

Removal of Organophosphorus (OP) Pesticide Residues from Vegetables Using Washing Solutions and Boiling

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Abstract

In a monitoring study, the effects of household processing on removal of organophosphate residues (malathion, fenitrothion, formothion, parathion, methyl parathion and chlorpyrifos) in tomato, bean, okra, eggplant, cauliflower and capsicum were studied. The processes included washing separately with (water, 0.9 % NaCl, 0.1 % NaHCO₃, and 0.1 % acetic acid, 0.001 % KMnO₄, 0.1 % ascorbic acid, 0.1 % malic acid and 0.1 % oxalic acid and 2 % aqueous solution of raw *Spondias pinnata* (SP)) and boiling. Organophosphorous (OP) residues were estimated (for real market samples and spiked samples) using multi residue analytical technique employing with capillary gas chromatograph with mass spectrometry detector (GCMSD). In all of the vegetables, washing with different household chemicals reduced the residues by 20-89 % and boiling reduced the residues by 52-100 %. Boiling of vegetables was found to be more effective than washing in dislodging the residues.

Keywords: Boiling, GC-MSD, Household chemicals, Pesticide residues, Vegetables, Washing

1. Introduction

Vegetables are an important source of food and are highly beneficial for health. In India, vegetables are a major constituent of daily diet as a majority of Indians are vegetarian Kumari *et al.*, 2008. Among the vegetables, okra, eggplant, tomato, beans, capsicum and cauliflower, are the ones most commonly grown as they give better return over investment to the farmers. To improve yield and quality and to combat the insects and pests, farmers resort to applying an inordinate amount of pesticides. This leads to contamination of vegetables with pesticide residues which has been reported by several researchers (Madan *et al.*, 1996; Kumari *et al.*, 2002, 2003 and 2008).

Organophosphorus pesticides such as malathion, fenitrothion, formothion, parathion, methyl parathion and chlorpyrifos are widely use (Madan *et al.*, 1996; Kumari *et al.*, 2002, 2003 and 2008). Many organophosphates are potent nerve agents, functioning by inhibiting the action of acetylcholinesterase (AChE) in

nerve cells. OP can be absorbed by all routes, including inhalation, ingestion, and dermal absorption. Their toxicity is not limited to the acute phase, however, and its chronic effects have long been noted. Neurotransmitters such as acetylcholine (which is affected by organophosphate pesticides) are profoundly important in the brain's development, and many OPs have neurotoxic effects on developing organisms, even from low levels of exposure. In non fatty foods, OPs are detected more frequently than the Organochlorines (OCs) and their residue concentration is typically slightly higher, whereas its opposite is true in case of fatty foods (Lehotay, 2006).

To estimate the potential pesticide exposure from contaminated food, it is important to estimate the level of exposure at the point of consumption after processing. It has already been reported that commercial and household processing such as washing, peeling, cooking, blanching and concentrating can reduce residue levels in food, which further reduces the impact on human health (Abou-arab, 1999; Soliman, 2001; Zohair, 2001; Byrne and Pinkerton, 2004; Pugliese *et al.*, 2004; Zhang *et al.*, 2007). Worldwide, the issue food safety is an area of growing concern on account of its direct bearing on human health. Extensive literature review demonstrates that in most cases processing leads to large reductions in residue levels in the prepared food, particularly through washing, peeling and cooking operations (Youssef *et al.*, 1995; Soliman, 2001; Zohair, 2001).

Traditional method of washing vegetables to remove debris and dirt prior to consumption has been assumed to reduce pesticide residues. Several washing solutions such as chlorine solution, ozonated water and strong acid have been proven successful in removal of pesticide residues during commercial crop process (Ong *et al.*, 1996; Zohair, 2001; Pugliese *et al.*, 2004). Washing as a process is prevalent in most households since it can be done with easily available plain water and also with solutions formulated from chemicals readily available in a household kitchen (Krol *et al.*, 2000). The chemicals recommended for the purpose of removing residues are salt, baking soda, distilled vinegar and potassium permanganate (Extension Toxicology Network, 1996). The treatment of fruits with lemon juice, a dip in 2 % tamarind solution for 5 min followed by a wash with tap water and steam cooking for 10 min were found to remove the residues of monocrotophos, fenitrothion and fenvalerate to an extent of 41.81, 100 and 100% respectively (Gardenmo.net, 2011). It has also been reported that Chlorothalonil and tetradifon were successfully removed from commercial eggplant and cucumber with an average removal efficiency of 95 % just after 5 minutes of pickling the vegetables in rice-bran paste (Adachi and Okano, 2006).

