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Review

Assessment of Health Risks Linked to Pesticide Residues in Tomatoes Cultivated in Tanzania

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Tomato contributes the highest percent to the fruit and vegetables consumed in Tanzania. Its high consumption is attributed to the presence of bioactive compounds and vitamins known to prevent non-communicable diseases. Pesticides used to control pests and diseases cause direct accumulation of pesticide residues in food. Consumption of pesticide contaminated tomato increases the risk of pesticide exposure. This review is on types of pesticides used in tomato production, health effects of pesticides, levels of pesticide residues in tomatoes, dietary pesticide exposure, awareness on pesticides effects and preventive measures as well as policies governing pesticide use in Tanzania. Clearly, there is evidence of extensive use of pesticides in tomato production, limited knowledge regarding pesticide use, as well as weak regulatory framework for pesticide use. Importantly, levels of pesticide residues in tomatoes consumed in Tanzania exceed the recommended maximum residual limits. In order to assure pesticide safety of food, there is a need to identify and control farmers' practices which are highly associated with pesticide contamination in tomatoes.

Key words: Contamination, exposure, pesticide, residues, tomato.

INTRODUCTION

Tanzania's economy is highly dependent on agriculture, which accounts for 26% of the gross domestic product (GDP) and about two-thirds of the total exports. Tomato (*Solanum lycopersicum)* is the single most dominant vegetable crop which contributes the highest percentage (63%) of all annually harvested fruits and vegetables in Tanzania (Ministry of Agriculture Food Security and Cooperatives, 2012; Putter et al., 2007). A survey done by Match-Maker-Associates-Limited (MMA, 2008) shows that, tomato production in Tanzania is basically in the temperate areas including Southern and Northern highlands. According to MMA (2008) and Mushobozi (2010), among regions cultivating tomatoes, Morogoro has the largest area of about 2,442 ha (9.2% of its land), followed by Kagera (2386 ha, 9%), Tanga (2,326 ha, 8.7%), Mwanza (2,235 ha, 8.4%) and Iringa (2,223 ha, 8.4%). The biggest markets for tomato are urban areas including Dar es Salaam, Mbeya, Moshi and Arusha

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(MMA, 2008; MUVI-SIDO, 2009). Muunganisho wa Ujasiriamali Vijijini- Small Industry Development Organization (MUVI-SIDO, 2009) reported that, in Tanzania, tomatoes are consumed as fresh, cooked or processed into various products including sauce, ketchup, chutney, jam and base of other sauces.

Tomatoes contain bioactive compounds including carotenoids and vitamin A, B, C and E which lower the risk of non-communicable diseases (NCD) (Canene-Adams et al., 2005; Frusciante et al., 2007; Ibitayo and Monosson, 2007; MUVI-SIDO, 2009; Raffo et al., 2002; Smith and Eyzaguirre, 2007). Polyphenolic compounds in tomatoes act as free radical scavengers and possess therapeutic power for inflammatory and cardiovascular diseases, obesity, type II diabetes, cancer, neurodegenerative diseases, and aging (Frusciante et al., 2007; Raiola et al., 2014). These beneficial effects increase importance of tomatoes to be a component of daily diets.

Over 50% of global agriculture products is lost prior to or following harvest as a consequence of pests, diseases and weeds (Mushobozi, 2010). It is estimated that, in Tanzania, about 31% of tomatoes is lost due to pest and diseases (MMA, 2008). Farmers use different pesticides to minimize crop loss and increase production to meet the demand of the increasing world population (Hossain et al., 2013). Insecticides are the most common pesticides used in Tanzania for the treatment of 770,036 ha or 71% of the total planted area, followed by herbicides (203, 175 and 19%), and fungicides (105,124, 10%) (Nonga et al., 2011). It has been reported that, there is extensive use of pesticides in tomato production in Morogoro, Manyara and Arusha regions (Busindi, 2012; Ngowi et al., 2007; Nonga et al., 2011). This extensive use is caused by farmers failure to interpret labelling languages and lack of agriculture trainings or extension services (Mdegela et al., 2013; Ngowi et al., 2007). Farmers apply pesticides in mixtures (Ngowi et al.,
2007) and use lambda cyhalothrin (karate) every seven days instead of fourteen days and one day instead of seven days before harvesting (Busindi, 2012). Application of pesticides in a mixture can induce phytotoxicity in tomatoes as a result of interaction between/among the pesticide types (Smit et al., 2002). Most of the pesticide residues from vegetable fields have been detected in soil and irrigation water in Ngarenanyuki and Uwiro estate; the key tomato production area in Arusha region (Kihampa et al., 2010a, b). Improper use of pesticides causes accumulation of residues in foods which decreases the safety and quality of food products and ultimately results in serious health problems (Al-Waili et al., 2012; Dewhurst and Marrs 2009; Kihampa et al., 2010a; Ntow et al., 2006). The most real risk is posed by consumption of fresh food as vegetables and fruits as these have higher levels of residues as compared to processed or semi processed food products (Baig et al., 2009; Price, 2008; Solecki et al., 2005). In Tanzania, tomato processing industry is poorly developed (MUVI-SIDO, 2009). This makes most of the grown tomatoes to be sold as fresh form.

