

Research Article

Determination of Pesticide Residues in Locally Consumed Vegetables in Kenya

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Background: Pesticides are being used today to control a variety of insects, weeds and plant diseases. Some of these pesticides can act as toxins to plants, animals and humans when found in significant concentrations.

Objective: The purpose of this study was to determine pesticide residues in locally consumed vegetables. This was done by analyzing vegetable samples from supermarkets and local markets in Nairobi and its environs.

Materials and methods: A total of 112 samples (kales 94, French beans 18) were collected from the study area and analyzed using gas chromatography for pesticide residues. Samples collection was done during the hot/dry season and cold/wet season.

Results: The pesticide residues were found especially during the hot/dry season and were mainly organophosphates. However, on washing and cooking the residue levels reduced were by 17% and 40% -respectively. Adherence to recommended pre harvest intervals resulted in 99% reduction of the pesticide residues.

Conclusion: This study clearly shows that adherence to good agricultural practice would significantly lower the levels of pesticide residues in vegetables.

Keywords: Pesticides residues, vegetables

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1. Introduction

Different pesticides are in use depending on the targeted pest, the crop it is being applied on, local environmental conditions, the persistence of the pest and the pre-harvest period. Some of the pesticides are harmful to humans on exposure if in high doses. This is because they are not selective in their mode of action. They affect the nervous system, respiratory system and cell membrane integrity of target and non-target organisms (Corbett, 1974). Due to this, there is need to ensure that humans are not excessively exposed to pesticides.

Occupational exposure can be controlled if the pesticide handlers use the recommended protective garments and spraying procedures. However, for exposure

through food and drink, it is a bit difficult for the consumer to take precautions since most consumers are not aware that there could be some residual pesticides in food (Kroes and Den Tonkelaar, 1990). The problem in this case can be traced down to the farmer, who has little knowledge on the safe use of pesticides and the consequences of misuse (Karembu, 1991). The horticultural industry in Kenya has greatly expanded in the past ten years, with exports to the EU increasing steadily by nearly 300 % over this period. The EU at the moment absorbs 90 per cent of Kenya's total horticultural exports (Kenya Times Newspaper 2nd February 2005). There is need therefore for the horticultural sector in Kenya to comply with the EU regulations (Eurep-gap) which state that traceability requirements have to be met; maintenance of sanitary

and phytosanitary standards (SPS) and compliance of maximum residue levels at analytical zero.

Failure to comply with recommended Maximum Residue Level (MRLs) leads to consumers' exposure to pesticides at dangerous levels. This could lead to adverse side effects especially if one is exposed to these pesticides in high doses or over a long period of time. Much emphasis is put on vegetables for export while the local farmer may not be aware of these latest developments. There is need therefore to analyze different vegetables in the market and determine whether the residue levels of pesticides in them are compliant with the international standards.

The hypothesis is that pesticide residues in locally consumed vegetables are not compliant with international MRLs and the main objective of the study is to determine pesticide residues in locally consumed vegetables.

2. Materials and Methods

2.1 Study location

Nairobi and its environs was the main study area with emphasis being put on areas that supply kales and French-beans to Nairobi. This is because, Nairobi being the capital city is bound to reflect what is anticipated in other areas of the country. The specific areas considered were Limuru, Karatina, Kinale, Thika, Juja and Kiambu. Most of the vegetables consumed in Nairobi are obtained from these areas. Qualitative data was also obtained from agrovets and farmers in these areas and Nairobi on the pesticides used.

2.2 Vegetables analysed and sampling

The vegetables that were analysed were kales and French beans. This is because kales are the main vegetables mainly consumed by Kenyans. French beans however, are some of the main vegetables exported and at the same time also consumed locally. Samples were also obtained from leading supermarkets and open air markets. Farmgate sampling was done at Karatina and Limuru areas.

To determine the main pesticides used, a survey was conducted using questionnaires that were mainly given to agrochemical suppliers and farmers.

2.3 Vegetable collection

Vegetables were collected during different environmental conditions (dry and wet seasons) from the market and placed in well labeled polythene bags and transported in a cool box. These were then taken to KEMRI where they were subjected to the extraction procedure.

2.4 Determination of pre-harvest intervals

Vegetables (kales) grown on an experimental plot were sprayed with the pesticide chlorpyrifos and the levels of pesticide residue determined at intervals of 1, 2, 3, 5, 9, 14 and 16 days after spraying.

2.5 Determination of effects of processing food on residue levels

To determine how different processing procedures affect residue levels, kales that had been sprayed with chlorpyrifos were taken from the experimental plot and boiled for 30 minutes. The levels of residual pesticides were then determined. To determine how washing affects the pesticide residue levels, some kales from the experimental plot that had been sprayed were washed and the levels of pesticide residue determined.