In this study, 553 market samples (Agricultural produce marketing committee, Azadpur, Delhi, India) were analyzed as per the Prevention of Food Adulteration Act, (PFA, 2009) which revealed the presence of OP residues in most of the samples. The purpose of this study was to determine the efficiency of water, recommended chemicals (0.9 % NaCl, 0.1 % NaHCO₃, 0.1 % acetic acid, 0.001 % KMnO₄, 0.1 % ascorbic acid, 0.1 % malic acid, 0.1 % oxalic acid and 2 % aqueous solution of raw *Spondias pinnata* (SP)) and boiling on the removal of analyzed OP residues. Along with this, the fate of all pesticide on degradation and dissolution when subjected to the specific washing solution was also included in this study.

2. Materials and methods

2.1 Materials

The composite samples, consisting of 5-6 kg of beans, eggplant, okra, cauliflower, capsicum and tomato were obtained from APMC (Agricultural produce marketing committee), Azadpur, Delhi, India at a weekly interval. Each sample was divided into three parts and was refrigerated and analyzed within two days of collection.

In order to assess the effects of household processing like washing and boiling, one part of the sample of each vegetable was washed for one minute under tap water and dried on filter paper. The other parts of the unwashed samples of all the six vegetables were mixed with 15 ml water and boiled till the samples softened. The washed and boiled samples were then processed in a manner similar to that of the unprocessed samples. For the purpose of spiking and quantitation, the reference materials of pesticides which were >98% pure (formothion, methyl-Parathion, fenitrothion, malathion, parathion, chlorpyrifos) were procured from Sigma-Aldrich (Sigma-Aldrich, Delhi, India). The standard stock solutions (1000 ppm) were prepared in ethyl acetate and stored at 4 °C. HPLC grade acetonitrile, acetone and ethyl acetate were procured from RFCL, Delhi, India. Other chemicals such as anhydrous magnesium sulfate, PSA (Primary Secondary Amine) and graphitized carbon black sorbent were obtained from Agilent Technology (LCGC, India). All chemicals (acetic acid, sodium chloride, ascorbic acid, malic acid, oxalic acid and potassium permanganate and sodium bicarbonate) were procured from Merck, Germany. In addition, the raw *Spondias pinnata* Kurz ((syns. *Mangifera pinnata* L. f), Family-Anacardiaceae is found in India, Sri Lanka and other South-East Asian countries. In India it is commonly seen in the deciduous to semi-evergreen forests of the Western Ghats, homesteads, fallows as well as on the road sides.

It is a deciduous, rigid and symmetrical tree of approximately 20 m height. It is a stately in appearance and has pinnate leaves (20-60 cm in length), composed of 9 to 25 glossy, elliptic or obovate-oblong leaflets (6.25-10 cm long) and finely toothed toward the apex. The fruit is a fleshy drupe, up to 4.5 cm in diameter and contains a large stone. The peels and seeds may amount up to 60 % of the total fruit weight. The genus *Spondias* includes 17 described species, 7 of which are native to the neotropics and about 10 are native to tropical Asia (Satpathy *et al.*, 2011)) was obtained from the market and dried at 50 °C before use. Food processor, homogenizer (Phillips India ltd, Delhi India), blender (Inter Science, Japan), vortex mixture (Jain Scientific, India), centrifuge, Sigma 2-16 K (SV Instrument, Delhi, India), microwave reaction system (Multiwave 3000Solv, Anton Paar, Europe) and rotary evaporator (Caterpillar, Prama Instrument, India) were used.

