

Vegetable Processing At Household Level: Effective Tool Against Pesticide Residue Exposure

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Abstract: Vegetables constitute an important component of a balanced diet. Being a rich source of vitamins and minerals, they protect us from micronutrient deficiencies and gastrointestinal disturbances. However, along with life-saving nutrients, they have turned into a major source of life-taking poisonous substances called pesticides and their residues into the human body. Many studies reviewed across the country have evidenced the presence of these agrochemicals in major vegetables. Presence of these persistent chemicals as residue elicits multiple health complexities ranging from mild allergies to deadly diseases. To minimise dietary exposure to pesticides, it is pertinent to explore strategies that effectively help in reducing the residue content at individual level. Several simple, labour-less and cost effective unit operations like washing, peeling and cooking singly or in combination can prove an effective means in reducing dietary consumption of pesticide residues even in poor populace. In a developing country like India, dissipation techniques at household level can serve as an effective tool in reducing risk related to dietary exposure to residues and henceforth controlling pesticide related adversities. This article is a collection of reviews that provide us the account of extent of residue reduction through commonly used processing treatments.

Keywords: Dissipation; Health hazards; Household processing treatments; Pesticide residues

I. Introduction

Vegetables are the inseparable components of Indian cuisine and are consumed throughout the country in different forms and preparations. They form the bulk and are the major source of vitamins and nutrients, hence fulfilling the requirements of our balanced diet. Vegetables are low in fat and are rich in vitamins and minerals. They are rich sources of calcium, magnesium, potassium, iron, beta-carotene, vitamin B-complex, vitamin-C, vitamin A and vitamin K. Apart from supplying micronutrients; they are home for antioxidants too; hence protect the human body from oxidative stress, diseases and improve immunity. Additionally, they are loaded with soluble and insoluble fibers viz; cellulose, hemi-cellulose, gums, pectin. These fibres retain excessive water and maintain colon health. Hence, they are necessary for good health.

II. Background

2.1 Vegetable Consumption Status

Modernization of agriculture has played a pivotal role in increasing the production of vegetables. Today, India is one of the leading producers of vegetables and is reaching new heights every day. In spite of all these facts, the consumption of vegetables in India is found below the recommended dietary intake set by ICMR in almost all the states. Low fruit and vegetable intake is one of the major contributing factors for the prevalence of micronutrient deficiencies in Indians [1]. Vegetable consumption has found to be quite low in almost all states except Orissa and West Bengal (Fig. 1).

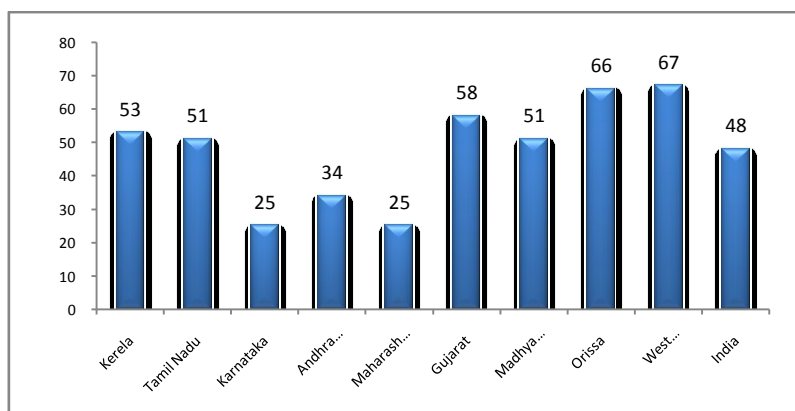


Fig. 1: Mean household consumption of vegetables (gmCU⁻¹ day⁻¹) in different states of India (Adapted from [2])