2.6 Pesticide extraction from vegetables

One hundred grams of sample were minced using a Horbat food mincer and 25g of this homogenate then macerated using 50 ml of acetone then decanted into 200 ml of a 2% solution of sodium sulphate in a separating funnel. This process of maceration was repeated and the extract poured into the 2% sodium sulphate solution. Fifty milliliters of hexane were added into the separating funnel and mixed. This partitioned into an aqueous layer and a non aqueous layer (hexane layer). The aqueous layer was removed into a beaker while the hexane layer was run through a chromatographic column packed with anhydrous sodium sulphate. This eluted into a round bottomed flask. A second portion of 50 ml of hexane was added to the aqueous layer, mixed and put in a separating funnel where it was allowed to partition. The aqueous layer was run off into a beaker while the hexane layer was run through a chromatographic column into the round-bottomed flask. This volume was evaporated using a rotary evaporator to approximately 10ml. This volume was then made up to 25 ml using hexane. This extract was analyzed for organophosphate pesticides using gas chromatograph with nitrogen phosphorus detector (NPD). For organochloride analysis and synthetic pyrethroid analysis, the extract was subjected to the clean-up procedure below.

2.7 Clean-up procedure

Ten (10) grams of florisil (60-100 mesh) were packed using hexane into a florisil column. 1cm layer of anhydrous sodium sulphate was then added on top. 5ml of the extract was then loaded and eluted with 200ml fractions of 6%, 15%, 30% and 50% diethyl ether in hexane. The eluent mixture was collected in a 500ml round-bottomed flask and evaporated to 1ml. This extract was then analyzed for organochlorines and synthetic pyrethroids using electron capture detector (ECD). This was done using gas-liquid chromatography using electron capture detectors (ECD) (for organochlorines and pyrethroids) and nitrogen phosphorus detectors (NPD) (for organophosphates). For each sample, a reagent blank, a spiked sample and a control sample were included (all samples were run in duplicate) (AOAC, 2004).

2.8 Data management and analysis

From the data obtained, pesticide residue levels obtained during different seasons, pre-harvest intervals and different food-processing procedures were recorded. Basic demographic factors were analyzed using percentage ratios and proportion. Quantitative

data was analysed using the Statistical Package for Science Students (SPSS).

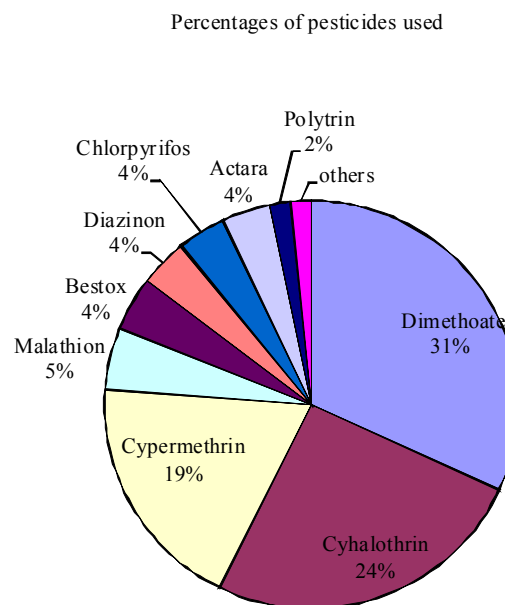
3. Results

3.1 Pesticides used by vegetable farmers in Kenya

From the market survey, it emerged that most local farmers use different pesticides which tend to vary regionally. Figure 1 shows that the pesticides commonly used in the study area on vegetables are organophosphates such as dimethoate and chlorpyrifos, synthetic pyrethroids such as cyhalothrin and cypermethrin. Organochlorines and carbamates are hardly used on vegetables.

From **Figure 1**, it is evident that synthetic pyrethroids and organophosphates are the main pesticides used with a preference of 46% and 45% respectively. Biologicals took 9% of the pesticides used.

Other pesticides such as organochlorines, dipyrillidiums and carbamates were hardly used in the study area on vegetables.



NB: Others include ridomil, bulldock and folimat.

Figure 1: Pesticides commonly used in the study area.

Table 1: Pesticide residues obtained from vegetables from the different sources

Sample	Type of vegetable	Source of vegetables	Pesticide obtained	Pesticide residue levels (ppm)
1	Kales	Kawangware	Dimethoate	0.020
2	Kales	kawangware	Chlorpyrifos	0.057
3	French beans	Wakulima	Dimethoate	0.064
4	Kales	Gikomba	Dimethoate	0.660
5	Kales	Gikomba	Dimethoate	0.096
6	French beans	Githurai	Chlorpyrifos	0.060
7	Kales	Gikomba	Dimethoate	0.100
8	Kales	Kangemi	Chlorpyrifos	0.085
9	French beans	Kangemi	Chlorpyrifos	0.127
10	French beans	Supermarket	Chlorpyrifos	0.050
11	French beans	Kangemi	Chlorpyrifos	0.060
12	French beans	Githurai	Dimethoate	0.017

3.2 Pesticide residues obtained from the market

Table 1 shows the residues obtained from kales and French-beans ranged between 0.017ppm and 0.66ppm. Out of the 12 pesticide residues obtained, 10 were obtained during the hot/dry season. Only 2 detectable levels were obtained during the wet/ cold seasons. The average residues obtained during the hot/dry season were 0.106ppm while during the cold/wet season, the average residues were 0.061ppm. The main residues obtained were chlorpyrifos and dimethoate.

