EFFECT OF PROCESSING ON PESTICIDE RESIDUES IN FOOD CROPS - A REVIEW


ABSTRACT

The use of pesticides is inevitable to control the pests in different crops, fruits and vegetable plants. It is increasing day by day in Pakistan. The persistent use of pesticides leaves behind toxic residues on food crops. These pesticides upon ingestion exert adverse effects on human health, in addition to disturbing ecosystem. The organochlorine, organophosphorus, carbamates and pyrethroid pesticides have been detected in samples of fruits and vegetables collected from various locations of the world especially in Indo-Pakistan. Most of the samples contained toxic residues exceeding maximum residues limits. Experiments have been carried out to determine the reduction in pesticide residues due to various processing techniques like washing, peeling, frying, freezing and cooking of fruits and vegetables. Likewise treatment of food crops with acidic or alkaline solution also minimized the pesticide residues. This paper reviews the literature published up to the year 2009 focusing on the injurious effects of pesticides and their degradation by processing and chemical treatment. In this literature, it is suggested that different processing operations can be effectively applied on fruits and vegetables to minimize the risk of pesticides on human health.

KEYWORDS: Pesticides; residues; food crops; toxicity; Pakistan.

INTRODUCTION

In Pakistan, crop losses are very alarming which are estimated as 30-40 percent pre-harvest, 10-30 percent post harvest and 50 percent crop losses are due to insects, weeds, diseases and rodents (21) In order to safeguard agricultural produce from ravage of pests, use of pesticides is considered as

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the only solution. Due to reason, pesticides consumption has increased manifolds during the last two decades (29). Most of the growth in world pesticide market is in developing countries. Globally, organophosphates account for nearly 40 percent of total insecticide sales by value followed by carbamates (20.4%), pyrethroids (18.4 %) and organochlorines (6.1%) (4).

Pakistan is importing a huge quantity of pesticides every year. In 1990, it imported 13030.14 tons of pesticides; which reached to 30479.00 tons in 1995. During year 2007 the import increased to about 41406.00 tons. So the import of pesticides is increasing day by day in the country (39).

**Pesticide a necessary evil and its injudicious use**

Sulfur was used as pesticide to control insects and mites 5,000 years ago. In ancient times, Chinese used mercury and arsenic compounds to control body lice and other pests while Greeks and Romans used oil, ash, sulfur, and other materials to protect themselves, as well as livestock, and crops from various pests. The cultural methods were also employed to control the pests, such as crop rotation, tillage and manipulation of sowing dates (12).

The modern era of chemical pest control began around the time of World War-II, when the synthetic organic chemical industry began to develop. The first synthetic organic pesticides developed were organochlorines, such as dichlorodiphenyltrichloroethane (DDT) in Switzerland in 1939. The DDT and other organochlorine insecticides (cyclodiene organochlorines, aldrin and dieldrin, endrin, endosulfan and isobenzan) were used as these insecticides acted against insects by blocking their nervous system, causing malfunction, tremors, and death (42). Hence, pesticides application became an essential component of modern agriculture. Although the wide-spread use of pesticides in Pakistan has controlled the pests, but like other countries, it has started causing environmental problems in the area. In some areas of Punjab and Sindh groundwater has been found contaminated and is constantly being contaminated due to pesticide use. There is considerable evidence that farmers have overused and misused pesticides especially in cotton-growing areas. It is evident from the biological monitoring studies that farmers are at higher risk for acute and chronic health effects associated with pesticides due to occupational exposure (39). However, pesticide use also has created concerns regarding its effect on the environment and the potentially toxic or carcinogenic residues remaining in the food chain (27).
Toxicity of pesticides