2.2 Need for pesticides:

Vegetable crops are highly sensitive to pest attacks. Even today about 30-40% of the vegetables grown are damaged by pest attacks. This is where the use of agrochemicals called pesticides comes into picture. Pesticides can be defined as a group of poisonous harmful chemicals that were applied to plants and their fruits to save them from getting damaged from pests. In India, the use of pesticides on agricultural crops started during the mid-sixties after the launching of the green revolution. It provided a breathing spell for achieving balance between growing population and food security [3]. Henceforth, they were used as an element in achieving sustainable food security effectively. Since then these Agrochemicals have been used by vegetable growers for enhancing productivity and earning huge profits in return. Today, India is the leading producer and exporter of different vegetables. It shares about 13% of the world's output of vegetables from only 2% of cropped area in the country. However, achieving monetary benefits is not the only reason for the use of pesticides. Looking at the other side, India is the second most populated country in the world. In order to achieve vegetable security for each and every individual in the country, vegetable production has to be doubled roughly in a decade's time [4]. Therefore, they are sprayed frequently several times in their lifecycle. Vegetables are exposed to pesticides at several stages starting with the treatment of the seeds. Initially, seeds are treated with herbicides to protect them from fungal infestation and then sowed. After sprouting, the cycle of repeated use of pesticides starts on the standing crops to control pest infestation.

III. Presence of pesticides in vegetables

Spraying of crops with different formulations of pesticides and their adsorption to soil particles is attributed to be the prime reason for contamination of vegetables. However, contamination because of the movement of these agrochemicals has always been underestimated. Motility of pesticides from one crop to another and their transport over long distances by means of wind, rainfall and running water streams has led to contamination of crops even in far off lands. Residues of pesticides sprayed on previous crops have also been found as contaminants in the vegetables. Vegetable samples collected from different states all over the country have evidenced the presence of pesticide residues in them. State wise distribution of such studies has been reviewed in Table 1. Highest rate of contamination has been observed in Haryana, Bihar, Delhi and Karnataka.

Table 1: Presence of Pesticides in vegetables in different states of India.

State	Vegetables	Percent contamination	Percent above MRL	Pesticides detected	References
Rajasthan	Cauliflower, brinjal, tomato, okra, cabbage, potato	40.11	35.62	Endosulfan, Cypermethrin, Methyl parathion, Fenvalerate and Monocrotophos, methyl parathion, Quinalphos	[5]
	Cabbage, Okra, tomato, Brinjal	41.67	13.33	Benzene Hexa Chloride, Chlorpyrifos, Cypermethrin, butachlor, chlordane. Monochrotophos	[6]
Uttar Pradesh	Bitter gourd, jack fruit, french-bean, onion, pointed gourd, capsicum, spinach, potato, fenugreek seeds, carrot, radish, cucumber, beetroot, brinjal, cauliflower, cabbage, tomato, okra and bottle gourd	52.38	20.00	HCH, Dicofol, -Endosulfan, Fenpropathrin, Permethrin-II, β -cyfluthrin-II, Fenvalerate-I, Dichlorvos, Dimethoate, Diazinon, Malathion, Chlorofenvinfos, Anilophos, and Dimethachlor	[7]
West Bengal	Fenugreek, coriander, sugatbeet	2.16	ng/g	Aldrien, dieldrien, Heptachlor, Lindane	[8]
Uttarakhand	Brinjal, Okra, tomato, sweet-pepper, cabbage, cauliflower			Endosulphan, carbendazim, chlorpyrifos, cypermethrin, imidachloprid	[9]
Bihar	Brinjal, Cauliflower, cabbage, green chilly	69	11	Cypermethrin	[10]
Haryana	Okra, bitter gourd, smooth/ridge gourd, cucumber, tomato, Brinjal	100	23	HCH, DDT, DDE, Aldrin, Endosulfan, Endosulfan sulphate, Permethrin, Cypermethrin, Deltamethrin, Fenvalerate	[11]
Andhra Pradesh	Tomato, Brinjal	45.5	4	Endosulphan, Monochrotophos, Cypermethrin	[12]
Jharkhand	Cauliflower, Brinjal, Okra	48.7	15.37	Endosulfan	[13]
Andaman Islands	Brinjal, Okra, Green chilli, Crucifers, Cucurbits	34	15.3	Endosulfan, Cypermethrin, fenvalerate, fluvalinate I, Deltamethrin, Cyhalothrin, Chlorpyrifos, profenophos, monochrotophos, ethion, dimethoate	[14]
Delhi	Vegetables	100	31	Cypermethrin, endosulfan	[15]

