remark	2	5.0

Opinions of respondents on how should the use of pesticides in Tanzania could be improved, showed that 57.5% proposed that training of farmers on proper use and handling of pesticides should be conducted, 30.0% proposed/suggested that improvement of enforcement of law to traders dealing with pesticides in order get proper and registered pesticides, 7.5 suggested that both training and enforcement of law should be emphasized and 5.0% had no comment/remarks. This study supports remarks made by Rajabu *et al.* (2017), that training on safe use of pesticides to stockiest and fumigators could be conducted by different stakeholders including institutions, such as, the Tropical Pesticides Research Institute (TPRI) and agricultural extension workers.

3.4.2 Processors

3.4.2.1 Demographic characteristics of processors

In this study, 15 processors were interviewed. Their ages ranged from 20 to59 years (Table 3.4) the respondents were placed into four age categories. The majority of the respondents (46.7%) 40 to 49 years old group followed by 26.7% of respondents who aged above 50 years.. The results of the study indicated that 86.7% of respondents were male and only 13.3% of them were female. About 46.7% of respondents attended primary education, 26.7% attended secondary school and 26.7% attained college education. The capacity of production per year for the processors was categorized into 3 groups: 26.7% produced between 1000-10 000 liters of wine, 66. 7% produces between 100, 001 and 1 000 000 liters, and 6.7 % produces above 1 000 000 liters of wine (Table 3.4).

Table 3.4: Demographic characteristics and production capacity of grape wineprocessors in Dodoma Urban and Bahi districts

Variable	Description	Frequency (N=15)	Percentage
Age	20-29	1	6.7
	30-39	3	20.0
	40-49	7	46.7
	%0 and above	4	26.7
		7	46.7
Level of education	Completed primary	4	26.7
	Secondary education	4	26.7
	Completed College		
		1	86.
		3	7
		2	13.3
Sex	Male		
	Female		
		8	53.3
		7	46.7
How many employees	1-4		
	5-49		
		4	26.7
		10	66.7
Capacity of production per year	1000-10000 liters	1	6.7
	100 001-1 000 000 Liters		
	Above 1 000 000 liters		

3.4.2.2 Pesticides handling practices

Table 3.5 indicates that 20.0% of processors obtained grapes from their own industry farms, 26.75% purchased from different farmers and 53.3% procured/sourced both from their private farms and different farmers. The results indicated that the determination of sugar concentration was the main criterion used by the processors to determine the quality of supplied grapes. The respondents acknowledged that grape pests and diseases necessitated the application of pesticides. Although it was observed that no precautions were taken by the processors to procure pesticide-free grapes, it is crucial to ensure that precautions were taken in order to obtain raw materials that were free from pesticide residues. For example, no tests were carried out by any of the processors to determine the level of pesticides residues in procured grapes. According to Jiang *et al.* (2009), grapes are usually harvested and directly used for follow-up fermentation without washing or processing. Therefore, among other best practices, withholding period after pesticide application should be considered in order to minimize the presence of pesticide residues in final products and promote safety.

This study indicated that 93% of the processors did not carry out any test to determine pesticide residues because of lack of testing equipment and 6.7% did not test because of lack knowledge on pesticides. Also 93.3 % of the processors did not take action to reduce pesticide residues from grapes, while 6.7% washed grapes before processing (Table 3.5). Most of the processors avoided the washing process on pretence that it removed the natural fermenting yeasts necessary for spontaneous fermentation of grapes for wine manufacture. Unfortunately, this practice promotes pesticides contamination of grapes and wine.

Grapes are usually harvested and directly used for fermentation without washing this might lead to the presence of pesticide residues in wine for sale to the public. Therefore, the determination of pesticide residues in wine is vital to ensure pesticide-free wines for safety of consumers and promotion of domestic and international trade

Table 3.5: Pesticides handling practices among grape wine processors in Dodoma Urban and Bahi districts

Variable	Description	Frequency (N=15)	Percentage
Source of raw materials	Own industry farm	3	20.0
	Different farmers	4	26.7
	Own industry farm and from different farmers	8	53.3
Criteria for receiving	Measuring level of sugar	15	100
Knowledge on grape pest and disease that necessitate use of pesticides	Yes	15	100
Precautions in getting grapes that are free from pesticides	None	15	100
Test performed to test pesticides before receiving grape	No	15	100
Reason to why they do not test	Lack of instruments		
	Lack of knowledge on	14	93.3
	Pesticides	1	6.7
Practice done to reduce the pesticide residues before processing	Washing		
	None	1	6.7
		14	93.3

3.4.3 Awareness of agricultural officers

Agricultural officers in t four wards namely, Hombolo Bwawani, Mbabala, Mpunguzi and Mtitaa offered on-farm training to farmers in the use and handling of pesticides. They also paid follow up to monitor proper application of pesticides all the respondents replied that, common pests and diseases which affect grapes in their location included: powdery mildew, downy mildew, grey mould and late blight. The pesticides recommended for use by farmers for pests and diseases included Ridomil or Linkimil (Metalaxy and Mancozeb), Master Kinga, Xantho (Hexaconazole), Falfone 25WP (Triadimefon) and Twigamox (Mancozeb and Cymoxanil). Ngowi *et al.* (2016) also recommended that agricultural extension workers should guide farmers on best practices, including safe handling practices of pesticides.

