# ASSESSMENT OF PESTICIDE MULTIPLICITY IN POTATO PRODUCTION AND STORAGE IN BOMET, KENYA

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## ABSTRACT

Potato (*Solanum tuberosum* L.) crisps are among the most appealing potato products to middle and high income households including women, youth and children and are produced from potatoes mainly grown in Bomet County. A cross-sectional survey was done in 305 potato growing households in Bomet County to establish categories of pesticides used in potato production and storage, level of awareness of pesticide residues and perceptions of risks associated with pesticide contamination at ingestion of potato and its products. Questionnaires were administered through simple random sampling of potato farmers, disaggregated according to their gender, level of education and age. The parameters of interest were type of pesticides applied, knowledge of banned or restricted pesticides and knowledge of presence of pesticide residues in potatoes and risks involved. Data was collected using open data kit (ODK) and analysis done using Statistical Package for Social Science (SPSS) software version 21. Descriptive statistics were used to generate socio-demographic characteristics (gender, age, education levels) and analysis of variance (ANOVA) was performed on the data about knowledge of pesticides. Results are presented as percentages, means and frequency distribution. Differences between the means were calculated at 95% level of significance using Fischer's test. The study showed that 72% of the respondents were male and 28% female. Most of the potato farmers aged between 20- 59 years (87.2%). A majority of the sampled farmers (26.9%) had up to tertiary level education while 31% attended primary school only. About 95% of the respondents used fungicides to control late blight while 14% used insecticides for pest control. It is worth noting that only 0.6% of the respondents used dimethoate and Diazinon, restricted/banned chemical compounds in Kenya. A significant number of fungicides (47%) used were WHO classification class II which are moderately hazardous. Most respondents (79%) could not tell which pesticides had high residues. However, majority (84%) perceived that potatoes in the markets or those cooked at home, restaurants or hotels contained pesticide residues which could harm consumers. The study demonstrated the need for more awareness creation on appropriate pesticide use and sensitization on pesticide residues in potato production.

**Key words:** Dimethoate, Dutch Robyjn, potato crisps, pesticide residues; pesticide toxicity.

## INTRODUCTION

The world population is increasing exponentially demanding intensification and industrialization of agriculturally produced food items to meet increasing demand for food (FAO, 2011). Urbanization, global travels and changing consumer habits has triggered growing consumer demand for wider variety of food items (Lombard, 2017). In addition, climate change worsens the situation since weather dependent- agricultural activities are directly affected, resulting to crop losses, poor or no yields and escalated pest and disease pressure (Awajobi and Tetteh, 2017). This has led to excessive use of pesticides.

Potato crisps are processed from potato variety 'Dutch Robyjn', which is mainly grown by potato farmers in Bomet County are a favorite among high and middle income population in Kenya (Sophie, 2018). Potato field production involves intensive pesticide application from emergence up to harvesting, and sometimes to storage. For this reason, knowledge on category of pesticides used during field production and storage as well as intensity of pesticide used is vital for consumers in understanding health risks due to pesticide toxicity exposure. Despite the fact that several studies have been conducted on vegetables, no studies have been done on potato produced in Bomet County to establish which type of pesticides are applied during field production of potatoes or level

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of knowledge and perception about possibilities of pesticide residues in potato and potato products (Devi *et al.*, 2018). This paper reports on pesticides used during potato production in Bomet County. Specifically, this paper reports on the type and class of pesticides used in potato production and inventorize pesticides used, level of perception and understanding of potato farmers towards potato pesticide residues. Information from this study will help to develop effective strategies towards awareness creation on risks associated with pesticide residues exposure and safe use of recommended pesticides.