	Vegetables	71	18	Endosulfan, chlorpyrifos, M Parathion, Quinalphos, Monochrotophos	[16]
Punjab	Cauliflower	42	-	Endosulfan, Endosulfan sulphate, Acephate, chloroxyriphos, fenamiphos, profenophos, quinalphos, cyhalothrin, β -cyfluthrin, fenpropathrin	[17]
Kerela	Basil, Spinach		16-78	Endosulfan	[18]
Karnataka	Beans, brinjal, cabbage, carrot	100	58	Aldrien, Dieldrien, endosulphan, HCH, heptachlor, acephate, chlorpyrifos, monochrotophos, phorate profenophos, cypermethrin, deltamethrin, cyhalothrin	[19]

IV. Health impacts associated with pesticides

Excessive use of pesticides can harm the ecosystem leading to several health impacts. Dr. MS Swaminathan feared and cautioned about the health impacts associated with the use of these persistent chemicals shortly before the launch of the green revolution. In his presidential address to the Agricultural Science Section of the Indian Science Congress in early January 1968 [20], he stated-

“.....exploitative agriculture offers great possibilities if carried out in a scientific way, but poses great dangers if carried out with only an immediate profit motive.....Indiscriminate use of pesticides, fungicides and herbicides could cause adverse changes in biological balance as well lead to an increase in the incidence of cancer and other diseases, through the toxic residues present in the grains, vegetables or other edible parts.....”

Decades later, his findings then have become the happening of today. What he feared almost forty-five years ago has today become a harsh reality. Uncontrolled use of pesticides, particularly at the fruiting stage and non-adoption of safe waiting periods has led to their accumulation in vegetables. It has landed us in the world full of complex health related adversities and exponentially increased burden of deadly diseases. The residues being persistent in nature infiltrate crops, contaminate water, pollute complete food chain and enter our body through diet. Many accidents have been reported in different parts of the world due to injudicious and indiscriminate use of pesticides. Developing countries suffer 99% of deaths from pesticide poisoning [21].

Pesticide exposure may produce biochemical alterations in the body long before adverse clinical health effects are manifested [22]. In spite of the well known fact that pesticide residues are responsible for a great deal of complexities, the adverse health effects cannot be correlated with exposure to a single pesticide. Multiple and prolonged pesticide exposure affect different organ systems differently [23]. Health effects from pesticides and their residues may range from mild allergies, rashes and breathing difficulties to deadly diseases like cancers etc. Cancers of all types have been reported on pesticide exposure including leukaemia, lymphomas, soft tissue sarcomas, brain, bone and stomach cancers. Pesticides known as endocrine disruptors are found to cause neurotoxicity, which elicit their adverse effects by mimicking or antagonising natural hormones in the body. It leads to confusion, irritability, drowsiness and even Alzheimer and Parkinson disease. Adversities related to reproductive system include irregular menstrual cycles, infertility, hypospadias, cryptorchidism, decreased penile length, low sperm counts, disruption of male and female hormone signalling pathway, still births and even foetal death [24, 25].

V. Mechanisms of post-harvest dissipation of Pesticide residues

5.1 Locale of the residues

Pesticides can be applied to fruits and vegetables during various phases of production. Some pesticides are applied before blooming while others at the growing stage and/or later at the time of harvesting. Depending on the location, pesticides are classified as systemic and contact [26]. Pesticides that are absorbed by the plant surface (waxy cuticle and roots) enter the plant transport system are termed as systemic pesticides. Contact pesticides remain on the surface of the plant. The concentration of pesticides was found to be higher in fruit stalk on exocarp and food receptacle in fruits and vegetables. In leafy vegetables, residue concentration was higher in the outer leaves than the inner ones [27].

5.2 Degradation mechanisms

Fate refers to the pattern of distribution of an agent, its derivatives and metabolites in an organism as a result of transport, partitioning, transformation or degradation [28]. Rate of pesticide movement and dissipation is based on the physiochemical properties and interaction with environmental factors. After application on the crops they may follow different pathways depending on the composition and physiochemical properties of vegetables and pesticides. It is the interaction between the combination of the properties of pesticides and vegetables with environmental factors that determines the extent of pesticide absorbance, penetration and degradation. After application, pesticides may interact with plant surfaces, may be exposed to environmental factors such as wind and sunlight and may be washed off during rain [29]. Their ability to resist degradation is

measured as half-life. Half life is defined as the time in days required for half of the initial amount of pesticide to breakdown. Half life of pesticides depends upon the environmental conditions, the type of vegetable and the amount of pesticide initially applied/present [30]. Half lives of some common pesticides in vegetables are given in Table 2.