This paper is a review on types of pesticides used in tomato production, health effects of pesticides, levels of pesticide residues in tomatoes, dietary exposure of pesticide, awareness on pesticides effects and preventive measures as well as policies governing pesticides use in Tanzania.

PESTICIDES USED IN TOMATO PRODUCTION

Diseases and pests remain the biggest problem in tomato production in Tanzania (Engindeniz, 2006; Mushobozi, 2010). Some important pests of vegetable crops are whitefly, aphids, thrips, leaf hoppers, caterpillars, mites and nematodes (Mushobozi, 2010; Sithanantham et al., 2002). Whiteflies, moth, cutworms, bollworms, wireworms and aphids are the frequent insect pests in tomatoes, while the acar and fungus pests include mites and bacterial spot, fusarium wilt, early blight, and downy mildew, respectively (Engindeniz, 2006; Mushobozi, 2010; Sithanantham et al., 2002). Table 1 shows the key pest and disease problems in tomatoes, requiring the use of pesticides. The problems are rated for their importance to the effect on crop yield and pesticide residues. Integrated pest management (IPM) requires that pesticides are used as the last solution and after their effectiveness and non-hazardous nature to the environment have been proven (Mushobozi, 2010).

Pesticides are classified according to their chemical classes such as organochlorines, and organophosphates; or based on their target action such as acaricides, herbicides or insecticides; or by their biochemical mode of action (MoA) (Tsipi et al., 2015).

In Tanzania, pesticides are regulated according to the Plant Protection Act (No 13) of 1997 and the Plant Protection Regulations of 1999 which require all pesticides to be registered before sale and use. Pesticide registration is a regulatory requirement which involves scientific process to examine the physical and chemical properties of the pesticide, its effectiveness, and likelihood of causing hazard to human health and environment (Damalas and Eleftherohorinos, 2011; Mushobozi, 2010). The body responsible for registration of pesticides in Tanzania is the Tropical Pesticide Research Institution (TPRI). Some pesticides registered by TPRI for use in tomato and other vegetables in Tanzania are chlorpyrifos, dioctyl sodium succinate, deltamethrin, dimethoate, fastac,alphacypermethrin, fenvalerate, lambda cyhalothrin, azadirachtin, copper hydroxide, mancozeb, folpet and carbofuran (TPRI, 2007). As of 2013, the active ingredients for most of these pesticides are gramoxone against weeds,

Table 1. Key pest or disease problems and their importance to tomato yield or pesticide residues.

Problem	Species name	Importance		Description
		Tomato yield	Pesticide residue	
Foliar pests				
Spider mites	*Tetranychus urticae*	***	**	Causes severe leaf damage and loss of yield
Glasshouse whitefly	*Trialeurodes vaporariorum*	***	*	Feed on leaves and cause leaves damage as well as cause sooty moulds on fruit.
Tomato leaf miner	*Liriomyza bryoniae*	**	*	Causes leaf damage.
Mealy bugs	*Pseudococcus viburni*	**	*	Cause leaf loss and sooty moulds.
Macrolophus	*Macrolophus caliginosus*.	**	*	Feed on young fruit and cause fruit damage.
Foliar/stem/root diseases				
Grey mould	*Botrytis cinerea*	***	**	Attacks all aerial parts of the plant and causes 'ghost-spotting' on fruit
Powdery mildew	*Oidium neolycopersici*.	**	*	Attacks leaves, stems and calyces
Verticillium wilt	*Verticillium alboatrum*	**	-	Causes leaf wilt and stem collapse.
Root rots	*Pythium, Phytophthora* and *Rhizoctonia solani*	*	-	Causes reduction in plant vigour and may cause plant collapse and death

*** = High: ** = medium: * = low: - = no importance because associated pesticides were not found or sought. Source: Caspell et al., 2006.

cypermethrine and dimethoate against insects, and metalaxyl, maneb, mancozeb and manizan against fungi (Abang et al., 2013).