## MATERIALS AND METHODS

### Experimental site

The study was conducted in Bomet County of Kenya located in the south of the Rift valley, which has the highest number of households growing potato variety 'Dutch Robyjn' (Sophie, 2018). Bomet county is situated 0º 29' and 1º 03' S and 35º 05' and 35º 35' E, bordering with Kericho to the north, Nyamira to the west, Narok to the south and Nakuru to the north-east (Figure 1a). The county receives mean annual rainfall of 1000 - 1400mm with temperatures ranging from 16 to 24 ºC. In this area, economic activities include tea growing and dairy farming in the high altitudes >2300m a.s.l while growing of vegetables, pyrethrum (*Chrysanthemum cinerarifolium*), maize and rearing of beef animals takes place in the lower altitude 2300 m above sea level (County Government of Bomet, 2018). The questionnaire was pre-tested in Limuru sub-county (Fig.1b) to test for precision and appropriate responses and review was done to amend where needed.

### Design of the study

A cross-sectional study assessing consumer awareness on pesticide use on potato production and exposure to pesticide residues on potato and potato products was done in Bomet Central, Bomet East and Konoin sub-counties, Bomet County. Purposive sampling of sub-counties producing potatoes was done with the assistance of the County Crops Officer. Within each sub-county, sampling of Wards with the highest population of potato growers was prioritized for study. Within the Ward, potato producing farmers who had produced potatoes for at least two seasons were randomly selected for the survey. Within each Ward, with the leadership of