Table 2: Half life of some common pesticides in vegetables

Vegetable	Pesticide	Initial dose	Half-life (days)	Reference
Brinjal	Benfuracarb	0.25 mgkg ⁻¹	3.90	[31]
		0.50 mgkg ⁻¹	4.73	
	Endosulphan	4.5 mgkg ⁻¹	3.30	[32]
Pepper	Pirimophos-methyl	10.49 mgkg ⁻¹	1.72	[33]
	Profenophos	10.67 mgkg ⁻¹	1.74	
Chilly	Multiresidue extraction		3.22	[34]
	Fubendiamide	60 ga.i./ha	0.96	[35]
Okra	Flubendiamide	0.28 mgkg ⁻¹	4.7	[36]
	Fenazaquin	125 ga.i./ha	3.13	[37]
	Propargite	1.36 mgkg ⁻¹	0.79	[38]
	β-cyfluthrin		0.91	[39]
Tomato	Bifenthrin	25 g a.i ha	1.83	[40]

Apart from half-life, dissipation of pesticides residues can also be explained through some basic processes viz; Volatilisation, hydrolysis, metabolism, enzymatic transformation, oxidation etc.

5.2.1. Volatilisation

It is the ability of the pesticide to vaporize or evaporate after application in the field. It is dependent on the vapor pressure of the pesticide. Pesticides with high vapor pressure tend to volatilize rapidly into the air while those with low vapor pressure remain longer on the surface. Volatilization rate also depends on the environmental factors such as wind speed and temperature. The faster the wind speed and the higher the temperature the more the pesticide will evaporate.

5.2.2 Hydrolysis

Hydrolysis is the breaking of the bonds in the presence of water. After cleavage, a new bond is formed by taking oxygen atom of water, hence introducing HOH or OH into the molecule. Products obtained after hydrolysis are more polar than the molecules from which they are derived and may be more water soluble and less subject to bioaccumulation. Hydrolysis is both biotic and abiotic types. Abiotic hydrolysis of pesticides usually takes place in low biological activity. Rate of hydrolysis depends upon the hydrogen ion concentration (pH) and acid-base characteristics (pK_a). The rate of hydrolysis of pesticides increases with increasing temperature [41].

5.2.3 Photolysis

Degradation of pesticides on exposed surfaces may be facilitated in the presence of sunlight by a phenomenon called photolysis. The process of photolysis results in pesticide degradation through direct and indirect pathways. In direct photolysis, molecules absorb energy from the sunlight especially in the UV-visible range resulting in pesticide degradation. In indirect transformation, absorption of photon leads to phototransformation of some other chemical compound excluding pesticides. These compounds, called sensitizers, undergo break down and get activated by sunlight. These sensitizers in return react with pesticides and are responsible for affecting pesticide molecules. Photolysis is insensitive to temperature and pH. However, it is affected by spectral distribution, intensity & duration of sunlight and angle of incidence of sunlight to the exposed surface. Photolysis produces oxidation products which are more water soluble, less volatile and less subject to bio-uptake than their parent molecule.

5.2.4 Microbial metabolism

Some pesticides may be degraded by microbial metabolism. Micro-organisms can use pesticides as nutrients thereby breaking them into carbon dioxide and other components [41]. Because of the difference between naturally occurring organic chemicals and pesticide structures, they cannot be assimilated by the microbes but they may be altered at reactive sites. The products formed may be less or more toxic than the parent chemical.

Environmental degradation viz; Photodegradation and many other degradation mechanisms generally cease to function or are greatly reduced once a crop is removed from the field situation. Hence it is necessary to apply several processing treatments even at the household level to reduce pesticide residues.