2.2 Sample preparation

2.2.1 Fortification, extraction and cleanup

100 g of each fresh vegetable was blended and homogenized and preserved at -20 °C. The samples were extracted by microwave extraction method (Satpathy *et al.*, 2011). Measurements were carried out on an Agilent 7890 gas chromatograph and 5975B mass spectrometer in trace ion detection mode. The instrument was equipped with a programmable temperature vaporizer injector (PTV) and 7683B auto sampler (Agilent) for sample introduction. The chromatographic separation was done on a fused silica HP-5ms (30 m capillary column with 0.25 mm internal diameter and 0.25 µm film thickness). 20 µl of injections were performed by empty baffled liner (Agilent # 5183-2037) in the PTV injector at solvent vent mode by programming as 78 °C (1.5 min), ramped at 600 °C/min to 280 °C (2 min), vent time: 1.2 min, vent flow: 100 ml/min, Purge flow: 60.0 ml/min, purge time: 2.00 min. The oven was programmed from 70 °C (2 min) at 25 °C/min to 150 °C (0 min), at 3 °C/min to 200 °C (0 min) and finally at 8 °C/min to 280 °C (10 min). Helium was used as a carrier gas. The head pressure was calculated using the RTL software so that *parathion-methyl* was eluting at a constant retention time of 16.569 min. Quadruple Mass selective detector (MSD) was used in EI mode with scan range (*m/z* 40-550). Screening of pesticides was performed using the DRS in combination with the RTL pesticide library and NIST'05 library. Quantitation of 6 pesticides was performed using the MSD in the selected-ion monitoring (SIM) mode at *m/z* (Table 1) for target and qualifier ions. The dwell time was set to 25 ms. The gas saver option was turned off; transfer line temperature was set to 300 °C, solvent delay was 3.0 min, ion source and quadruple temperature were 230 °C and 150 °C, respectively.

2.2.2 Washing solution preparation

All washing solutions for treatment were prepared from the Merck reagents. These consisted of filtrated water generated from ultra violet water purifier plus: 0.9 % NaCl, 0.1 % NaHCO₃, 0.1 % acetic acid, 0.001 % KMnO₄, 0.1 % ascorbic acid, 0.1 % malic acid, 0.1 % oxalic acid and 2 % aqueous solution of dried raw SP. The ultra violet water was used as diluents for all the solution treatments.

2.2.3 Studies on degradation of malathion, fenitrothion, formothion, parathion, chlorpyrifos and methyl parathion in washing solutions

Stock solution of malathion, fenitrothion, formothion, parathion, chlorpyrifos and methyl parathion were diluted with filtrated water accordingly to the concentration of 100 ppm active ingredient. The pesticides were then mixed with the treatment washing solutions in 1:9 ratio and were allowed to stand for 15 min. 0.5 ml of this mixture was taken and extracted immediately to determine the effect of the washing solutions on pesticide degradation.

2.2.4 Studies on reduction and dissolution of malathion, fenitrothion, formothion, parathion, chlorpyrifos and methyl parathion in washing solutions

One part of each vegetable sample was soaked in malathion, fenitrothion, formothion, parathion, chlorpyrifos and methyl parathion solution (100 ppm) for 5 min to enable the deposition of pesticide on them. The treated samples were then air-dried for 1 hr. in shade. Samples from each vegetable which were treated with pesticides were collected and analyzed for the pesticides. The remaining samples were then divided into nine unique identity categories assigned for specific washing solution tests. The freshly prepared washing solution treatment was used fifteen times to the volume of treated pesticide vegetables as described in the procedure of Iuzmi (Izumi, 1999). The treated pesticide samples were soaked in the washing solution for 15 min, after an initial 15 sec gentle rotation by hand. We believe that this method mimics the actual procedure of washing vegetables in the households. Following the washing process, vegetable samples were air-dried for 1 hr. The vegetable samples and the solutions after washing were then collected and extracted as above for pesticide residue analyses.

The extracts were kept in refrigerator until further analysis. The solutions were filtered and quantitatively transferred to centrifuge tube and the experiment was proceeded as above.

2.2.5 Recovery study

To evaluate the performance of the analytical procedures, recovery studies were performed at 1.0 ppm fortification level of each pesticide for three extractions. The samples of pesticide-free vegetables were prepared by adding a stock solution of standard malathion, fenitrothion, formothion, parathion, chlorpyrifos and methyl parathion (Sigma-Aldrich, USA) at known amount to the 10.0 g of samples before extraction. The extractions were performed as described earlier. % recovery was derived from the equation; (amount of pesticide obtained/amount of pesticide added) * 100.