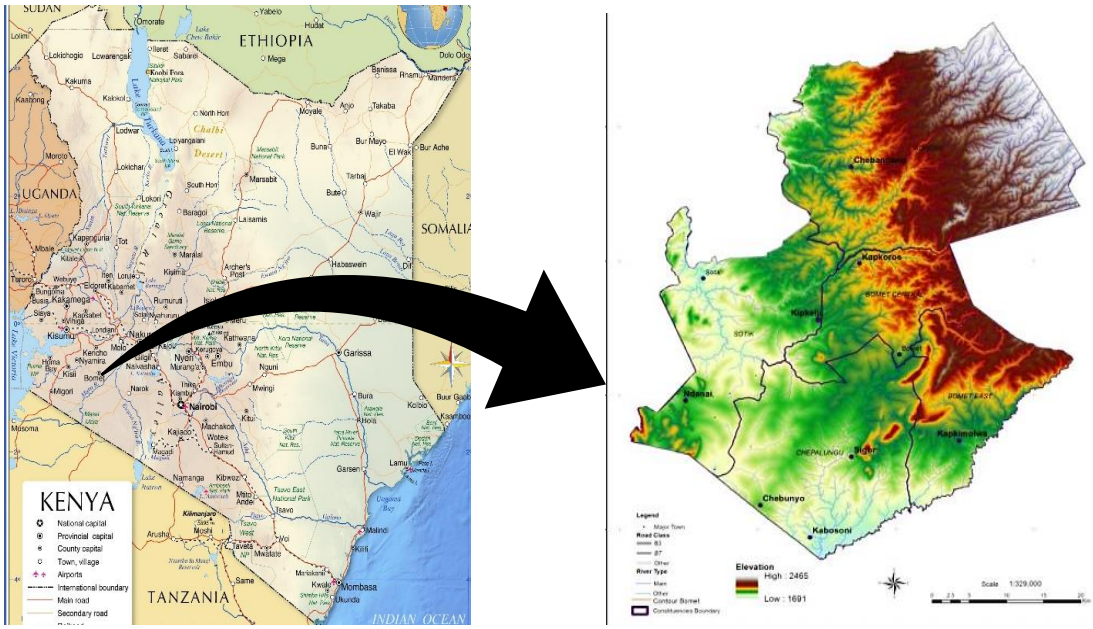


**Figure 1a:** Map of Bomet County and sub-counties. Source: (County Government of Bomet, 2018)

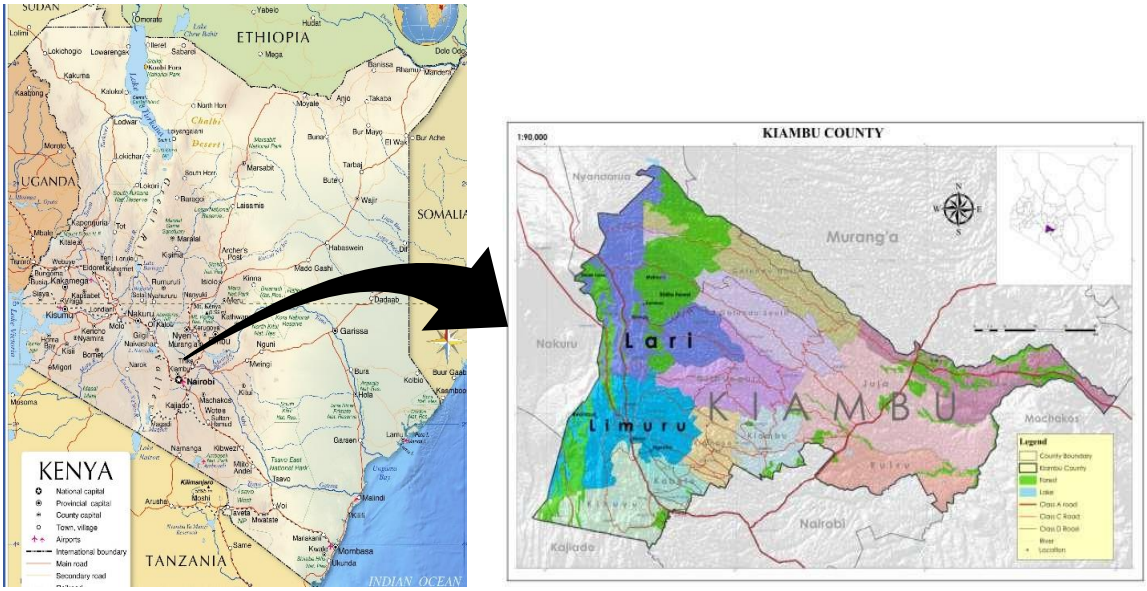


**Figure 1b Map of Kiambu County and sub-counties.** Source: Orbital Geospatial services www.orbital.co.ke.

County Agricultural officer, enumerators were able to cover most of the households in the villages depending on the population density. A total of 305 potato growing farmers were randomly selected and interviewed using a structured questionnaires and face –to –face interviews.

**Sample size**

The proposed number of respondents was 384 obtained by using Cochran's formula (Glen, 2020)., with 50% of the target population and $Z$ score of 1.96 (assuming a 95% level of confidence) standard deviation as 0.5, margin error of -/+5%;

$$n_o = \frac{Z^2 pq}{e^2}$$

Where $n_o$ - the desired sample size if target population is more than 10,000,

$Z$ – the standard deviation at the required confidence level of 1.96 (Z value found in Z table),

$e$ – the desired level of precision (margin of error) i.e., level of statistical significance set,

$p$ – the estimated proportion of the population desired = 1-p

From the study, 384 households were randomly selected to participate in the study. However, 79 households had stopped engaging in potato production or had produced potatoes only for a season, hence were not included in the study.

**Sampling procedure**

In each sub-county, County Agricultural officers were tasked with the responsibility of identifying and recruiting enumerators through personal communication and advertisement placed on their noticeboards. Enumerators were chosen from the list of youths who had participated in previous surveys conducted in the County. The pre-selected criteria was that the potential enumerator must have basic university degree, own a smart phone or tablet, be able to use a smart phone or tablet, experience in conducting similar surveys in the past and have good communication skills. In addition, be fluent in communicating in the local language. A total of five (5) enumerators were hired and were assigned with the responsibility of ensuring questionnaires were properly uploaded on their smart phones or tablets and the number of questionnaires each enumerator would fill daily. The study population consisted of all households and individual potato farmers who had grown potatoes for more than two (2) seasons.

**Data collection**

A semi-structured questionnaire was used for data collection. The tool was uploaded on a digital platform, open data kit (ODK). Socio-demographic data was

collected on age, education level and gender. Data on gender was to understand the gender role in potato farming, since previous study by World Bank Group (2020) showed that up to 56% primary food producers in Africa were women. Data on age was to underpin age factor in potato production. Data about type of pesticides used and perceptions concerning presence of pesticide residues in harvested potatoes, cooked and processed potato products was also collected. Additional information was obtained by interviewing selected key informants who included agro-input dealers, county or national government officials, village elders and opinion leaders in the communities.