VI. Household processing treatments for reduction of pesticide residues

Food processing techniques in vegetable processing implies the set of methods and unit operations used to transform raw ingredients into edible forms for direct consumption either in the home or by the food processing industry. Reviewing extensive literature showed that in most cases these steps lead to considerable reductions in residue levels in the prepared food, particularly through, washing and peeling, fermentation, refrigeration singly or in combination. The behaviour of residues in storage and processing can be rationalized in terms of the physico-chemical properties of the pesticide and the nature of the process [42].

Transition of processed products from raw agricultural commodities through food processing results in change in concentration in pesticide residues. This change in concentration is often measured by transfer factors or food processing factors (Pf). These processing factors are expressed (1) as the concentration of pesticide after processing divided by the concentration before processing [43].

$$\text{Processing factor (Pf)} = \frac{\text{Concentration of Pesticide after processing}}{\text{Concentration of pesticide before processing}} \quad (1)$$

The risk of exposure to organophosphorus pesticides in Dutch diet was assessed using processing factors [44]. General processing factors were derived to be 0.76 for washing, 0.44 for peeling and 0.74 for canning of fruits and vegetables. Washing processing factors were 0.9 ± 0.3 for pyridaben, 1.1 ± 0.3 for pyrifenos and 1.2 ± 0.5 for tralomethrin in tomato [45].

The impact of each unit operation commonly practiced at household level is explained hereafter.

6.1 Washing

Washing of vegetables is the most traditional and the preliminary unit operation applied to remove debris and dirt from vegetables prior to consumption. It is the most prevalent practice in every household as it is the cheapest and easiest method of cleaning [46]. Vegetables can be washed by using plain water or by chemical formulations in commercial and household processing. Formulations commonly used are brine, chlorine solution, ozonated water, strong acid, baking soda, vinegar, lemon water, potassium permanganate etc [47, 48, 49]. The extent of residue reduction by washing depends on the physiochemical properties of the pesticides, such as water solubility, hydrolytic rate constant, volatility and octanol-water partition coefficient (Pow), in conjunction with the actual physical location of the residues; washing processes lead to reduction of hydrophilic residues which are located on the surface of the crops.

Surface residues are amenable to simple washing operations whereas systemic residues present in tissues are little affected. For example, in tomatoes, systemic methamidaphos was the only one that could not be removed from a group of pesticides by washing [50]. Pyrethroids and some organophosphates being nonsystemic in nature remain attached as microparticles on the surface and are easily removed by the mechanical stirring with water during washing. Thus washing has a significant effect on the removal of residues in several vegetables depending on the pesticide because of less/no penetration of the chemical into the cuticle layer of the plant surface and resulting in deposits removable by washing. These results agree with those obtained by several researchers [51, 52] who reported 50-60% removal of the residues by the washing operation. A reduction of 10-30% of alphamethrin residues in tomato and eggplant have been reported [68]. Washing reduced 90% of pesticides from carrots [53]. Effectiveness of washing in dislodging pesticide residues in different vegetables has been synthesized in Table 3.

6.1.1 Washing by Tap Water

Tap water washing is the most commonly followed practice in every household before the processing of vegetables. Effectiveness of washing operation was checked in vegetables based on the solubility of pesticides. Plain water washing reduced fat soluble residues of bifenthrin, endosulphan and profenofos in cauliflower by 25%, 28.1% and 14.32% respectively. Degree of reduction on plane water washing on water soluble pesticides namely deafenthiuron, imidacloprid in cauliflower were to be 40.69%, 39.07% and 2117% respectively [54]. Deltamethrin was reduced by washing upto 35% in tomato, 32% in cauliflower, 26% in potato and 10% in spinach [55]. Washing reduced cypermethrin residues by 33.42-35% and decamethrin by 25-27.90% in brinjal. Chlopyriphos residues were found to get reduced by 33% in Spinach, 30% in potato, 25% in cauliflower and 10% in tomato [56]. Imidacloprid residues reduced from 0.31-0.082 ppm in okra by detergent washing (73% removal) [57]. λ -cyhalothrin residues in tomato were reduced in the range of 37-40% by washing [58]. In cauliflower washing was found to reduce the residues of monocrotophos and para thion to the extent of 48.6-70%. However it was found less effective in reducing phorate (16.27%), permethrin (6.80%) and dichlorvos (3.32%) [59].