The selection and application of pesticides is governed by Good Agricultural Practices (GAPs) promoted by the Ministry of Agriculture, Livestock and Fisheries in Tanzania (Larcher, 2005). Application of GAPs may reduce the risk of exposure to pesticide to some extent. However, absolute avoidance of pesticide residues is not possible even when pesticides are used in accordance with GAPs (Essumang et al., 2008).

Health effects of pesticides

All pesticides can be harmful, but the levels of toxicity vary from pesticide to pesticide. The levels of danger are defined as Ia (extremely hazardous), IIb (highly hazardous), II (moderately hazardous), III (slightly hazardous), or unclassified and normally marked on the pesticide label by colour code or as hazard classification (WHO, 2010). Pesticide toxicity occurs when chemicals intended to control a pest affect non-target organisms such as human beings. The toxicity occurs in three forms which are single short-term very high level of exposure (acute toxicity), long-term high-level exposure and long-term low-level exposure (Gupta, 2011; Hamilton ad Crossley, 2004; Owen and Pickering, 2006). Long-term low-level exposure or chronic toxicity is linked with pesticide residues in food as well as contact with pesticide residues in the air, water, soil, sediment, food materials, plants and animals (Gupta, 2011; Hamilton and Crossley, 2004; Owen and Pickering, 2006). Acute toxicity explains how poisonous a pesticide is to a human, animal, or plant after a single short-term exposure. The effects of acute toxicity appear quickly, or within 24 h of exposure. Acute toxicity can be measured as acute oral toxicity, dermal toxicity and inhalation toxicity. According to Pesticide Safety Education Program (PSEP, 2012) and Kamel and Hoppin (2004), toxicity is the basis for levels warning statements on the pesticide container label. Chronic toxicity is a concern for general public as well as those who work directly with pesticides. It involves pesticide exposure through food, water and air normally determined after three months of either continuous or occasional exposure (Barrett, 2005; PSEP, 2012).

Pesticide poisoning causes mortality and morbidity throughout the world particularly in developing countries (Litchfield, 2005) due to the lack of suitable national Maximum Residual Limits (MRLs), overlapping mandates, complex label instruction, limited trainings in pesticide application procedures or hazard awareness in addition to unwillingness of manufacturers to generate new data for crops of importance to these countries (Agriculture-Consumer-Protection, 2001)

The nature of pesticide toxicity cannot be changed but measures can be taken to prevent the possibility of poisoning and controlling exposure. In other words, the risk of harm from pesticide exposure is equal to how poisonous the pesticide is, multiplied by the amount and route of exposure to the pesticide (PSEP, 2012).

Pesticide effects on the body depend on the length and magnitude of exposure; and toxicity of the chemical. Higher consumers of pesticide contaminated tomatoes have the greatest exposure to these pesticides. Increased risk for health outcomes is higher during a critical period of development, such as conception to puberty (Weselak et al., 2007). Effects of pesticides ranges from mild skin irritation to birth defects, tumours, genetic changes, blood and nerve disorders, endocrine disruption, and even coma or death (Hong-Sheng Wang et al., 2011; Tebourbi et al., 2011). It also affects reproductive, endocrine and immune systems. Chronic exposure causes infertility, neurobehavioral disorder, diseases such as cancer and mutagenic effects (Al-Waili et al., 2012).

In Tanzania, farmers have been affected by direct pesticide exposures which are linked with lack of protective gears. The health effects observed were headache, stomach ache, chest pain, skin and eye irritation, difficulty in breathing as well as nausea and vomiting (Mdegela et al., 2013; Ngowi et al., 2007). There is limited information on health effects associated with pesticide dietary exposure from pesticide contaminated foods in Tanzania, hence efforts need to be taken to generate such information. The only available information was generated by Kariathi et al. (2016) whereby they investigated pesticide exposure from fresh tomatoes.

Intensive application of pesticides affects, in addition to human health, the environment due to residues that remain in different environmental matrices as well as water and air (Mekonen et al., 2014). In Tanzania, pesticide residues were detected in the samples of irrigation water for which frequency of detection was increased for samples collected downstream in the fields as well as in fresh tomatoes (Kihampa et al., 2010b). Despite the established evidence of intensive use of pesticide in tomato production, detectable amount of residues and proven risk of pesticide dietary exposure, there is limited information on the pesticide residual levels from other food products and their associated health risks to consumers in Tanzania.