2.2.6 Statistical analysis

All treatments were replicated 3 times. Values are shown as means \pm SD. The effects of washing solutions on the % degradation, % reduction and % dissolution of pesticides were analyzed by ANOVA as a split-plot design, with the six, pesticides served as main effects and the nine washing solution (including water) served as minor effects. Statistical significance was conducted using student t-test for comparison of the results obtained as reduction (%) with degradation (%) and dissolution (%). Differences at $P < 0.05$ were considered significant.

3. Results and discussion

3.1 Recovery study

Mean recoveries of the standard malathion, fenitrothion, formothion, parathion chlorpyrifos and methyl parathion added to the pesticide-free vegetables at range of 0.1-1 ppm were 97 ± 9.5 , 92 ± 8.5 , 89 ± 10.5 , 87 ± 13 , 103 ± 8 and 91 ± 6.5 %, respectively. The recovery %s in this study was higher than 80 %, which indicated good and validated analytical procedure. The requirements, regarding the processes, for the quantitative analysis of pesticide residue are generally considered satisfactory if the recovery is over 70 % with the coefficient of variation of 20 % for repeatability (Sanco, 2007). The standard deviation of recovery for parathion was relatively higher than others, but it is still acceptable for an analytical method of this type.

3.2 Pesticide degradation study

Effect of washing solution treatments on the pesticide degradation is shown in Figure 1. After 15 min in the washing solutions, all pesticides showed different degrees of degradations. Fenitrothion was found to be more degradable than other pesticides ($p < 0.05$) in 0.001 % KMnO_4 washing solution (69 %) followed by 2 % SP (58 %). However, the degradation of fenitrothion among the rest of the washing solution did not show any significant difference. In water, formothion was rather stable with only small amount of it being degraded (5.6 %). On the contrary, formothion, parathion, malathion and methyl parathion had different levels of degradation. Most of the pesticides exhibited higher degree of degradation in KMnO_4 and 2 % SP washing solutions. 19-47 % degradation of formothion, parathion and methyl parathion was found in 0.001 % KMnO_4 and 0.1 % acetic acid washing solutions. The extent of degradation indicated that formothion, parathion and methyl parathion were more resistant to degradation in the washing solution treatments than others (Figure 1). This may probably be due to the difference in properties between these pesticides.

3.3 Pesticide dissolving ability study

The % dissolution of pesticides from the treated samples in the washing solutions was examined by using the amount of pesticides left in the solutions after washing process as compared to the total amount of pesticides in the treated samples. Results showed (Figure 2) that fenitrothion (37-54 %) dissolved more than other studied pesticides (12-43 %).

Differences were also obtained in pesticide dissolution (%) among the washing solutions. In fenitrothion, chlorpyrifos and malathion treated samples, the 0.001 KMnO_4 , 2 % SP and 0.1 % acetic acid wash showed more pesticide dissolving capability than the others. A similar pattern was observed in other treat-samples, even-though the extents in % dissolution were smaller when compared to fenitrothion.

3.4 Pesticide reduction study

The percentage reduction of malathion, fenitrothion, formothion, parathion, chlorpyrifos and methyl parathion in vegetable are presented in Table 2. To determine the % of pesticide reductions, each wash treat sample concentration was compared to the non-wash treated sample concentration. In the non wash samples, the total concentrations of the six studied pesticides were 8.7 ± 0.5 , 12.5 ± 0.5 , 5.3 ± 0.5 , 6.9 ± 0.7 , 7.9 ± 1.1 and 6.8 ± 1.4 ppm for malathion, fenitrothion, formothion, parathion chlorpyrifos and methyl parathion, respectively. After

the washing process, the reduction of pesticides in malathion, fenitrothion, chlorpyrifos treated samples was shown to be superior than the reduction in formothion, parathion and methyl parathion treated samples. This may be due to the physiochemical property of these pesticides. This could prevent much of formothion, methyl parathion and parathion to react with other existing compounds in the solutions. As shown in figure 1, the lower degree of degradation was observed for formothion, parathion and methyl parathion in all washing solutions and that could be the reason behind getting a lower reduction for these compounds. Thus, the lower degree of degradation of formothion, methyl parathion and parathion in the samples may be another reason for the difficulty in their removal.

Washing the malathion, fenitrothion and chlorpyrifos treated samples showed reduction between 42 to 89 %, while washing the formothion, parathion and methyl parathion treated sample decreased between 20 to 48 %. This indicated that fenitrothion, malathion and chlorpyrifos were easier to remove by the washing procedure than the other (Table 2).