Deaths from exposure to pesticides are not uncommon. Each year thousands of farmers, especially in developing countries, are affected by exposure to pesticides especially those living near the farms. Recent estimates quoted by Food and Agricultural Organization (2000) from Pesticide Action Network (PAN) show that approximately three million people are poisoned and 200,000 die from pesticide poisoning each year. The largest number of deaths occurs in developing countries. For example, hospital statistics in Sri Lanka show that on average 14,500 individuals were admitted to government hospitals and around 1500 individuals a year died from pesticide poisoning during the period 1986–1996 (National Poisons Information Centre, 1997). However, these figures should be interpreted with caution. It should be pointed out that not all hospital admissions and deaths were due to occupational poisoning but include cases of self ingestion (suicides), accidental ingestion and homicides. Moreover, there is evidence suggesting that some pesticides can produce immune dysfunction among animals when exposed to pesticides (40). A study (16) showed that women who had chronically ingested groundwater contaminated with low levels of aldicarb had significantly reduced immune response, although these women did not exhibit any overt health problems. However, it should be noted that study of immune suppression potential for pesticides is still in its infancy and that the evidence available is inconclusive (40). Even in developed countries, despite the strict regulations and use of safer pesticides, occupational exposures may be significant (4). It is believed that in developing countries incidence of pesticide poisoning may even be greater than reported due to under-reporting, lack of data and misdiagnosis (17).

The incidence and severity of ill health from pesticide-use are far greater in developing countries than in developed countries due to many reasons. Most of the farmers in developed countries use pesticides from a closed environment such as an aircraft or a tractor, while farmers (who are largely small scale farmers) in developing countries use hand sprayers, thus increasing the incidence of direct contact with pesticides. Moreover, as noted by WRI (4) farmers in the developing world use more insecticides, they use them more frequently and also apply insecticides that are more toxic than those used in developed countries. Inadequate education, training and pesticide regulations in the use of pesticides lead to accidents, haphazard application and over-use. Access to medical treatment is limited and most farmers rely on homemade remedies thus increasing the severity and duration of illnesses. Poor health and diet are other factors that are believed to increase the incidence of illnesses from exposure to pesticides in

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developing countries (4). Inadequate or non-existent storage facilities, poor living conditions and water supplies contaminated with pesticides also affect the health of families.

**Pesticide residues in raw fruits and vegetables**

The organochlorine, organophosphorus and pyrethroid pesticides were monitored in samples of fruits and vegetables procured from the whole sale market of Karachi during July 1988 and June 1990. A total of 250 samples were screened out of which 93 samples were found to be contaminated with variety of pesticides. Forty five samples were found to contain residues above maximum residues limits (MRLs) proposed by FAO/WHO while 48 samples contained residues well within permissible limits. In remaining samples, no pesticides residue was detected (39). In 2001 a total of 315 samples representing a wide variety of produce were tested. Of these 73 percent samples were fresh produce and 27 percent were processed foods. Pesticide residues were found in 47 percent samples of fresh produce and 7 percent of processed foods samples (41). Frank et al. (18) surveyed Ontario grown vegetables in Canada for pesticide residues during 1980-85. A total of 354 samples were screened. Most of the samples contained residues well within maximum residues limits (MRLs) while the limits were exceeded in only a small number of samples. In 1998 a total of 180 samples of vegetables were tested, 89 percent were fresh produce and 19 percent were processed vegetables. Pesticide residues were found in 35 percent of fresh produce samples and 10 percent of processed vegetables (39, 41).

**EFFECT OF PROCESSING ON PESTICIDE RESIDUES**

Experiments were carried out to determine changes in pesticide residues due to washing, peeling and cooking process (blanching and frying). The purpose of these experiments was to assess the stability of pesticides in vegetables and their products. There are strong evidences that through processing of vegetables pesticide residues decrease (25, 33, 34, 37). Unit operations in processing typically include washing the raw product with large volumes of water, frequently using high-pressure sprays and often incorporating surfactants or other washing aids; peeling the product mechanically with knives, abrasive disks, or water; blanching with hot water or steam; and in case of canned or cooked foods, cooking of the product at temperatures at or above the boiling temperature of water. Thus, residue that may be present was subjected not only to physical removal by washing or peeling but also acid or base hydrolysis and thermal degradation (11).

