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Review on Pesticide Residue in Plant Food Products: Health Impacts and Mechanisms to Reduce the Residue Levels in Food

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ABSTRACT

Residues of organochlorine and organophosphorus are found in a lot of food items in different countries; some of them are below the Maximum Residue Levels (MRLs) and safe for health. Based on the review there are food commodities containing residue above the MRLs set by different authorities like FAO and WHO and different countries legislation. Consumption of plant food products having pesticide residues greater than the MRLs have revealed to cause illness and chronic diseases based on the adequate daily intake (ADI) and acute reference dose (ARfD). It's revealed that safety limits are assessed in comparison with ADI for short term exposure or ARfD. The consumer is considered not to be at risk if the estimated dietary intake of a pesticide residue does not exceed the ADI or the ARfD. However, monitoring and settings of maximum residue levels for pesticide residues in food commodities is an effective control mechanism for safety of the consumers to combat health impacts of toxic chemicals. There is evidence to show that consumption of organic crops is healthier than non-organic. In most of the research findings higher pesticide residues are found in non-organic crops than organic ones, organic crops are also rich in antioxidants. Processing method like washing, immersing, peeling, husking, cooking, boiling and frying are reported to reduce the level of pesticide residue in plant foods.

Key words: Organophosphorus pesticides residues, Organochlorine pesticide residues, Organic foods, Conventional foods

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INTRODUCTION

Pesticides are widely applied in a variety of different ways during the production of foods to control the growth of weeds and fungi or to prevent crop damage by insects, mites, rodents, and other pests. Most sectors of the agricultural production use pesticide to prevent pests and to improve yield as well as quality of the produce [1]. They are also frequently used on crops postharvest to prolong storage life and improve quality. Despite their use, health risk of pesticides residues on food and in drinking water for the general population has been raised [1, 2]. Pesticide can cause adverse health impacts notably death, disease, and birth defects (teratogenic) among humans and animals. Many of these chemical residues, especially derivatives of chlorinated pesticides, exhibit bioaccumulation which could build up to harmful levels in the body as well as in the environment [3]. Common effects of pesticide residues in human body include nausea, vomiting, blurred vision, coma, difficulty in breathing, deficit hyperactivity disorder, disorder in foetuses and children [4]. The WHO estimates an annual three million cases of acute and severe pesticide poisoning worldwide with some 220,000 deaths [5]. The majority of these cases of poisoning and deaths occur in developing countries, although far greater quantities of pesticides are used in the developed countries [6].

Due to food safety and environmental reasons, laws have been established in most countries worldwide to set maximum permissible levels of pesticide residues in crops. Controls on pesticide residues in crops are based on Maximum Residue Limits (MRLs). Maximum residue levels are the highest levels of residues expected to be in the food when the pesticide is used according to authorized agricultural practices [7]. MRL's are typically range between 0.01 mg/kg and 10 mg/kg and are a useful means of enforcing acceptable pesticide and inadequate as a

guide to human health risks from residues. Pesticide residues that are below the MRL set by the European Commission are considered by regulators not to pose risk to consumers or the environment, as they are significantly lower than concentrations for which negative health or environmental impacts can be detected in the regulatory pesticide safety testing carried out as part of the pesticide approval process [8]. Analytical monitoring is often conducted to determine if residues are present for food safety, regulatory, product liability, quality, research and food labeling purposes. The levels of these residues in foods are often stipulated by regulatory bodies in many countries. Percentage of samples with residues at or below the MRL in food of plant origin ranged from 20% to 60% of the samples analyzed, exceed in MRLs ranged from 1.5% to 4.6% [9].

Different processing mechanisms which are used to reduce pesticide residue in plant food products are investigated by researchers. For the most part, pesticide residues in food commodities are reduced or concentrated after several processing such as washing, peeling, blanching, cooking and sterilization [10, 11].