Almost 48 % of parathion and methyl parathion and 89 % of fenitrothion were removed from the treated samples with the 0.001 % KMnO_4 wash, while washing with water alone resulted in a reduction of 20 and 31 % for all studied pesticides in treated samples (Table 2). In 0.9 % NaCl , 0.1 % NaHCO_3 , 0.1 % oxalic acid, 0.1 % ascorbic acid and 0.1 % malic acid, the efficiency of pesticide reduction was not as effective as in the 0.001 % KMnO_4 solution, but they were more effective than the water wash. In this study, the residue reduction was not attributed to pesticide solubilization in water. Malathion which has water solubilization higher than fenitrothion (124 vs 34 mg/l), showed lower degree of reduction. This is consistent with the earlier studies which showed that the reduction of pesticides on fruits and vegetables were not directly correlated with water solubility of pesticides (Youssef *et al.*, 1995; Izumi, 1999).

As in the case of fenitrothion, chlorpyrifos and malathion, the degrees of reduction in formothion, parathion and methyl parathion treated sample varied and depended on the specific washing solution. Results of the washes from the chemically prepared washing solutions were more effective in reducing all studied pesticides than water alone. The rest of the solutions did not have much statistical difference from water (Table 2). So, the difference in fenitrothion dissolution may be attributed to the variation in the reduction. Unfortunately, data on % dissolvable of malathion in each washing solution did not support the suggestion. It was found that malathion in the treated sample had dissolved more in water than in the 0.9% NaCl , 0.1% NaHCO_3 , 2 % SP and 0.001% KMnO_4 washing solution (Table 2). The lower degree of dissolution of malathion in 0.001% KMnO_4 could be explained by the high degradation of malathion in this solution. However, this explanation could not be applied to 0.9 % NaCl and 0.1 % NaHCO_3 as the degradability of fenitrothion in these solutions did not exceed that of water. The cause and effect of the reduction in 0.9 % NaCl and 0.1 % NaHCO_3 washing solutions is still not known in this study and needs further investigation.

The variation in each pesticide reduction depended upon the specification of washing solution. In fenitrothion, the 0.001% KMnO_4 revealed the greatest effect on residue reduction. This could be partially explained by the degradation effect of this solution. Other studied pesticides were also found highly degraded in the 0.001% KMnO_4 solution (Table 1) because KMnO_4 is a strong oxidizing agent and the solution resulted in a high redox potential when used as the active ingredient for a given concentration. Oxidative compound such as hypochlorous acid in strong acids electrolyzed water has also been reported for its most effectiveness in reducing dimethoate concentrations by oxidation (Zhang *et al.*, 2007). Thus, the oxidative property of KMnO_4 could also have a significant effect on degradation which shall contribute to the reduction of studied pesticides after the wash.

It is also found in this study that chlorpyrifos and malathion, which degraded with 0.1 % acetic acid were in the similar extend to the 0.001% KMnO_4 . This may be due to the high acidity and/or high redox potential of this solution. The pH and oxidation reduction potential (ORP) of the 0.1 % acetic acid was reported as 3.74 and 617 mV, respectively (Klinhom *et al.*, 2008). Thus, it could be the reason that, chlorpyrifos and malathion got partially degraded at such a low pH solution.

In the current study, the degradation of pesticides in the washing solution had confounded effect on the % dissolution, as had been noticed in the 0.001 % KMnO_4 solution, so the % dissolution of pesticide in the washing solution may not be used accurately in estimating the reduction of pesticides in the vegetables.

Almost 31.1 % of formothion and 86.8 % of fenitrothion was removed by 2 % SP. This indicated that not only the chemical substances (0.001 % KMnO_4 washing solution) used in this study could provide benefit over water for removal of pesticide residues but also the solution of biomaterial (2 % SP) is an effective treatment for all pesticides. This might be due to its chemical constituents (crude fibers and carbohydrates etc), presence of