**Washing**

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Surface residues are amenable to simple washing operations whereas systemic residues present in tissues will be little affected. For example, highly pola and systemic methamidaphos was the only pesticide whose residues could not be removed from field tomatoes by washing. There is evidence for a variety of crops and pesticides that the proportion of residue that can be removed by washing declines with time (19, 33, 34, 36, 37). This has been interpreted as being due to residues tending to move into cuticular waxes or deeper layers. For example the fractions of fenitrothion or methidathion residues on cauliflower that could be removed by washing or blanching were inversely proportional to the days after spray application (38).

Hot washing and blanching are more effective than cold washing and the effectiveness may be further improved by detergent (19). Blanching removed 82 percent of methidathion residues from cauliflower and did not show any effect of withholding period as compared to the lower proportion of residues removed by washing (30). Domestic rinsing is less effective compared to thorough commercial washing. Hot caustic washes used in some commercial peeling operations can efficiently remove and degrade residues of hydrolysable pesticides (15).

**Peeling, hulling and trimming**

The majority of insecticides or fungicides applied directly to crops undergoes very limited movement or penetration into the cuticle. Therefore, residues of these materials are confined to the outer surfaces where they are amenable to removal in peeling, hulling or trimming operations (20, 35). Peeling fresh fruits such avocado, bananas, citrus, kiwifruit, mango and pineapple achieves virtually complete removal of residues from the fruit. There is substantial data showing non-detectable residues in pulp of citrus and edible portion of other fruits that support these conclusions. For example, supervised field trials of pirimiphos-methyl on various citrus crops gave non-detectable (< 0.03 mg/kg) residues in the pulp compared to residues in the peel (0.5 to 5 mg/kg) (5). Post harvest dipping trials were conducted on pineapple with the fungicide triadimefon which has some trans-laminar action. Residues in the flesh were only 0.5 to 1 percent of those in the peel (20). Under Codex, MRL’s are based on the whole fruit which is appropriate for assessing compliance with Good Agricultural Practices (GAP) (39). These MRLs are of limited significance in assessing exposure to pesticides from consumption of fresh fruits which are peeled or juiced. However, apples and tomatoes may be consumed either whole or after peeling.

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Residues of systemic pesticides can enter the flesh of crops. Following early season soil incorporation of phorate, residues in washed whole potatoes of 0.37 mg/kg (parent plus oxidation products) were reduced only by 50 percent through peeling (5). Similarly disyston residues in potatoes were reduced only 35 percent by peeling (8) whereas residues of the much more lipophilic chlorpyrifos were completely removed in the peels (24). The hulls of cereal grains generally contain the majority of pesticide residues from any field treatments. Residues of parathion in oat or rice grains were reduced eight folds on hulling (5). Pirimiphos methyl residues in rice were reduced 70 percent and 90 percent by husking and polishing, respectively (13). Husking of corn (maize) removed 99 percent of the residues from field treatments with tetrachlorvinphos (14).

Cooking and canning

The processes and conditions used in food cooking are highly varied (25). The details of time, temperature, degree of moisture loss and whether the system is open or closed are important to the quantitative effects on residue levels. Rates of degradation and volatilization of residues are increased by the heat involved in cooking or pasteurization. For example, in a study on radio labeled chlorothalonil residues, cooking under open conditions resulted in 85 to 98 percent losses by volatilization. Cooking under closed conditions resulted in hydrolysis with 50 percent of the chlorothalonil being recovered unchanged on the crop and hydrolysis product being found in the liquor (5). For compounds that are of low volatility and relatively stable to hydrolysis such as DDT and synthetic pyrethroids, losses of residues through cooking may be low and concentrations may actually increase due to moisture loss. However, deltamethrin has been reported to have a half-life of 9 minutes in boiling water and residues were reduced by 66 percent by cooking of various vegetables (10).

Commercial processing in its various forms combines elements of washing, peeling, juicing, cooking and concentration. Processing of whole tomatoes with vinclozolin residues of 0.73 mg/kg gave residues in canned juice, puree and ketchup at level of 0.18, 0.73 and 0.22 mg/kg, respectively (5, 25). In this case the relatively stable fungicide vinclozolin was carried through the process in significant amounts. Only 13 percent of parathion residues on tomatoes were found in canned juice or ketchup.