Out of all the samples with detectable residues, most were from the market. Only one sample from the supermarket had detectable pesticide residues.

3.3 Pesticide residue levels in vegetables harvested in different seasons

In total, 110 samples were analyzed. These comprised 18 French-beans and 92 kales. Out of all these samples, 12 had detectable pesticide residue levels. Six out of the 18 French beans samples had residues while 6 out of the 92 kales samples had detectable residues. These gave percentages of 33% and 6.5% respectively. The residues obtained were mainly dimethoate and chlorpyrifos. In total, 8.6% of the kales sampled during the dry season had pesticide residues. These reduced to 2.9% during the wet season. Out of the samples of French beans analyzed, 42% had pesticide residues during the dry season. These reduced to 16.7 % during

the wet season. Residues found in kales during the dry season ranged between 0.02– 0.66 ppm (SD +0.27). In French-beans they ranged between 0.05- 0.127ppm (SD + 0.031).

Table 2 shows the pesticide residues in kales and French beans in the study area. The results also show that in the wet season, the frequency of vegetables with pesticide residues was non-significantly lower than in

the dry season ($X^2= 2.1$; $p=0.125$). In both the French beans ($X^2=3.84$; $p=0.31$) and the kales ($X^2 = 3.84$; $p=0.29$), the residue levels were not significantly related to the season. The frequency of French-beans with residues in the dry season was significantly higher than kales ($X^2 = 6.68$; $p < 0.05$). The presence of residues was related to the type of vegetables significantly ($X^2 = 10.8$; $p=0.003$) irrespective of the season.

Table 2: Pesticide residues in different seasons for kales and French beans

Season	Vegetables		
	No. of samples analyzed	No. with residues (%)	Type of pesticide
Dry	Kales (58)	5(8.6%)	3 Dimethoate 2 Chlorpyrifos
	French-beans (12)	5(42%)	4 Chlorpyrifos 1 Dimethoate
Wet	Kales (34)	1 (2.9%)	Dimethoate
	French beans (6)	1(16.7%)	Dimethoate

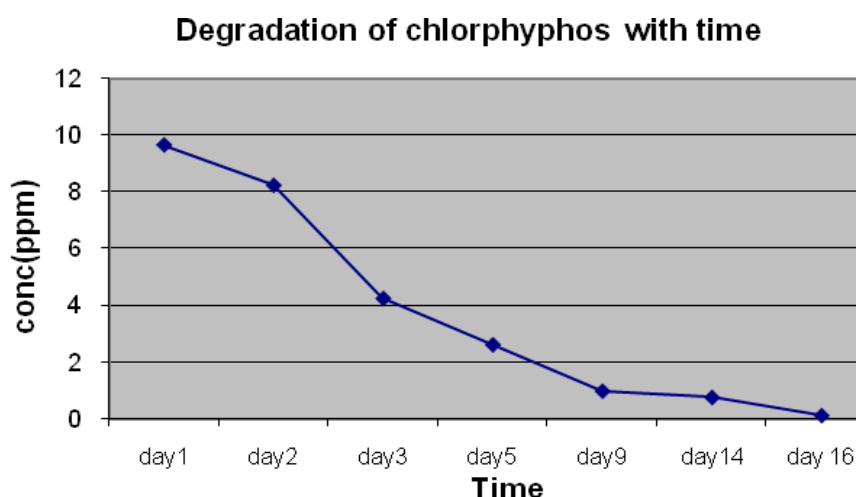


Figure 2: Degradation of chlorpyrifos with time

Table 3: Reduction of pesticide levels after different processing procedures

Procedure	Washing	Cooking	Washing then cooking.
Pesticide residues(in ppm)	8.0	5.8	4.8
Percentage change	17%	40%	50%

3.4 Variation of residue levels with pre-harvest intervals

The pre- harvest intervals (PHI) were determined using chlorpyrifos * on kales leaves. The levels of chlorpyrifos residues in kales were determined after 24 hours from time of spraying. The levels were 9.6ppm on day one. This reduced gradually to 0.12 ppm after 16 days. **Figure 2** shows this degradation with time. Results show there was a decrease of chlorpyrifos with time. The overall decrease over the 16 weeks was 99%.