Even though the use of pesticide for agricultural product is increasing in different areas of countries the health impact of the pesticide residues is not well investigated in developing countries. Awareness creation, conducting a research and training of societies on the effect pesticide residue and how to keep safety of food is less practiced. The main aim of this article is to review the pesticide residues in plant food products, impact of pesticide residues through ingesting of food on human health and the mechanisms used to reduce the residue in plant foods.

Pesticide Residue in Fruits and Vegetables and their Health Effects

Fruits and vegetables provide essential nutrients to human being. A high intake of fruits and vegetables (five or more servings per day) has been encouraged not only to prevent consequences due to vitamin deficiency but also to reduce the incidence of major diseases such as cancer, cardiovascular diseases and obesity [12]. However, the use of pesticides during production often leads to the presence of pesticide residues in fruits and vegetables after harvest. Pesticide residues have toxic effects such as interfering with the reproductive systems and foetal development as well as capacity to cause cancer and asthma [13]. Some of the pesticides are persistent and therefore remain in the body causing long term exposure.

Most farmers and commercial producers are treated fruit and vegetable with pesticides on several occasions during growing. This is because pesticide decrease toxins produced by food infecting organisms, increase productivity and are less labour intensive. The presence of pesticide residues is a concern for consumers because pesticides are known to have potential harmful effects on human being. Kostik et al. (2014) reported that about 98.8% of the samples that were found to contain residues well below the relevant MRLs. According to their investigations cucumber was the crop with the highest number of pesticide residues with the predominant presence of methomyl, (0.015-0.21 mg/kg), metalaxyl (0.04-0.16 mg/kg), and imidacloprid (0.017-0.036 mg/kg). Methomyl is a carbamate insecticide with restricted use because of its high toxicity to humans. The MRLs for methomyl and thiodicarb (sum of methomyl and thiodicarb expressed as methomyl) for the most of fruits and vegetables is set at the 0.02 mg/kg in the Regulation (EC) 396/2005. The other pesticide residues found in cucumber samples were boscalid, chlorpyrifos, cyprodinil, fenhexamid, imidacloprid, metalaxyl and tebuconazole [14].

Many commodities contained more than one residue per product, up to 9 residues in grapes and tea were determined, up to 5–9 residues in citrus fruits like orange, mandarins, lemons, peaches, pears and up 3–5 residues in pomegranates, plums, cucumbers, tomatoes, strawberries [9]. The most frequently detected pesticide residues were imazalil, thiabendazole, chlorpyrifos, maneb group, procymidone, methidathion, lambda-cyhalothrin, carbendazim, iprodione, orthophenylphenol, vinclozolin, endosulfan, pyrimethanil, fenhexamid, prochloraz, cyprodinil, boscalid. The reason of high detection frequency of thiabendazole, imazalil residues is that these pesticides are widely used for post-harvest treatment of citrus fruits and bananas in order to preserve fruit during the transport process which may take several weeks [9]. Residues of these pesticides were found in 70% of the imported citrus fruits and bananas at or below the MRL.

A study in Belgium revealed that pesticide residues were detected in 72% of the samples and standards were exceeded for 6% of the samples [15]. Nevertheless, the exposure of the Belgian population to pesticide residues (15 years or older) appears to be under control, even when consuming frequently or high quantities of fruit and vegetables. According to Claeys et al. (2011) for children there is an indication that high consumption of fruit and vegetables could for some pesticides lead to an exceeding of the ADI (Acceptable Daily Intake) [15]. The ADI is the estimated amount of a substance in food, usually expressed in mg/kg on a body weight basis that can be ingested daily over a lifetime without appreciable chronic long-term risk to any consumer [7]. The ADI is set on the basis of all known facts at the time of evaluation, taking into account sensitive groups within the population (e.g. children). The consumer is considered not to be at risk if the estimated dietary intake of a pesticide residue does not exceed the ADI or the ARfD [7].