different acids (oxalic acid, tartaric acid, malic acid, ascorbic acid, citric acid, gallic acid, salicylic acid, ellagic acid, chlorogenic and p-caumaric acid) and the reported saturated fatty acids; palmitic acid, stearic acid, oleic acid and myristic acid and unsaturated fatty acids; linoleic and linolenic acids and low lipid content represents distinctly separate entities (Satpathy *et al.*, 2011). Thus washing with different chemicals can be replaced by washing with the 2 % solution of SP, which does not have any side effect. As an instance the most effective KMnO_4 can retain some Mn residue over the vegetable which is not degradable on cooking and availability of KMnO_4 to every kitchen is sometime not practically feasible. Table 2 shows the removal efficiency of pesticides by both 2 % SP and other organic acids reported for SP. The removal by 2 % SP is higher than the other organic acids. Based on these results we have concluded that removal of pesticides by 2 % SP is dependent on the uptake of pesticides in different acids and may also be dependent on the presence of spherosomes in SP (Adachi and Okano, 2006). SP is an underutilized, inexpensive, exotic fruit which is available in different species all over the world. The utilization of SP in this manner subsidizes its underutilized status as well. Taken together, this study suggests that the use of SP for removing pesticide residues from vegetables is an efficient, cost-effective and toxic free practice.

Based on statistical analysis, the results of intuitive analysis of OP residues removed from vegetable samples by cooking treatment are given in Table 2. The results obtained in eggplant sample with boiling agreed with those observed by others (Zhang *et al.*, 2007), where nearly 100 % of all residues were eliminated from treated eggplant by boiling at 100 °C for 5 min. Based on the type of vegetable and the pesticide treatment, the effects of cooking on removal of residues from vegetables were different (Ling *et al.*, 2011). As the results show, with boiling, the average removal of chlorpyrifos and malathion from tomato, okra and cauliflower was more difficult than from other vegetables. The results also showed that the chlorpyrifos and malathion applied may be trans-located into internal plant tissues and were therefore not easily removed by washing for 15 min and cooking for 5 min. The average removal % of parathion, methyl parathion and formothion residues by cooking is higher than that of washing, which indicates that removal by cooking was more effective than by washing.

4. Conclusion

In the present study, the effects of washing and cooking on OP residues in six vegetables were studied. Many factors such as physical and chemical property of pesticide, the type of vegetable, processing procedure, application of pesticide, etc. affected the removal of pesticide residues. In conclusion, pesticide residues studied in the six vegetables were reduced by various degrees, depending on the behavior and physiochemical properties and the specificity of chemicals used for washing preparation. Washing vegetables with the chemical reported here enhances the removal of pesticide residues from produce more than that of washing with water alone. Among the washing solution treatments, the 0.001 % KMnO_4 washing solution was found to be most effective in reducing the pesticide residues which was due to the high degree in the pesticide degradation. Washing with 2 % SP also exhibited equivalent reduction capability similar to 0.001 % KMnO_4 . Hence, this study suggests that the use of chemical washing solution can remove the pesticide residues from vegetables. Furthermore, it was seen that a solution of the underutilized citrus commodity is capable of removing the residues efficiently in a cost efficient and safe manner.

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Table 1. Pesticide levels detected in selected vegetables collected from Agricultural produce marketing committee, Azadpur, Delhi, India

Name	Beans n =10	Eggplant n =18	Okra n =5	Cauliflower n =11	Capsicum n =4	Tomato n =11
Formothion	ND ^a	ND	ND	ND	ND	ND
Methyl Parathion	ND	ND	ND	ND	0.08±0.03	0.12±0.05
Fenitrothion	ND	0.33±0.17	0.41±0.16	0.08±0.05	0.16±0.17	0.33±0.17
Malathion	^b 0.19±0.05	ND	ND	0.22±0.12	ND	0.19±0.12
Parathion	ND	ND	ND	0.11±0.04	ND	ND
Chlorpyriphos	0.27±0.09	0.13±0.27	0.33±0.17	0.23±0.19	0.33±0.17	0.33±0.17

^aND: not detected

^bresults: mg/kg ± SD

Table 2. Reduction (%) of pesticide in Eggplant, Okra, Tomato, Beans, Cauliflower and Capsicum