(*Chlorpyrifos was used since it gives sharp peaks in the chromatograph unlike dimethoate)

Table 5 shows the effect of different processing procedures on kale leaves that have been sprayed with chlorpyrifos. Results show that after washing the kale leaves, there was a 17% reduction from 9.6ppm to 8.0ppm. Cooking resulted in a 40% decrease in the chlorpyrifos levels. When the kale leaves were washed and cooked, there was a 50% reduction in chlorpyrifos levels.

4. Discussion

The pesticides used in farming when not applied according to GAP, lead to their accumulation in the produce. There are set international limits for pesticide residues when GAP is applied. In the study, residues were obtained above the recommended levels in some samples. Significant pesticide residues were found in French-beans than in kales. This can be attributed to the difference in texture of the French beans and that of kales. The coarse nature and dense texture of French beans slows down the rate of volatilization, a process by which pesticides dissipate. In kales, the texture is quite smooth and the leaves are less dense thus the pesticides dissipate easily (Bedos et al, 2002)

The market survey to evaluate the pesticides used on vegetables in the study area showed that most large scale farmers in Kinale use synthetic pyrethroids such as lambda cyhalothrin and cypermethrin. Small scale farmers in Kiambu, Karatina and Thika areas mainly use organophosphates such as dimethoate and chlorpyrifos. This is in agreement with the study done by Bull(1982), that showed that large scale farmers tend to use more expensive pesticides with short pre harvest intervals(PHI) unlike small scale farmers who go for cheap pesticides that have long PHI. Similar studies by Ngatia and Kabaara (1976) in Kenya, Kebede et al, (1990) in Ethiopia and Ngambeki et al, (1992) in Uganda all showed that economic empowerment which is associated with the farm size, determines whether a farmer adheres to GAP or not. In most cases, small scale farmers did not.

Vegetables harvested during different seasons and analysed for pesticide residues showed that those harvested during the hot/dry season had higher pesticide residues compared to those harvested during the cold/wet season. This is because during the wet season, pesticides tend to be washed off thus reducing the residue levels unlike in the hot season. It was further observed that during the hot/dry season, there was a shortage of kales in the market with a sack of kales being sold for Ksh. 3000 while during the wet/cold season, it was being sold for Ksh. 500 (Ministry of Agriculture, Daily Nation 3rd February 2006, 5th May 2006). This shows that during the hot/dry season, the demand for kales was bound to outstrip the supply. Due to this, most farmers in a bid to capitalize on the demand did not observe the required PHI. During the cold season, the vegetables were in great supply thus most farmers observed PHI.

The main residues found were organophosphates namely chlorpyrifos in French beans and dimethoate in kales. This is attributed to their long PHI (upto 14 days). No detectable levels of synthetic pyrethroids were found, which could be attributed to the low PHI that

most of them have which range from 24 hours to 3 days(IPA Database, 2007)

Analysis of PHI of chlorpyrifos showed that the amount of chlorpyrifos residues vary inversely with time. The levels on the first day were at their highest but decreased with time to very low levels on day 16. This decrease could be attributed to degradation of the active ingredients over time, washing off, metabolism by the plant and biotransformation by photolysis, oxidation, reduction and hydrolysis (Pilger, 2007. I.U.P.A.C, 1996). The amounts of chlorpyrifos obtained from the vegetables analyzed were almost equal to those obtained during the last days of PHI levels. This shows that most of the residues obtained occur when vegetables are harvested before their recommended PHI. This is in line with studies done by Gambarcorta et al, (2005) which showed that pesticides after spraying degraded by first order kinetics resulting in a decrease of levels with time.

Cooking and washing resulted in a decrease in the pesticide residue amount on vegetables. This shows that when vegetables are consumed before being subjected to any of these processing procedures, chances of residues being consumed are high especially during the hot/dry season. This can occur when vegetable salads that are not well cleaned are consumed (Krol et al, 2000; Wan et al, 2003; Balinova et al, 2006)

The results from this study show that there are pesticide residues in vegetables. The presence of this residues depends on the season, type of pesticide or type of vegetable being consumed. These levels can be reduced if GAP is practiced. It is important to avoid consuming vegetables with residues since studies have shown that consumption of pesticides has an effect on physiological systems. Studies have shown that biochemical analytes are affected by consumption of pesticides. Exposure to pesticides over a long period of time has been shown to predispose individuals to asthmatic attacks and some cancers (Peris et al, 2002; Riyat, 1990; Jurewics et al, 2006)

It is important that farmers to adhere to GAP so as to reduce incidences of asthma and some cancers that are on the increase. Agricultural extension officers should teach farmers on the need to adhere to GAP. Farmers should also be taught alternative methods of pest control such as use of biological controls. Consumers should also be encouraged to wash and cook their vegetables before consumption where possible.

Conflict of Interest declaration

The authors declare no conflict of interest.

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