Dietary exposure of pesticides

Human exposure to pesticides and their metabolites occurs via ingestion of contaminated food, inhalation, across the placenta or dermal contact (Gilden et al., 2010). In the food chain, the exposure is direct, through the consumption of treated foods, or indirect, through the transfer of residues into products of animal origin from treated feed items (Tsipi et al., 2015). Dietary exposure from the ingestion of contaminated food is the primary route of exposure of most pesticides and is the route of exposure for the general population (Aktar et al., 2009; Dougherty et al., 2000; Gilden et al., 2010; Matthews, 2006; Oates and Cohen, 2011). Consumption of pesticide active ingredients through food ingestion has been shown to be up to five times higher than other exposure routes like ingestion of drinking water and air inhalation. Fresh food consumption bring serious problems as they are expected to contain higher pesticide residue levels than other food groups (Pavel et al., 2013; Pogăcean et al., 2013; Solecki et al., 2005). This implies that consumers have to be guided in terms of how to choose pesticide free tomatoes or process them to reduce contamination.

Pesticide residues levels in tomatoes

The need for intensive use of pesticides in horticultural crops means that farmers have to be knowledgeable on how to apply them. However, it has been confirmed that pesticide application knowledge is very limited amongst farmers in Tanzania. Ngowi (2002) reported that, farmers in East Africa use hazardous pesticides though most of the pesticides approved for use in Tanzania are reducing in the level II which is moderately hazardous (Nonga et al., 2011). Also, vegetable farmers in the Northern zone of Tanzania, lack appropriate knowledge and skills of safe pesticide handling and use (Ngowi et al., 2007). The poor knowledge is evidenced by farmers practice of applying different formulations so as to cure serious pest problems (Ngowi et al., 2007). Additionally, farmers are not aware of authorized maximum residue limits for pesticides in food, approved and prohibited substances, acceptable dose level, choice of pesticides, restrictions on use and pre-harvest interval (PHI) (Mushobozi, 2010; Sithanantham et al., 2002). The involvement of extension services in pesticide application is thus crucial (ESRF, 2010).

The limited knowledge on pesticide application and awareness of pesticide impacts on human health causes unacceptable levels of pesticide residues in foods. In the survey of pesticide residue in Cameroon, fresh tomato was one of the products for which at least one result had greater than the limit of detection (LOD) among the locally produced foods (Gimou et al., 2008). Tables 2 and 3 show pesticide residues in tomatoes in some European, and African countries including Tanzania. In these tables, tomatoes from both European and African countries have detectable pesticide residues and some have even exceeded the MRL which might pose health risks to consumers.

Effects of processing on pesticide content in food

Good agricultural practices (GAP) and good manufacturing practices (GMP) are very crucial in lowering the risks associated with pesticides exposure in tomatoes if observed. In most areas with intensive use of

Table 2. Pesticide residues above the legal limit reported in tomatoes from European and Asian countries.

Country	Pesticide	Residue(mg/kg)	[1]MRL (mg/kg)	Reference
Italy	Chlormequat	0.20	0.05	PAN-UK (2006)
Italy	Chlormequat	0.07	0.05	
Spain	Chlormequat	1.50	0.05	

[1]MRL- Maximum residue limit.

Table 3. Pesticide residue levels in tomatoes from some African countries.

Country	Pesticide	Mean residue (mg/kg)	MRL (mg/kg)	Reference
Nigeria	p,p'-DDE	0.058±0.0110	0.1	Benson and Olufunke (2011)
	p,p'-DDD	0.086±0.086	0.1	
	p,p'-DDT	0.046±0.010	0.1	
Ghana	Chlorpyrifos	0.046±0.01	0.5	Bempah et al. (2012)
	Cypermethrin	0.035±0.005	0.5	
	Permethrin	0.015±0.015	0.05	
	p,p'-DDE	0.013±0.009	0.05	
	p,p'-DDT	0.012± 0.006	0.05	
	Fenvalerate	0.014±0.008	0.1	
	Diazinon	0.009±0.003	0.5	
	Dimethoate	0.013±0.009	0.02	
	P-methyl	0.017±0.007	0.2	
	Malathion	0.038±0.032	3.0	
Egypt	Fenpropathrin	0.080±0.01	0.01	Ahmed et al. (2014)
	L-Cyhalothrin	0.070±0.01	0.1	
	Ethion	0.270±0.005	0.01	
	Malathion	0.025±0.005	0.5	
	Chlorfenapyr	0.030±0.01	0.05	
	Profenofos	0.181±0.01	0.05	
Tanzania	Chlorpyrifos	7.528	1.0	Kariathi et al., (2016)
	Permethrin	5.289	1.0	
	Ridomil	2,854.729	0.5	