6.1.2 Washing in formulated solutions

Residues of Monochrotophos, fenitrothion and fenvalerate were removed to an extent of 41.81%, 100% and 100% by dipping in lemon juice, dipping in 2% tamarind solution for 5 min followed by wash tap water and

steam cooking for 10 min respectively [60]. Five vegetables namely beans, eggplant, okra, cauliflower, capsicum and tomato were analysed for malathion, fenitrothion, formothion, parathion, chlorpyrifos and methyl parathion. The samples were spiked with pesticides. In unwashed samples concentrations were 8.7 for malathion, fenitrothion (12.5), formothion (5.3), parathion (6.9), chlorpyrifos (7.9) and methyl parathion (6.8). Washing removed 42-89% malathion, fenitrothion and chlorpyrifos residues while formothion, parathion and methyl parathion were found to be decreased upto 20-48% [61].

Table 3: Reduction of pesticide residues by washing in some common vegetables

Vegetable	Pesticide analysed	Initial content(mg kg ⁻¹)	Percentage reduction	References
Okra	Σ-HCH		38	[62]
	Σ-DDT		20	
	Endosulfan		36	
	Chlorpyrifos	1.41 ± 0.148	13-35	[63]
	Cypermethrin	1.17±0.1	45-50	[64]
	deltamethrin	1.08±0.12	30-35	
	cyhalothrin	0.48±0.03	20-25	
	Brinjal/ eggplant	Quinalphos		31-32
B- cyfluthrin			35-43	[65]
Endosulphan		2.13	40-47	[32]
Cypermethrin		1.57	20-25	[66]
Carbofuran			21	[62]
Deltamethrin		0.174± 0.018	20	[55]
DDT		0.056- 0.178	37	[62]
Decamethrin		1.095	30-42	[67]
Alphamethrin			29-16	[68]
Quinalphos		4.78	21-61	[69]
Methomyl		3.98	21-61	
Tomato	Flufenzin		43-48	[70]
	Fenpyrozimate		46-55.6	
	λ-cyhalothrin		37-40	[71]
	Bifenthrin		17-19	[40]
	ethylenethiourea		70	[72]
	Benomyl		83	[73]
	Deltamethrin	0.00855	47-50	[74]
	Endosulphan	2.9	41.3	[75]
	Fenvalerate	1.5	15.6	
	Chlorpyriphos	1.6	38.2	
	Malathion	2.8	52.0	
Cauliflower	Chlorpyrifos	9.0	78.6	[75]
	Quinalphos	24.8	28.9	
	Endosulfan	14.6	34.1	
	Fenvalerate	10.5	65.1	
	deltamethrin	2.5	50.8	
	chlorantranilprole		17-40	[76]
	Dichlorvos	91.51	3.32	[77]
Cabbage	Monocrotophos	2.54	70	[78]
	Quinalphos		27.72-32.48	
Asparagus	Chlorpyriphos		24	[52]
	Cypermethrin		35	
	ethylenebisdithiocarbamates		52	
Ginger	Trifloxystrobin	0.005	ND*	[79]
	Fosthiazate	0.003	ND*	
Green Chilli	Acetamiprid	0.015	46.67	[79]
	Trifloxystrobin	0.064	20.31	
Spinach	Azoxystrobin	0.004	100	[79]
	Endosulfan	1.25±0.044	22.22	[80]
Cucumber	Trichlorfon	0.41	53.7	[81]
	Dimethoate	0.46	32.6	
	Dichlorvos	0.84	52.4	
	Fenitrothion	0.45	26.7	
	Chlorpyrifos	0.81	62.9	
Tomato	Metalaxyl	1.45	28.97	[82]
	Mancozab	9.92	39.92	
	Ethylenethiourea	2.03	39.41	
	Carbendazim	0.28	29.34	
Potato	Endosulfan	0.177±0.003	20.34	[80]
	Deltamethrin	0.023±0.003	26.09	[55]

* Not detectable.