Respondents were informed of the intent of the study prior to administration of the questionnaire and consent obtained. In addition, the respondents were informed that their information was not going to be used for any political activities or shared with anyone but will be entirely be utilized in the study and Kenya Agricultural Research organization (KALRO) was the custodian of their information, hence confidentiality of their information was assured.

**Data analysis**

Responses were uploaded onto ODK application and sent to cloud based server. Data was retrieved from the cloud based storage and were cleaned, validated, coded, organized then transferred to Microsoft Excel. Thereafter, data were exported to Statistical Package for Social Science version 21 (SPSS) software and analyzed. Descriptive statistics were used to generate the socio- demographic characteristics (gender, age, literacy levels). Analysis of variance was carried on association of knowledge on pesticide residues with factors such as personal protective gear availability as well as knowledge of the presence of pesticide residues in fruits and vegetables. The differences between the means were calculated at 95% significance level using Fischer's test.

## RESULTS

**Socio-demographic characteristics of the population**

The survey showed 71.8% of respondents were men. A majority of the respondents (53.1%) were 30-49 years old, though it's worth noting that most potato farmers (87.2%) aged between 20-59 years. Most of the respondents (68.9%) had at least primary school education. A minority of the respondents (7%) had not attended school at all (Table I).

TABLE I- PERCENT SOCIO-DEMOGRAPHIC CHARACTERISTICS ON GENDER, AGE AND EDUCATION LEVELS

| Demographic characteristics (n=305) | Variable | Frequency | Percent (%) |
|---|---|---|---|
| Gender | Male | 219 | 71.8 |
| | Female | 86 | 28.2 |
| Age | 20-29 | 60 | 19.7 |
| | 30-39 | 96 | 31.5 |
| | 40-49 | 66 | 21.6 |
| | 50-59 | 44 | 14.4 |
| | 60-69 | 28 | 9.2 |
| | 70-89 | 11 | 3.6 |
| Education level | Never attended school | 02 | 0.6 |
| | Primary school | 93 | 30.5 |
| | Secondary school | 128 | 42 |
| | College | 60 | 19.7 |
| | University | 22 | 7.2 |

**Type of potato varieties grown**

The main potato variety grown in Bomet was 'Dutch Robyjn', followed by 'Desiree' then 'Shangi' (Figure 2). 'Dutch Robyjn' is the preferred variety for crisps processing.

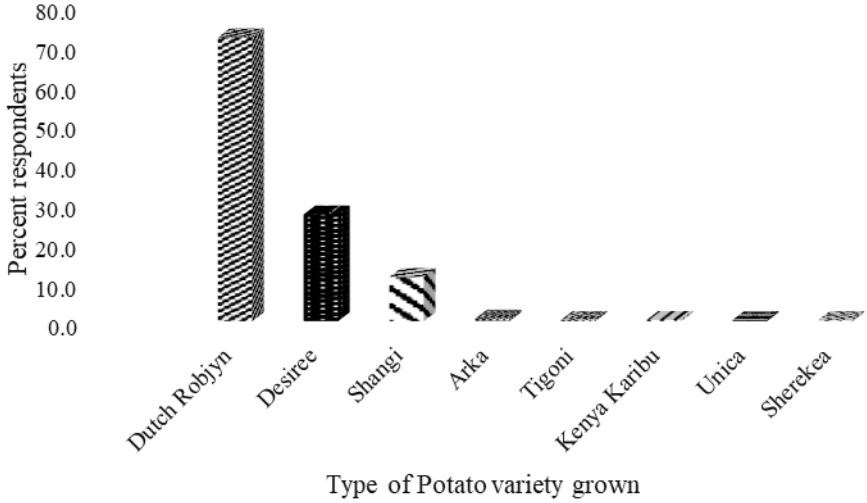


**Figure 2:** Potato varieties (%) grown in Bomet County

**Type of pesticides applied during potato production**

Respondents applied pesticides during field production of potatoes. From the pesticides applied, the most applied pesticide was fungicide, followed by insecticides, then herbicides. A very small number of farmers (1.6%) did not use any pesticides while 0.3% misunderstood foliar fertilizers to be pesticides (Figure 3).