Eggplant	0.001% KMnO ₄	0.1% ascorbic acid	0.1% acetic acid	0.1% malic acid	0.1% oxalic acid	0.1% NaHCO ₃	0.9% NaCl	Water	2% SP	Boiling
Parathion	41±4	57.4±2	88.1±3	54.7±2	54.3±7	73.1±6	78.7±5	23±4	64.1±4	96.5±2
Methyl parathion	52±2	66.4±3	91±2	47.8±4	57.4±2	77.4±3	83.8±3	22±3	68.9±2	88.4±3
Malathion	38±3	59.9±2	79.2±4	66.5±3	61.3±2	86.8±3	95.3±2	45±1	71±3	93.9±3
Fenitrothion	89±6	79.4±3	84.5±2	39.9±4	67.7±3	82.3±3	76.5±3	37±2	86.8±4	100±1
Formothion	34±5	69.8±2	89.6±3	77.4±4	59.3±2	86.4±2	90.3±3	20±4	84.1	96.7±3
Chlorpyrifos	42±2	83.7±3	69.6±5	71.6±2	81.1±2	74.9±4	84.8±5	37±2	79.3±4	100±1
Okra										
Parathion	36.5±3	57.4±5	88.1±0.6	54.7±3	54.3±3	73.1±2	78.7±4	29±3	64.1±2	96.5±2
Methyl parathion	92.6±4	66.4±4	91±3	47.8±4	57.4±3	77.4±1	83.8±2	29±5	68.9±4	88.4±3
Malathion	42±4	42±3	40±2	46±4	41±5	36±3	35±3	39±5	40±2	93.9±4
Fenitrothion	66±5	54±3	53±2	59±4	57±4	52±2	46±2	35±4	64±5	100±2
Formothion	90.7±3	69.8±3	89.6±2	77.4±1	59.3±5	86.4±4	90.3±3	20±2	84.1±3	96.7±2
Chlorpyrifos	87.6±3	74.5±2	87.7±3	82.6±1	67.8±4	87.2±3	50.3±2	31±3	76.8±2	97.6±3
Tomato										
Parathion	86.5±2	57.4±4	88.1±5	54.7±3	54.3±3	73.1±1	78.7±4	37±4	64.1±2	96.5±4
Methyl parathion	92.6±4	66.4±2	91±4	47.8±2	57.4±4	77.4±2	83.8±2	32±3	68.9±2	88.4±3
Malathion	88.9±2	59.9±4	79.2±2	66.5±3	61.3±3	86.8±2	95.3±1	41±5	71±4	93.9±3
Fenitrothion	81±3	76±5	74±3	63±2	59±4	57±4	55±2	34±4	76±5	100±1
Formothion	90.7±4	69.8±2	89.6±3	77.4±1	59.3±2	86.4±3	90.3±2	27±3	84.1±3	96.7±4
Chlorpyrifos	87.6±2	74.5±3	87.7±3	82.6±1	67.8±4	87.2±3	50.3±1	39±3	76.8±2	97.6±4
Beans										
Parathion	86.5±2	57.4±4	88.1±3	54.7±1	54.3±1	73.1±2	78.7±3	33±3	64.1±2	96.5±4
Methyl parathion	92.6±2	66.4±3	91±2	47.8±2	57.4±3	77.4±3	83.8±4	35±2	68.9±2	88.4±2
Malathion	88.9±2	59.9±4	79.2±3	66.5±2	61.3±3	86.8±3	95.3±3	43±6	71±5	93.9±4
Fenitrothion	63±5	59±4	57±4	55±2	43±4	42±4	49±4	39±2	58±6	100±4
Formothion	90.7±4	69.8±3	89.6±2	77.4±1	59.3±5	86.4±3	90.3±5	27±3	84.1±4	96.7±4
Chlorpyrifos	87.6±3	74.5±4	87.7±3	82.6±1	67.8±2	87.2±2	50.3±3	31±5	73.8±4	97.6±3
Cauliflower										
Parathion	86.5±2	57.4±2	88.1±4	54.7±4	54.3±3	73.1±5	78.7±3	32±2	64.1±3	96.5±4
Methyl parathion	92.6±4	66.4±3	91±4	47.8±3	57.4±2	77.4±4	83.8±2	34±3	68.9±3	88.4±1
Malathion	88.9±2	59.9±3	79.2±3	66.5±4	61.3±4	86.8±2	95.3±4	39±5	71±4	93.9±2
Fenitrothion	59±3	54±4	45±2	47±4	44±3	46±6	51±3	36±3	86.8±4	100±4
Formothion	90.7±3	69.8±2	89.6±4	77.4±3	59.3±2	86.4±3	90.3±3	29±6	84.1±5	96.7±5
Chlorpyrifos	87.6±3	74.5±3	87.7±5	82.6±3	67.8±3	87.2±1	50.3±3	35±4	72.8±2	97.6±3
Capsicum										
Parathion	86.5±4	57.4±3	88.1±2	54.7±5	54.3±5	73.1±5	78.7±3	37±3	64.1±3	96.5±5
Methyl parathion	92.6±5	66.4±3	91±6	47.8±6	57.4±4	77.4±4	83.8±3	36±2	68.9±2	88.4±2
Malathion	88.9±5	59.9±2	79.2±4	66.5±3	61.3±4	86.8±5	95.3±3	40±5	71±4	93.9±5
Fenitrothion	65±4	60±2	54±3	51±6	55±2	42±3	36±5	34±2	61±5	100
Formothion	90.7±4	69.8±3	89.6±6	77.4±4	59.3±4	86.4±3	90.3±1	27±6	84.1±4	96.7±2
Chlorpyrifos	87.6±2	74.5±4	87.7±3	82.6±3	67.8±3	87.2±3	50.3±3	31±4	76.8±2	97.6±2