3.5 Conclusion

The results indicated that pesticide management practices were poor. It was observed that there was lack of compliance with recommended practices such as not following instructions on pesticide disposal practices and lack of use of personal protective equipment during application of pesticides due to higher cost, discomfort and/or unavailability of such equipment. This could lead to human ill-health and environmental pollution due to exposure to pesticides. Creation of awareness and use of best practices by commodity value chain stakeholders is recommended.

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CHAPTER FOUR

4.0 Overall Conclusions and Recommendations

4.1 Conclusions

This study investigated the levels of pesticide residues in grape wine produced in Dodoma urban and Bahi Districts, Tanzania. The results indicated that, the majority of grape wine samples were contaminated with pesticide residues, some of which had concentrations above the MRL. From the public health perspective, these products were not safe for human consumption. The observed levels of pesticide residue could pose a potential health risks to the public. The study indicated that pesticide management practices were poor and there was lack of compliance with the recommended best practices. This could cause ill-health to consumers and environmental pollution.

4.2 Recommendations

From the findings of this study the following are recommended;

i. Surveillance should be conducted on larger number of samples of grape wine in and to perform assessment of health risks associated with pesticide residues in Tanzania.

ii. Grape wine processors should frequently test their products to determine the pesticide residue levels (at least twice a year in certified laboratories to assure the quality of their products).

iii. Create awareness and educate pesticide users and the stakeholders best practices such as good agricultural practices including proper pesticide application.

iv. The high priority should be given to develop strategies for pesticide reduction in agriculture through promoting alternatives to chemical pest control such as biological control.

v. Intervention strategies by regulatory agencies such as Tropical Pesticides Research Institute (TPRI) should be developed to strengthen the enforcement mechanisms of current pesticide laws at the farm and retail level which are a necessity in promoting safe pesticide use. Trainings to farmers on adherence to pesticides instructions, especially pre-harvest intervals and correct dosage needs to be ensured.

APPENDICES

Appendix 1: Questionnaire

Farmers

A. Personal information

1. Farmer's name …………………………….................Age: ……………………

2. How many people live in your home …………………………..

3. Location: Hombolo bwawani ( ) Mpunguzi ( ) Mbabala ( ) Mtitaa ( )

4. Main crops cultivated: Cash ………………………………………..

Food ……………………………………….

5. What is the level of education attended? I) not attended ( ) Primary ( )

Secondary ( ) Degree ( )

6. Which months of the year do you harvest grapes? ……………………………………

B. Pesticides use and handling practices

7. Which are the most common grape pests and diseases in your area?

i)…………………………………….

8. What pesticides do you use to treat grape pest and diseases (in order of preference?)

1)……………………... 2)…………………………. 3) …………………………

9. Which other ways do you use to protect your grapes from pest attack other than using the Pesticides mentioned in (8) above. Give 3 different ways if any.

1)……………………..2)………………………..3)………………………….

10. Where do you obtain your pesticides? Open market ( ) Shops ( ) Chemist ( )

11. Have you ever changed from one pesticide to another? Yes ( ) No ( )

If yes why?

Reason……………………………………………………………………………

12. Have you had any training in pesticide handling? Yes ( ) No ( )

13. Do you always read the label on pesticide before using? Yes ( ) No ( )

14. Do you wear personal protective equipments when applying pesticides?

( ) Yes ( ) No

If no, please pick one: ( ) too expensive ( ) not available ( ) uncomfortable other

(Specify): ……………………………………………………………………

If yes, check one or more of the following: gloves ( ) overalls ( ) eye glasses ( ) respirator face mask ( ) boots/shoes ( ) long-sleeve shirt ( ) long pants ( ) other (specify):

15. How do you dispose the following materials? (i) Unused pesticide…………………

(ii) Empty pesticide containers…………………………..………………………..

16. In which other agricultural activity do you use pesticides?

Activity Pesticide Used: 1)………………… 2)………….....3…………

17. When pesticides are applied in the field? …………………………………………

18. Do you observe the pesticides with holding period before you harvest your grapes for Selling? Yes ( ) No ( )

19. If no in 18 above give reasons……………………………………………………….

C. Information of health effects of pesticides

20. (a) Is there any reported cases of illness during handling and use of pesticides?

Yes ( ) No ( )

(b) What were symptoms of illness in 18 (a) above …………………………………

21. Has any person been reported as poisoned by pesticides? Yes ( ) No. ( )

22. Have you ever noticed any environmental change after application of pesticides?

Yes ( )

No ( )

If yes explain how: …………………………………………………………………..