**Problems addressed by fungicide application**

Majority of the respondents (91%) applied fungicides to address the problem of late blight (Figure 4). It is worth noting that some respondents applied fungicides to address bacterial wilt, a soil born disease that has no cure in Kenya (Figure 4). Insecticides were applied to address insect pests and worms (95%) though few farmers applied to address bacterial wilt (4.7%) and late blight (7%).)

**Category of fungicides used in potato production**

Mancozeb was the most commonly used active ingredients

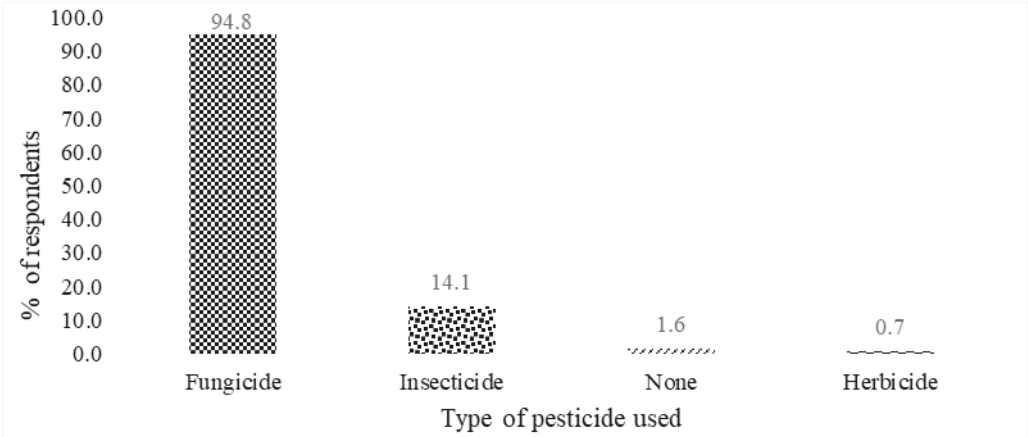


**Figure 3:** Type of pesticides used by potato farmers

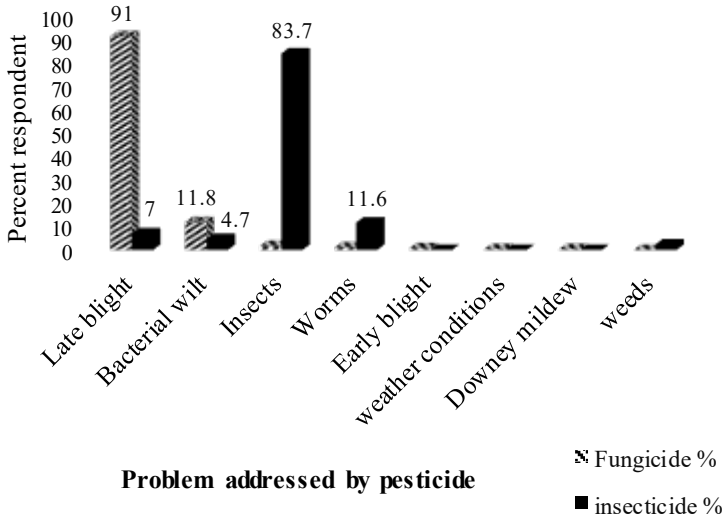


**Figure 4:** Type of problems addressed by pesticides applied

of the fungicides followed by metalaxyl+mancozeb active ingredients, at 88% and 24% respectively (Table II).