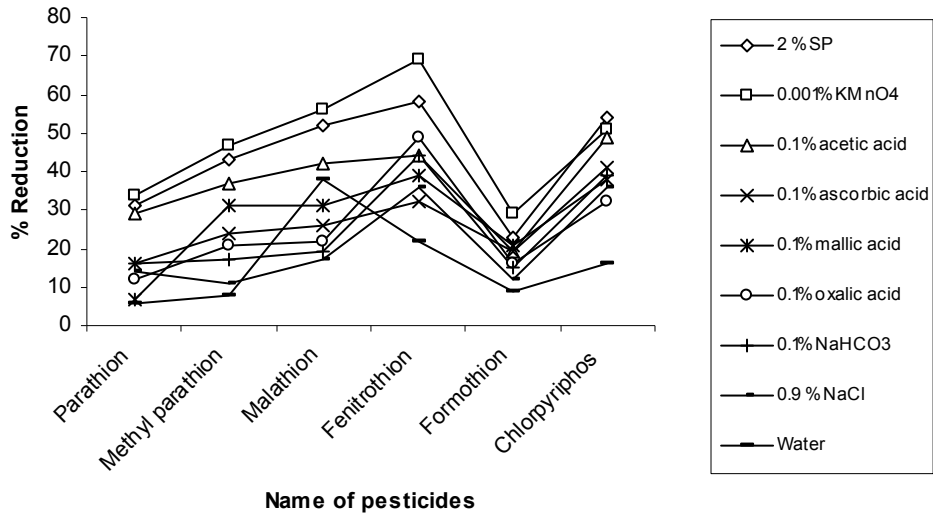


Figure 1. Effect of washing solution treatments on the pesticide degradation

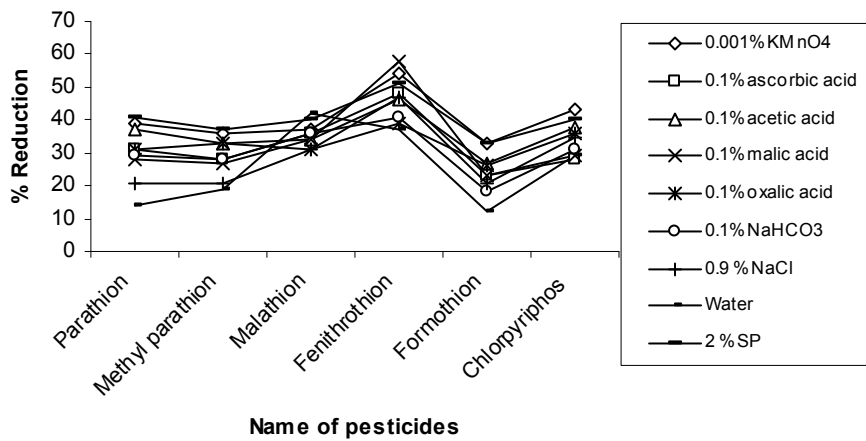


Figure 2. Dissolution (%) of pesticides from the treated sample in the washing solutions