High level of pesticide residues was determined in imported blackberries, strawberries and other berries as well as mangoes, papaya, pepinos, bitter melon, peas, beans, eggplant, spinach and other vegetables[16,17]. The commodities with the highest level of pesticide residues found in China were cabbage, legumes and leaf mustard [18]. According to [19] among thirty-eight batches of rape from a market in Shanghai (China) determination of pesticide residues was performed in samples using the direct sampling technique was obtained in one batch, chlorpyrifos residue was found at a concentration of 1.03 mg/kg, which is above the MRL set by the MOA of China. Chlorpyrifos inhibition of cholinesterase was the most sensitive effect in rats, mice, rabbits, dogs and in humans, regardless of exposure duration [20]. According to US EPA in animals, significant inhibition of plasma and RBC cholinesterase occurs at doses below those that cause brain cholinesterase inhibition. EFSA have set dietary reference values for chlorpyrifos considering the ADI of 0.001 mg/kg body weight per day and ARfD of 0.005 mg/kg body weight [21]. Apples, papayas, sweet peppers and strawberries were among products with the highest percentage of samples with residues above the MRL found in Brazilian pesticide residues monitoring program. High level of pesticide residues in pears, grapes/ raisins, citrus fruit, peppers, cucumbers, tomatoes, carrots were obtained in Lithuania [9].

A study in Ghana showed that pesticide residues were found in all the monitored fruits and vegetable samples from all the selected markets from Kumasi metropolis. Among the selected samples 37.5% of fruit and vegetable samples analyzed contained no detectable level of the monitored pesticides, 19.0% of the samples gave results with levels of pesticide residues above the MRL, while 43.5% of the samples showed results below the MRLs [22]. Based on the result they have suggested that the consumers of the Kumasi metropolitan city are exposed to concentration of pesticides that may cause chronic diseases.

Pesticide residue concentration in vegetables and finds that the risk posed to consumers varies with the season [7]. The winter season has the highest pesticide concentrations in vegetables that might accumulate in the person's body and lead to fatal consequences in the long run. However, only methyl parathion residues have a significant hazard index, so this result is also pesticide-dependent. Methyl parathion is a pesticide that is used to kill insects on crops. Exposure to very high levels of methyl parathion for a short period in air or water may cause death, loss of consciousness, dizziness, confusion, headaches, difficult breathing, chest tightness, wheezing, vomiting, diarrhoea, cramps, tremors, blurred vision, and sweating [23].

Pesticide Residue in Grain and their Health Effects

Insects and pests can cause a loss in the quality and quantity of grains and their products. The losses can vary between countries and crops, but one estimate suggests an overall loss of around 40%. Another more assessment suggests losses of 26 to 29% for soybean and wheat, and 30 to 40% for maize and rice. The same study suggests that losses for wheat could be as high as 50 per cent without effective plant protection, and even higher for other crops. The application of pesticide is widely used for grains before harvest and after harvest to protect the grains from damage or loss. Cultivation and storage of grains often require an intensive use of pesticides, which may then be found in grains and in foods prepared from them [24]. Cereal grains are treated with degradable pesticides, including organophosphates, carbamates, synthetic pyrethroids and insect growth regulators, both in storages and prior to shipment in order to prevent insect infestation. Organophosphorus Pesticides (OPPs) are widely used for protection of stored commodities [25]. They are used for post-harvest treatments of wheat because of their relatively low rates of degradation under storage conditions that exist in practice. But post-harvest pesticides have been attracting much attention because their residues in stored cereal grains may be hazardous to human health [26]. Improved crop protection in the face of new pests and diseases, as well as resistant strains of current diseases, will rely on a variety of approaches. The well-managed use of different classes of pesticides (herbicides, fungicides, insecticides, etc) must continue to play a key role. In face of this, particular attention should be addressed to pesticide residues due to the common use of these compounds in agriculture [27]. The Food and Agriculture Organization and World Health Organization have recommended residue limits for bioresmethrin, bromophos, carbaryl, chlorpyrifos-methyl, deltamethrin, dichlorvos, etrimfos, fenitrothion, fenvalerate, malathion, methacrifos, permethrin, phenothrin, pirimiphosmethyl and pyrethins used for the protection of grains [28].