TABLE II- TYPE OF FUNGICIDES APPLIED ON POTATO CROP

| Type of fungicide used/ Active ingredient | Frequency (n=289) | % |
|---|---|---|
| Mancozeb | 254 | 87.9 |
| Mancozeb+ Metalaxyl | 70 | 24.2 |
| Mancozeb+Cymoxanil | 11 | 3.8 |
| Active ingredient not known | 6 | 2.1 |
| Propineb+Cymoxanil | 5 | 1.7 |
| Name not known | 1 | 0.3 |
| Difenoconazole | 1 | 0.3 |
| Deltamethrin* | 1 | 0.3 |

*Insecticidethoughmentionedbyrespondentasfungicide

**Pest management during potato production**

Concerning pest management, 86% of the respondents did not apply any insecticide to control pests in the field since they claimed very low pest incidences in their potato crop (Table III). The few who applied, sprayed the following active ingredients; lambda cyhalothrin, alpha cypermethrin, chlorpyrifoas+cypermethrin, deltamethrin, lambda cyhalothrin+thiamethoxam, dimethoate (2-dimethoxyphosphinothioylsulfanyl-N-methylacetamide) and Diazinon (Table III). Dimethoate and diazinon are among active ingredients that are restricted in use and/or banned for use on food/ horticultural crops by Pest Control and Products Board (PCPB) (Government of Kenya, 2019).

TABLE III- TYPE OF INSECTICIDES APPLIED IN POTATO

| Insecticide applied/Active ingredient | Frequency (n=305) | Percent respondents |
|---|---|---|
| Don't apply any insecticide | 262 | 85.9 |
| Lambda cyhalothrin | 14 | 4.6 |
| Alpha cypermethrin | 7 | 2.6 |
| Mancozeb* | 5 | 1.6 |
| Farmer does not know by name | 9 | 2.6 |
| Alpha cypermethrin, Lambda cyhalothrin | 2 | 0.6 |
| Alpha cypermethrin, chlorpyrifos+Cypermethrin, Lambda cyhalothrin | 1 | 0.6 |
| Mancozeb*, Mancozeb+Metalaxyl* | 1 | 0.3 |
| Deltamethrin | 1 | 0.3 |
| Lambda cyhalothrin+Thiamethoxam | 1 | 0.3 |
| Dimethoate | 1 | 0.3 |
| Diazinon | 1 | 0.3 |

*Fungicide though mentioned by respondent as insecticide

**Active ingredients and WHO classification of pesticides used in potato production**

Majority (56.3%) of the fungicides and insecticides applied on potato during production belonged to WHO class II (moderately hazardous) (Table IV). Pesticides which are moderately hazardous may pose low chronic health risks to humans but are very toxic to pollinators and the environment. Most insecticides were synthetic pyrethroids followed by organophosphates (Table V).

TABLE IV- WHO CLASSIFICATION OF FUNGICIDES APPLIED

| Active ingredient | WHO classification |
|---|---|
| Mancozeb | Class U (Unlikely to present acute hazard) |
| Mancozeb | Class U (Unlikely to present acute hazard) |
| Metalaxyl +mancozeb | Metalaxyl- Class II/moderately hazardous |
| Cymoxanil+mancozeb | Cymoxanil -Class II/moderately hazardous |
| Metalaxyl+mancozeb | Metalaxyl- Class II/moderately hazardous |
| Propineb +cymoxanil | Propineb- Class U (Unlikely to present acute hazard) |
| Difenoconazole | Class II/moderately hazardous |
| Mancozeb +Cymoxanil | Cymoxanil -Class II/moderately hazardous |

TABLE V- WHO CLASSIFICATION OF INSECTICIDES APPLIED

| Active ingredient | WHO classification |
|---|---|
| Lambda-cyhalothrin | Pyrethroid (moderately hazardous- class II) |
| Alpha cypermethrin | Pyrethroid (moderately hazardous- class II) |
| Chlorpyrifos+cypermethrin | Organophosphate (moderately hazardous-Class II) |
| Deltamethrin | Pyrethroid (moderately hazardous-Class II) |
| Lambda-cyhalothrin+thiamethoxam | Thiamethoxam (moderately hazardous- Class II) |
| Dimethoate | Organophosphates (moderately hazardous/Class II) |
| Diazinon | Organophosphates (moderately hazardous/class II) |

**Consumer general awareness about pesticides and pesticide residues in potato**

The overall assessment of association of knowledge on pesticide use and pesticide residues in fruits, vegetables, potato and potato processed products with training, showed levels of significance except training on pesticide use and safety (Table VI). Approximately 88% of respondents wore protective gear during spraying, 65% were aware about restricted or banned pesticides, 79% think that potatoes sold in roadside markets, cooked at home, in restaurants and in hotels do have pesticide residues and 87% thought that pesticide residues were harmful to human health (Table VI)