6.2 Heat Treatments

Processes involving heat can enhance volatilization of chemicals and their hydrolysis thus reducing residue levels. Depending upon the chemical properties of pesticides different heat treatments had different impact on residue content. Sun drying reduced up to 93% fat soluble and 96% water soluble pesticides; dehydration is reported to reduce (up to 84% of fat soluble and 87% of water soluble pesticide) and blanching (up to 72% of fat soluble and 79% of water soluble pesticide [54]. Dislodging of cypermethrin residues was observed more in grilling (50.12%), followed by cooking in oil (45.2%), cooking in water (41.4%), and microwave cooking (40.89%) [66].

6.2.1 Blanching and Boiling

Blanching treatment was also found effective traditional method by which residues of emamectin benzoate, diafenthiuron and imidacloprid were reduced up to 55.94, 68.69 and 79.11%, respectively from an initial concentration of 1.040, 0.052 and 1.010 ppm respectively [54].

Cooking lowered deltamethrin residues from 19 to 40% in vegetables [55]. Boiling reduced OPs by 32-100% in brinjal, cauliflower and okra. By boiling process maximum (100%) reduction of OP insecticides was observed in brinjal followed by 92% in cauliflower and 75% in okra [62]. Boiling reduced trifloxystrobin residues in green chillies from initial concentration of 0.064 ± 0.0409 to 0.023 ± 0.0108 depicting a reduction of upto 50% [79]. Stir frying reduced trifloxystrobin residues from 0.064 ± 0.0409 to 0.030 ± 0.0157 in green chillies [79]. Pre-heating, pulping, evaporation and half-pasteurization increased deltamethrin 2.33% while decreasing endosulfan 66.5% after washing. The whole process decreased endosulfan and deltamethrin, 76.8% and 46.3%, respectively. The residues were mostly collected in pomace [74]. Boiling reduced the residues of organophosphates in tomato, bean, okra, eggplant, cauliflower and capsicum by 52-100 % [61].

6.3 Peeling

Peeling of root, tuber and bulb vegetables with a knife is common household practice. As pesticides are applied on the outer surfaces of vegetables they undergo very little amount of penetration in the cuticle. Therefore, their residues are mostly confined in the peel where they are amenable to removal by peeling or trimming. The removal of the outer part of peeling is the most effective household processing operation for pesticide removal from vegetables and reduces large fractions of residues.

Peeling reduced 73% chlorpyrifos, 82% lindane, 75% cypermethrin and 77% ethylene bis-thiocarbamate in asparagus [52]. Peeling reduced deltamethrin residues to 76 to 80% and cooking further lowered it from 19 to 40% in all tested vegetables [55]. Peeling of potatoes reduced 91-98% chlorpropham residues from an initial concentration of 3.8 ppm in tubers 10 days after application [84]. Diazinon levels in cucumbers decreased by 67.3% from an initial level of 0.822ppm [85]. Malathion residues were reduced by more than 45.9% and 60.6% in cucumbers by peeling [86]. Peeling reduced procymidone (0.86ppm) level by 77% in tomatoes [88]. Washing plus peeling removes 99% of carbaryl and malathion residues from tomatoes. Peeling processing factors were 0.3 ± 0.2 (70% reduction) for pyridaben and 0.0 ± 0.0 (100% reduction) for both pyrifenox and tralomethrin in tomato [45].

6.4 Fermentation

Fermentation is a simple process during which the enzymes hydrolyze most of the proteins to amino acids and low molecular weight peptides; starch is partially converted to simple sugars which are fermented primarily to lactic acid, alcohol and carbon dioxide [88].

In a study, fermentation of cucumbers leads to significantly lower amount of benomyl and mancozeb [89]. Fermentation of vegetable mix (Tomato, celery, green bean, cabbage, cauliflower) by lactic acid bacteria for a period of 48 hrs reduced malathion residues from an initial concentration of 3.5 mgkg⁻¹ to 0.5 mgkg⁻¹. However, Diazinon showed a decrease of only 0.1 mg kg⁻¹ from an initial concentration of 0.5 mg kg⁻¹ [90]. Effect of different processing treatments on pesticide residues have been reviewed in Table 4.