DDE = Dichloro-diphenyldichlorethylene, DDD = dichloro-diphenyldichlorethane, DDT = dichloro-diphenyltrichloroethane, L = Lambda, P = Pirimiphos.

pesticides, food safety has become a major public health concern (Aktar et al., 2009). Household tomato processing such as washing and peeling may reduce pesticide residues to some extent (Kwon et al., 2015) though they are unable to clear all pesticides. Tomato drying and boiling to produce jam and paste are commonly industrial processing technologies in Tanzania (MUVI-SIDO, 2009) which tend to increase pesticide residues due to evaporation which concentrate pesticides (Kwon et al., 2015). Since tomato processing technologies in Tanzania are poorly developed and are not capable of reducing pesticide residues in tomatoes, an assessment on the extent of pesticide contamination as well as the consumption pattern for tomatoes in order to be able to advice on appropriate preventive measures against exposure of pesticides in Tanzania is recommended.

Consumers' awareness on pesticides effects and preventive measures

In European countries, consumers are anxious about the pesticide residues in their food and want to avoid them as much as possible (Keikotlhaile and Spanoghe, 2011; Petersen and Jensen, 2012). In Turkey and possibly other countries, consumers are also willing to pay a higher price for slightly damaged vegetables because it is clear that the use of pesticides was low, and so residues are low (Engindeniz, 2006). In a study conducted in Nairobi-Kenya by Ngigi et al. (2010), it was observed that consumers purchase fresh vegetables in supermarkets and specialty stores because they perceive vegetables sold in such stores are safer than those in the wet markets. As in other countries around the world, consumers in Tanzania are willing to pay premium for pesticide free tomatoes and choose organic and inspected products to be free from pesticide residues (Alphonce and Alfnes, 2012). This observations show the importance of formulating and implementing measures that can assure the consumers that tomatoes from Tanzania are free of unacceptable pesticide residual levels.

REGULATION OF PESTICIDE RESIDUES IN FOODS

Generally, pesticide contamination in tomato occurs during production, post-harvest handling or other unit operations (Mushobozi, 2010). Tomatoes are highly targeted in chemical treatment against pests than other vegetables (Abang et al., 2013; Mdegela et al., 2013) and there is a high risk for presence of residues at levels that exceed the MRL. The MRL for most registered pesticides used in Tanzania ranges from 0.2 to 5 mg/kg for tomatoes (Codex, 2013). Levels above MRLs occur when GAPs or post-harvest preventive measures are not followed. Non-observance of GAPs can include the use of non-approved protocols linked to wrong pesticide selection, incorrect dosage, poor observation of harvesting interval, wrong calibration of sprayer, inadequate cleaning between uses as well as contamination of produce due to pesticide storage conditions (Al-Waili et al., 2012; Mushobozi, 2010).

The Tanzania Food and Drug Authority (TFDA) is responsible for protecting consumers against the consumption of unsafe food products. It regulates both imported and domestically produced foods by enforcing Tanzania Food, Drugs and Cosmetics Act (No 1) of 2003. The major challenge is enforcement of MRLs as most of tomatoes are consumed fresh and sold in informal market. There is a need for a risk assessment which will advise on the level of pesticide exposure through the informal sector tomatoes.

CONCLUSIONS

Farmers in Tanzania apply pesticides intensively in tomato production because the crop is highly susceptible to infestation and diseases. Available reports show that most farmers in Tanzania are unaware of good practices for pesticide application. Based on these reports, there is evidence that, tomatoes grown and consumed in Tanzania contain pesticide residues at levels that can harm the consumers. In view of the worries, there is an urgent need to generate more data on levels of pesticide residues in tomato and other food products from Tanzania and use the data to perform a risk assessment to estimate the risk of exposure of pesticide residues in Tanzania. The outcome of the exposure assessment and those of the recent assessment by Kariathi et al. (2016) can be used in advising the government on strategies that can be employed to prevent improper application of pesticides in food production and protect the general public from exposure of pesticides. These will ensure permanent access to safe food products by all the consumers and protect them from health effects of pesticides.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

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