**Pesticides suspected to have high pesticide residues in potatoes and potato products**

Respondents were asked to mention pesticides which they thought had high pesticide residues in potato and potato products. It is evident that many of them (81%) didn't know while 3% mentioned dimethoate (Table VII). A majority of respondents (71.1%) gave no reason for the perception that potatoes and potato products contained high pesticide residue levels. Several other reasons were mentioned for this perception as either being highly toxic, chemical is used often or chemical takes too long to break down (Table VIII).

TABLE VI- ASSOCIATION OF KNOWLEDGE OF PESTICIDE RESIDUES WITH TRAINING, PROTECTIVE GEAR, PRESENCE IN FRUITS AND VEGETABLES AND RISKS TO HEALTH OF CONSUMERS

| Pesticide use question | % Respondents (N=305) | | P value |
|---|---|---|---|
| | Yes | No | |
| Have you been trained on pesticide use and safety? | 53.4 | 46.6 | 0.229$^{ns}$ |
| Do you wear protective gear while handling pesticides? | 87.9 | 12.1 | <.001$^{***}$ |
| Do you know of pesticides restricted for use or banned in Kenya? | 64.6 | 35.4 | <.001$^{***}$ |
| Have you heard about pesticide residues in fruits and vegetables? | 56.4 | 43.6 | |
| Can pesticide residues cause diseases to consumers of fruits and vegetables? | 83 | 17 | <.001$^{***}$ |
| Can pesticides sprayed during potato production be within the potatoes sold in the market? | 70.2 | 29.8 | <.001$^{***}$ |
| Can the pesticides sprayed during potato production be found in potatoes cooked at home, in restaurants, hotels and road side markets? | 78.7 | 21.3 | <.001$^{***}$ |
| Can pesticides be present in processed potato products such as chips and crisps? | 83.9 | 16.1 | <.001$^{***}$ |
| If present, do you think those pesticides are dangerous to the health of those eating the potatoes or potato products? | 87.4 | 12.6 | <.001$^{***}$ |

*** - highly significant, *- significant and NS- not significant at P≤0.05

TABLE VII- PESTICIDES SUSPECTED BY POTATO FARMERS TO HAVE HIGH PESTICIDE RESIDUES IN POTATO AND POTATO PRODUCTS

| Pesticide | Frequency(N=168) | % |
|---|---|---|
| Name not known | 136 | 81 |
| Dimethoate (Organophosphate) | 5 | 3.0 |
| Alpha cypermethrin (Pyrethroid) | 4 | 2.4 |
| Mancozeb (carbamate) | 4 | 2.4 |
| Diazinon (organophosphates) | 4 | 2.4 |
| Chlorpyrifos+ cypermethrin (Organophosphate) | 2 | 1.2 |
| Metalaxyl (Metalaxyl) | 1 | 0.6 |
| Difenoconazole | 1 | 0.6 |
| Roundup (Glyphosate) | 1 | 0.6 |
| Metalaxyl (Metalaxyl) | 1 | 0.6 |
| Profenofos+cypermethrin (Pyrethroid) | 1 | 0.6 |
| Mercury | 1 | 0.6 |
| Deltamethrin (Pyrethroid) | 1 | 0.6 |
| Acetamiprid (Neonicotinoid) | 1 | 0.6 |
| Carbofuran (Cabarmate) | 1 | 0.6 |
| Mancozeb( Cabarmate) | 1 | 0.6 |
| p,p'-DDT (Organochlorine) | 1 | 0.6 |
| Booster (foliar feed) | 1 | 0.6 |

TABLE VIII- REASONS GIVEN FOR PERCEPTION OF HIGH PESTICIDE RESIDUES IN POTATO OR POTATO PRODUCTS

| | Frequency (N=45) | % |
|---|---|---|
| Reason unknown | 32 | 71.1 |
| Highly toxic | 3 | 6.6 |
| Used often | 2 | 4.4 |
| Takes long to break down | 1 | 2.2 |
| Sprayed during head formation | 1 | 2.2 |
| Possible to penetrate into tubers during dry season | 1 | 2.2 |
| Others | 5 | 11 |