Stir-frying and freezing

Pesticide residues can be effectively decreased by stir-frying (32, 45). These can be reduced up to 49 and 53 percent by peeling and frying (33). Freezing
of food is a common method of food preservation which slows both food decay and most chemical reactions. Freezing of tomatoes decreased the pesticide residues from 5 to 26 percent after six days and 10 to 31 percent after 12 days of pesticide contamination (1). Zhang et al. (45) estimated the pesticides residue levels in cabbage after preserving in refrigerator. In some vegetables, pesticide residues are decreased after refrigeration. By increasing the time of refrigeration there is gradual increase in reduction of pesticide residues. After three days of freezing, HCB, lindane, DDT, dimethoate, profenofos and pirimiphos-methyl decreased by 4.91, 6.32, 4.07, 13.0, 11.5 and 9.35 percent, respectively (15).

EFFECT OF CHEMICAL SOLUTIONS ON PESTICIDE RESIDUES

Acidic solutions

Soaking in acidic solution like citric acid, ascorbic acid, acetic acid and hydrogen peroxide at a concentration of 5 and 10 percent for 10 minutes indicates proficient reduction of pesticide residues. Acidic solutions give more pesticide dissipation than neutral and alkaline solutions. The acidic solutions of 5 and 10 percent eliminated pesticide residues completely while, citric and ascorbic acid solutions of 5 and 10 percent eliminated pesticide residues upto 80 percent (43). Some other scientists (14, 31, 36) also reported that partial removal of residues was affected by the washing operation (water and/or acetic acid, sodium chloride).

Neutral solutions

Sodium chloride (NaCl) solution is largely used to decontaminate the pesticide residues from different fruits and vegetables. There are several studies (14, 31, 36, 46) to prove the efficacy of salt water washing for dislodging the pesticides from fruits and vegetable surfaces. In this process, samples of chopped fruits and vegetables were put in a beaker containing 5 and 10 percent NaCl solution for 15 minutes. The samples were gently rubbed by hand in salt solution and water was decanted. Twenty eight to 93 percent reduction in organochlorines and 100 percent organophosphates removal was achieved by using 5 and 10 percent NaCl solution (43). The percentage reduction in pesticide residues increases with the gradual increase in concentration of solutions (1, 22). NaCl with 2, 4, 6, 8 and 10 percent solution caused 20 to 90 percent reduction in pesticide residues. Similarly 18 to 65 percent loss in pesticide residues was reported by Soliman (37) by using 2, 4, 6, 8 and 10 percent acetic acid solution.

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Alkaline solution and ozonation

Solutions of NaOH, acetic acid, potassium dichromate and soap are used as decontaminating agents. Dipping of fruits in NaOH solution removed 50 to 60 percent surface residues of pyrethroids compared to 40 to 50 percent removal by hydrolytic degradation with NaOH and a detergent solution removed 50 to 60 percent residues (6).

Ozone because of its powerful oxidizing property is effectively applied in drinking water and waste water treatment. Recently some scientists found that certain pesticides like 2, 4-dichlorophenoxyacetic acid, carbofuran, phorate, chlorophenylurea, can readily be degraded in aqueous solution by ozone (7, 9, 26). Ozonation is a safe and promising process for the removal of pesticides from aqueous solution and vegetable surface under domestic conditions. Tap water treatment along with ozonated water treatments significantly reduced the pesticide residues on vegetables, as compared to no-wash treatment (41).

CONCLUSION

From the extensive review on the use and fate of pesticides during food processing, it is concluded that pesticides are inevitable part of the agriculture but their indiscriminate use can cause serious health problems. In a developing country like Pakistan there is a great need to regulate the use of pesticides where the extensive use of pesticides is causing serious health and alarming environmental problems. To minimize the risk of pesticides on health different processing operations are applied on fruit and vegetable crops that reduce the pesticide residues below the risk level. It is further concluded that treatment of vegetables with acidic and alkaline solutions can effectively minimize the pesticide residues. There is a need to educate the consumers through media.

REFERENCES