The consumption of grains contaminated with organophosphate pesticides residues above the MRLs can cause human health. People in direct contact with organophosphate pesticides can inhibit the enzyme acetyl-cholinesterase (AChE) and this enzyme inactivates the neurotransmitter acetylcholine in the body, which cause neurological problems [29].

A study in Pakistan on pesticide residue of cereals showed that wheat contained the highest concentration of tested pesticides (HCH, BHC, DDT and Dieldrin) than maize and rice and maize contained much higher concentration of pesticides than rice [29]. According to Zia et al. (2009) pulses samples were also found contaminated with multiple pesticides especially Gram and Mung contained high concentration of HCH and

residues of methyl parathion were found maximum on Masoor, followed by Mash and Mung. Wheat and barley treated with methyl mercury fungicides led to one of the worst epidemic in Iraq in 1992, in which 100,000 people were poisoned and 6000 died [30].

The study in Poland revealed that out of 380 samples of the cereal grains, 62 % did not contain any residues, 34 % residues of plant protection products were below limits, 3 % were above maximum residue limits [31]. According to their investigation out of the analyzed cereals, the smallest amount of plant protection products residues was in mixed cereal grains (below 10 %) and Avena grains (below 15 %) where as Hordeum and Triticum grains contained the highest content of plant protection product residues (over 50 %).

A study in Nigeria on Organochlorine pesticide (OCP) residues analyzed from cereal grains (Millets, Guinea corn, Maize) showed that Aldrin (0.03 to 0.13 mg/kg), Dichloran (0.01 mg/kg), Dieldrin (0.018 to 0.02 mk/kg), Endrin (0.0003 to 0.03 mk/kg), Endosulfan (0.005 to 0.02 mg/kg), Heptachlor epoxide (0.02 mg/kg), Lindane (0.25 to 1.25 mg/kg), Methoxychlor (0.03 to 1.17), Mirex (0.008 to 0.02 mg/kg), DDT (0.04 mg/kg) respectively (Anzene et al., 2014). According to Anzene et al. (2014) Lindane was the OCP whose level was detected in the highest concentration in all the grain samples (0.25 to 1.25 mg/kg) which are above the 0.01mg/kg Maximum residue limit (MRLs) for Lindane stated by FAO/WHO (2013) [32] and also the levels of Aldrin present in all the grains was found to be above the FAO/WHO recommended MRLs value of 0.02 mg/kg for cereal grains. Most common pesticides applied to food crops on field and during storage are organochlorines [33].

Methods Used to Reduce Pesticide Residue in Food

Now day's different types of pesticides are in use in different countries for different types of crops to prevent pests, insects and weeds. Because of the expansion of worldwide trade, more foods which are treated by pesticide are being imported into different countries. These worldwide trades increase the expansion of pesticide residues in different areas of the world and it's the issue of public health concern. There are safety concerns of these commodities due to reports of the presence of banned antimicrobial agents in imported food products, and pesticides in produce [34]. It's commonly known that pesticides can affect the nervous, endocrine, immune, and reproductive systems. Infants, young children, the unborn, and the elderly are more susceptible to pesticide poisoning.