23. In your opinion how should pesticide use be improved in this country: ………..…..

(Thank you for your cooperation)

Processors

A. Personal information

1. Name …………………………………..…………….. Age: …………….

2. Name of the Industry ……………………………………………………….

3. Location: …………………………………………………………………

4. What is your position in the industry: …………………………………………

5. What is the level of education attended? ………………………………......

6. How many employees do you have in your industry?

(i) 1-4 employees ( )

(ii) 5-49 employees ( )

(iii) 50-99 employees ( )

(iv) Above 100 employees ( )

7. What is the capacity of wine production per year …………………………….

B. Pesticides handling practices

8. Where do you get the grapes as raw materials for your industry?

i) Own industry farms ( )

ii) Contract farmers ( )

iii) Different farmers ( )

iv) Importation ( )

9. What criteria do you use in receiving the raw materials? (Grapes)

i)………………………………………………………………………………

ii)……………………………………………………………………………….

iii)………………………………………………………………………………

10. Do you know that there are grapes pest and diseases which necessitate the use of Pesticides in grape vineyard Yes ( ) No ( )

11. If yes in 9 above what precautions do you take in order to get raw material which are free from Pesticides residues?

i)……………………………………………………….…………………………….

ii)……………………………………………………………………………………..

12. Do you perform any test to ascertain the amount of pesticides residues in the grapes before receiving from your suppliers? Yes ( ) No ( )

13. If no in 12 above why………………………………………………………………

14. What practices do you do in order to reduce the pesticides residues load in your grapes before processing? 1……………………………. 2……………………………....

(Thank you for your cooperation)

Agricultural Officers

A. Personal information

1. Name …………………………………………….. Age: ………..………….

2. Location: ……………………………………………………………………

4. What is your position: …………………………………………………………

5. Which wards do you save (i)…………………………… (ii) …………………

B. Pesticides use and handling practices

6. Which is the most common grapes pest and diseases do you know:

i)……………………………………………….…….

ii)……………………………………..…………

7. What pesticides do you advice your farmers to use to treat grapes for cropping (in order of Preference?)

1……………………..….. 2……………………….. 3……………………………….

8. Where do you advice your farmers to buy pesticides? Open air market ( ) Shops ( ) Chemist ( )

9. Do you provide any training in pesticide handling and use to your farmers?

Yes ( ) No ( )

10. If yes in 9 above how many times do you provide training in a year?

Once ( ) twice ( )

Other mention……………………..

11. If No in 10 above give reasons? ……………………..

12. Do you visit your farmers in their farms to observe how do they practice what they learnt? from the training? Yes ( ) No ( )

13. If No in 12 above give reasons……………………………………………………

C. Information of health effects of pesticides

14. (a) Is there any reported cases of illness during handling and use of pesticides?

Yes ( ) No ( )

(b) What were symptoms of illness in 14 (a) above ………………………………….

15. Have any person been reported as poisoned by pesticides? Yes ( ) No. ( )

16. Have you ever noticed any environmental change after application of pesticides?

Yes ( ) No ( )

If yes explain how: ……………………………………………..……………..

17. In your opinion how should pesticide use be improved in this country?

…………………………………………………………………………………

(Thank you for your cooperation

Appendix 2: Anova table for analysed Pesticides

```
> siaov=aov(Concentration~Pesticides+Brand+Irr_scheme+Scale+Color, data=silong)
> summary(siaov)
              Df Sum Sq  Mean Sq F value  Pr(>F)    
Pesticides    48 0.9046 0.018846  30.317 < 2e-16 ***
Brand          1 0.0001 0.000063   0.102 0.74964    
Irr_scheme     2 0.0024 0.001206   1.939 0.14401    
Scale          2 0.0000 0.000020   0.033 0.96796    
Color          1 0.0048 0.004844   7.793 0.00529 ** 
Residuals   2444 1.5193 0.000622                    
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
$groups
                       Concentration groups
Pyroquilon              1.066443e-01      a
Ethofumesate            6.249560e-02      b
DEET                    4.934122e-02     bc
Chloroneb               3.818980e-02      c
Azobenzene              1.508713e-02      d
Metalaxyl               1.151401e-02      d
Chloropyrofos           3.099544e-03      d
Cypermethrin_III_beta   2.883268e-03      d
Deltamethrin            2.120878e-03      d
Cyproconazole           1.534474e-03      d
DDT_o_p                 1.170549e-03      d
Cycloate                9.185573e-04      d
Thiometon               7.465109e-04      d
Endosulfan_1            6.709371e-04      d
Phosmet                 6.691568e-04      d
Metazachlor             6.084819e-04      d
Chlormephos             3.685409e-04      d
Dipnenylamine           3.658564e-04      d
Demeton_S_methyl sulfon 2.711683e-04      d
Mevinphos               1.441949e-04      d
Chloropropylate         6.982249e-05      d
Tubuconazole            2.328948e-05      d
Piperophos              1.098323e-05      d
Nitrapyrin              4.165017e-06      d
Butafenacil             0.000000e+00      d
Chlorothalonil          0.000000e+00      d
Cloquintocet_mexyl      0.000000e+00      d
Cyanofenphos            0.000000e+00      d
Cyfluthrin_I            0.000000e+00      d
Cyphenothrin_II         0.000000e+00      d
Dichloroaniline         0.000000e+00      d
Diclobutrazole          0.000000e+00      d
Diphenamid              0.000000e+00      d
Esfenvalerate_II        0.000000e+00      d
```