6.5 Freezing and Refrigeration

Low temperature storage is a common method of food preservation which slows both food decay and most chemical reactions [91]. Zhang *et al* estimated the pesticide residue levels in cabbage after preserving in the refrigerator and found decreased pesticide residues after refrigeration [92]. In a study it was found that when cucumbers contaminated at level of 2 L / 1000 L in water were refrigerated the reduction of residues were 5.3%, 22.4%, 43.7%, 52% and 68.2% after 2, 4, 6, 8 and 10 days with diazinon and 14.7%, 28.2%, 49.1%, 63% and 74.7% loss after these specific days with malathion, respectively [86]. Brinjals stored at refrigerated temperature showed a decline of 3.95, 1.70, 1.35 and 1.1 respectively after 0, 3, 5 and 7 days from an initial dose of 4.5 mg kg⁻¹. A decline of 72.1% was observed on the seventh day under refrigerated conditions [32].

Table 4: Reduction of pesticide residues by different processing treatments

Processing treatment	Vegetable	Pesticide analysed	Initial content(mg kg ⁻¹)	Percentage reduction	References
Boiling	Green chillies	Trifloxystrobin	0.064±0.0409	50	[79]
	Okra	Σ-HCH		47	[62]
		Σ-DDT		35	
		Endosulfan		38	
		Emamectin benzoate	0.51	35	[57]
	Tomato, bean, okra, eggplant, capsicum, cauliflower	Organophosphates		52-100	[61]
Washing + Half pasreurization	Tomato Pomace	Alphamethrin	0.606±0.052	19.47	[68]
		Brinjal	0.322±0.075	24.53	
Washing + boiling	Okra	Endosulfan		76.8	[74]
	Cabbage	Deltamethrin		46.3	
Washing+ Cooking	Okra	Chlorpyrifos	0.129	64-77	[63]
		Cabbage	Quinalphos		69.02-77.68
	Brinjal	Quinalphos	4.78	28.2-76.1	[69]
		Methomyl	3.98	28.2-76.1	
		fenpyrozimate		70 to 75	[70]
		flufenzin.		67 to 70	
	Tomato	Cypermethrin	0.6	31-42	[67]
		Decamethrin	0.43	26-37	
		Metalaxyl	1.45	78.6	[82]
		Mancozab	9.92	74.5	
Grilling	Brinjal	Ethylene thiourea	2.03	48.28	[66]
		Cypermethrin	1.57	50.12	
Cooking in oil	Brinjal	Cypermethrin	1.57	45.2	[66]
Cooking in water	Brinjal	Cypermethrin	1.57	41.4	
Cooking	cauliflower	Chlorpyrifos	0.036±0.003	29	[56]
		Dichlorvos	91.51	67.46	[77]
		Monocrotophos	2.55	85.3	
		Deltamethrin	0.306±0.014	59.48	[55]
	Brinjal	Monocrotophos	40.93	29.68	[59]
		Endosulfan	1.364	64.22	
Peeling	Asparagus	Cypermethrin		40	[52]
		Chlorpyrifos		73	
		Lindane		82	
		Ethylene bis-thiocarbamatein		77	
	Potato	Chlorpropham	3.8	91-98	[84]
		Endosulfan	0.177	74.01	[80]
	Cucumber	Diazinon	0.822	67.3	[85]
		Malathion		45.9 - 60.6	[86]
	Tomatoes	Procymidone	0.86	77	[87]
	Brinjal	Endosulfan	2.43	64.12	[80]
	Potato	Chlorpyrifos	0/136±0.015	85	[56]
	Eggplant		1.25±0/125	75	
Microwave	Brinjal	Cypermethrin	1.57	40.89	[66]
Fermentation	Vegetable mix (Tomato, celery, green bean, cabbage, cauliflower)	Malathion	3.5	85.71	[90]
		Diazinon	0.6	16.67	

VII. Conclusion

India, being an agrarian economy is dependent on agriculture for its development. Use of pesticides on vegetables is an inevitable part of agriculture but their unscientific usage can cause significant health adversities. There is a need to regulate pesticide intake for leading a healthy life. In a developing country like India, where quite a large proportion of the population lives below poverty line burden of deadly diseases can be a great curse. From the extensive review collected on the extent of dissipation of pesticide residues and mechanisms involved during household processing techniques, it is concluded that these can serve as an effective tool for reduction of residues within safe limits. However, there is dearth of knowledge involving exact mechanism of action by which different processing treatments ought to reduce pesticide residues in different food items.

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