Researchers have been conducted on the mechanisms to reduce the effect of pesticide residues in food. It is desirable to reduce the levels of pesticide residue in foods to lower the exposure and risk to human health [34]. One of the methods used to reduce the effect of pesticide residue in food is to eat organic crops than non-organic ones. According to the standard meta-analyses done by Baranski et al. (2014) the frequency of occurrence of detectable pesticide residues was four times higher in non-organic crops than organic crops [35]. There are evidences that indicated organic food consumption can reduce exposure to pesticide residues in food [36, 37]. Organic crops, on average, have higher concentrations of antioxidants, lower concentrations of Cd and a lower incidence of pesticide residues than the non-organic comparators across regions and production seasons [35]. It's advisable to consume foods rich in antioxidant to reduce effects of chronic disease by suppressing oxidative activity. An increased dietary intake of antioxidant/(poly) phenolic-rich foods to protect against chronic diseases, including Cardio Vascular Diseases, certain cancers (e.g. prostate cancer) and neurodegenerative diseases [38, 39]. Significantly higher frequencies of occurrence of pesticide residues in conventional crops were also detected when data reported for fruits, vegetables and processed crop-based foods were analyzed separately. Conventional fruits had a higher frequency of occurrence of pesticide residues than vegetables and crop-based compound foods, while contamination rates were very similar in the different organic crop types [35] (Baranski et al., 2014). According to Baranski et al., higher frequency of occurrence of detectable residues in conventional fruits (75 %) than in vegetables (32 %) may indicate higher levels of crop protection inputs being used in fruit crops, but could also have been due to the use of more persistent chemicals, different sprayer technologies used and/or pesticide applications being made closer to harvest.

The second methods reported to reduce pesticide residue in food is washing. Washing may reduce pesticide residue in food commodities [40, 41&42]. Washing with water and various chemical solutions for domestic and commercial applications is necessary to decrease the pesticide residues from produce [43]. The efficiency of the washing treatments on pesticide removal depends on the washing solution, the chemical properties of the pesticide, the surface area, the nature of the food, the length of time the pesticide is in contact with the food, and the formulation and application method of the pesticide. Usually, the pesticide is lodged in the outer wax-like layers and then moves to the inside, making washing and removal of the pesticides less effective [44].

Another method used to reduce pesticide residues is processing food commodities especially fruit and vegetables. An important factor leading to reduction of any residues left on crops at harvest are processing treatments such as washing, peeling, canning or cooking that the majority of foods receive prior to consumption [42]. Fruits and

vegetables like other foods pass through different processing treatments to increase the palatability of the food. The effects of food processing techniques have been found to reduce the pesticide residue levels except in cases where there is concentration of the product like in juicing frying and oil production [12]. Celik et al. (1995) also investigated the effects of the food processing techniques reduce the pesticide residue levels, except in cases where there is concentration of the product like in juicing, frying and oil production[41]. Pesticide residue levels in fruit and vegetables may change due to processing, such as peeling, boiling, frying, fermentation, grinding [15]. Cooking also may reduce pesticide residues in food; boiling may remove only 35-60% of organophosphate residues and 20-25% of organochlorines [40]. No pesticide residues were detected in any of the samples of processed vegetables and fruits [14].

Husking and Immersing of fruit and vegetables are reported to reduce pesticide residues. Residues of organophosphorus pesticides (Ops) generally exist on the surface of fruits. The risk of OPs intake can be reduced if fruit is husked or immersed in water for some time before eating [45]. According to their study OPs found in samples were chlorpyrifos, ethion, bromophos methyl, fenchlorphos, carbophenothion, cyanophenphos, and parathion in which contents were even lower than limits of detection (LOD) regulated in national standard of China.

CONCLUSION

The increasing applications of pesticide in different areas of the world initiate researchers to conduct their study on pesticide residue in food commodities and set optimum levels which may be safe for health. MRLs set by different countries/ or organizations legislation are good indication for consumers in aspect of human health prospective. The ability to determine residues of toxicants in food is crucial to support efforts that are designed to protect human health. Residues of organophosphorus pesticides (Ops) were obtained in fruit and vegetables and some of them are above MRLs which may be toxic to human being. Most residues of organochlorines (OC) are also found in grain storages which are reported to cause health of the people. Consumption of organic foods than conventional was recommended to reduce pesticide residue and good for health of human being. Different processing methods like washing, peeling, cooking or boiling, frying, fermentation, grinding of food commodities were also investigated to reduce pesticide residues. Appropriate use pesticide for crops before and after harvest is crucial in management of the residues.

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