## DISCUSSION

From the survey, the age of potato farmers tends towards the younger generation, reversing previous reports about age of Kenyan farmer being 60 years (Birch, 2018). This could be attributed to transformation in agriculture from subsistence to commercial enterprises, entry of several financial institutions to support agriculture, use of modern technology and particularly information and communication technologies (ICTs) that has enabled access to markets, advisory services and networks. Most of the land ownership (85%) globally is by men, a comparative advantage to the younger generation to have direct access to resources especially male farmers (Kaaria and Osorio, 2018). This could also be the reason for more male potato farmers involved in potato production than their women counterparts (Langat, 2016).

The study revealed that Bomet County is a major producer of potato variety 'Dutch Robyjn' used to make potato crisps. In addition, it is evident that intensive pesticide spraying is done during field production of potatoes. Among the pesticides used, fungicides were the majority, followed by insecticides then herbicides, agreeing with findings by Okonya and Kroschel, (2015) who found similar trends. Parallel discoveries were reported by Mutuku *et al*., (2014) and Abong'o *et al.* (2014). However, Ngowi *et al.* (2007) reported more insecticides (59%) used, followed by fungicides (29%) then herbicides (10%) in northern Tanzania. Previous studies have reported that most pesticide categories were carbamates and organophosphates which is similar to this study where most fungicides used were carbamates while insecticides were synthetic pyrethroids and organophosphates (Ndunda *et al.,* 2018). Synthetic pyrethroids are synthesized by duplicating the structure of natural pyrethroids, are non-persistent as they easily get broken down when exposed to light though highly toxic to insects and aquatic life but safe to mammals and birds.

Majority of the farmers had good knowledge about choice of pesticide to use and when to use and for what purpose which could be attributed to high levels of education (Nguetti*, et* al., 2018) Therefore, most farmers used fungicides to control late blight though 2.1% did not know the name of chemical. Since pesticide names are technical, keeping good records and proper storage of packages would ensure farmers are able to keep information about type of pesticide used. In addition, considerable number of farmers did not apply insecticides. When respondents were asked why they did not use insecticides, they responded that the pest populations did not meet the economic threshold for insecticide application. This could imply that these farmers were ware potato growers and not certified seed potato producers. Production of certified seed potato requires that their seed crop is sprayed against pests such as aphids and white flies which easily spread potato viruses. Some farmers (0.6%) were still using banned/ restricted pesticides such as dimethoate and diazinon, showing that these pesticides were still being sold by agro-input dealers. There is need for Pesticide Control Products Board (PCPB) to carry out aggressive campaigns with all stakeholders to withdraw banned pesticides as well as intensive sensitization and stringent measures put in place for those products that have restricted use.

Majority (over 90%) of the respondents had received primary, secondary and tertiary levels of education although only 65% were aware about restricted use of some pesticides and/or banned pesticides in Kenya. In addition, 56% of the respondents were aware about pesticide residues in fruits and vegetables, despite the high literacy levels. This finding agrees with Nguetti *et al*. (2018) who found out that consumers who have attained tertiary levels of education were not able to comprehend well about chemical residues on tomatoes.

This is in contrast to previous studies by the same author showing that knowledge grows with level of education and the higher the level of education, the higher the level of awareness about food safety issues. More factors related to environment of a person play a key role in understanding food safety issues such as health news from radio, or health centers or previous interactions with other farm surveys, focusing on similar studies .

## CONCLUSION

From this study, 'Dutch Robyjn' is the dominant potato variety grown in Bomet County and used in production of crisps in Kenya. Fungicides and insecticides are intensively used during potato production. The fungicides and insecticides used in potato production belong to WHO classification II of moderately hazardous category. This implies that pesticides used may have long term effects on fauna. There is need for more sensitization on food safety issues where use of pesticides is concerned, safe use of pesticides as well as risks to pesticide residues of consumers in relation to food production.

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