Measurement of permethrin, deltamethrin and malathion pesticides in the wheat flour and breads and probabilistic health risk assessment: A case study from Kermanshah, Iran

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Abstract

This study was conducted to investigate the residues of pyrethroid and organophosphorus pesticide in flour and breads which were collected from local markets in Kermanshah province, Iran. Four different types of breads and two types of flour samples with high distribution were taken from market and their residues of pesticides were measured. A simple dispersive liquid–liquid microextraction (DLLME) method with solidification of floating organic drop was developed for the measurement. The health risk of these pesticide on adults and children was assessed by target hazard quotient (THQ) using Monte Carlo simulation (MCS) method. About, 15% and 11.1% of total samples contained detectable levels of deltamethrin and malathion, respectively. None of the tested samples, showed any permethrin residue. About 85% of pesticide residue detections were

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observed in tropical and mild weather area which is due to high consumption rate of insecticides in these area.The percentile 95% of THQ is due to bread ingestion content of deltamethrin which was 0.033 and 0.070 for the adults and children, respectively and this value for malathion was found to be, 0.015 and 0.030, respectively. In the adults and children for both deltamethrin and malathion, the percentile 95% of THQ value were lower than 1 (acceptable level). The non-carcinogenic health risk assessment indicated that bread consumers in Kermanshah proviance are not at a considerable risk because of deltamethrin and malathion.

KEYWORDS: Permethrin; Deltamethrin; Malathion; Kermanshah; Bread; Risk assessment

1. Introduction

Pesticides are a group of toxic chemicals that pose health and environmental risks [1-3]. Pesticides, especially insecticides, fungicides are extensively being used for the food and fiber protection, human health and comfort [4-7]. About 70% of the pesticides are used in developed countries and 30% in the developing countries [8]. However, the excessive use/misuse of pesticides led to environmental pollution and they also finds their way to the food chain [9, 10]. Among pesticides, organophosphate, organochlorine and pyrethroid pesticides are the most extensively used pesticides in the Iranian market. For example, just in January 2000, more than 27000 tons of pesticides were used in Iran [11]. Phosphorus pesticides could be detected in different environment such as material's surface, and in water and foodstuff, however these are not the most toxic pollutants [12]. On the other hand, insecticides such as pyrethroid possess higher photo-stability and insecticidal activity, but relatively have low toxicity than organochlorine and organophosphorus (OPs) insecticides and these insecticides are a mixture of more than one isomer [13]. Due to widespread usage of various pesticides and dietary intake of their residues which

cause carcinogens and/or toxins effects, the research on monitoring and dynamics of multi-kinds of pesticides in the food stuff has become essential [14, 15].

Recently, we conducted a monitoring program for determination of pesticides and insecticide residues in foodstuff and crops in Kermanshah province, Iran. Some of these studies include determination of diazinon, fenthion, phosalone and chloropyrifose in summer crops such as cucumber, watermelon, melon and ribbed melon [16], determination of diazinon and chlorpyrifosin in rice sample [17], determination of imidacloprid and diazinon in apple and pear samples [18], determination of fenvalerate in tomato [19] and so on. The concentration of pesticides or insecticides residues was different in different samples and in some samples it was higher than Maximum Residue Limits (MRL), the limit which has been established by Codex Alimentarius Commission [20]. Malachova et al [21] found only trichothecenes A and B and enniatins in total 116 samples derived from white flour and mixed flour, breakfast cereals and snacks. Pussemier et al [22] reported the mean ochratoxin A, deoxynivalenol and zearalenone concentrations of 0.067, 675 and 75 μg/kg in conventional wheat samples against 0.063, 285 and 19 μg/kg in organically produced wheat samples in 2002 in Belgian, respectively. In another study performed by Pirsaheb et al [23] in the stored wheat at Kermanshah province's, Iran, 61.2% of the samples contain pesticide amount below the method detection limits. They investigated deltamethrin, permethrin and malathion in stored wheat samples in silos. Bolletti et al. [24] observed that residue concentrations of pirimifos, chlorpyriphos methyl, and malathion were significantly lower in the breads than in the flours, since in cookie the processing reduced their concentrations significantly

The ultrasonic-assisted solvent extraction combined with dispersive liquid-liquid microextraction based on the solidification of floating organic drop (UA–DLLME–SFO), was used for sample-

preparation where could extract the pesticides and insecticides. A high-performance liquid chromatography (HPLC) withultraviolet detector was used for measuring the concentration of selected pesticides. This is a simple, precise, rapid and reproducible method which has a high level of linearity over a wide range of analyte concentrations [25]. It uses small volumes of solvents and samples, which reduces the risk for human health and the environment.

The bread which is produced commercially is an important component of every day diet in Kermanshah province. Wheat flour is used for production of different cookies and also spaghettis,however, wheat bread is a main staple food among Iranian. To the best of our knowledge, this is the first report on the determination of pyrethroids and organophosphorus pesticide residues in wheat bread in Iran.

The main objective of this study was to detect the residues of two pyrethroid pesticides namely permethrin (3-phenoxibenzyl-3-(2,2-dichlorovinyl)-2,2-dimethyl cyclopropanecarboxilate) and deltamethrin ((S)-α-cyano-3-phenoxybenzyl (1R, 3R)-3-(2-2-dibromovinyl)-2-2-dimethyl cyclopropanecarboxylate) and one organochlorine pesticide, malathion (S-1,2-bis(ethoxy carbonyl) ethyl O,O-dimethyl phosphorodithionate) in wheat flour and bread samples in Kermanshah province, Iran. Several methods have been proposed for health risk assessment due to the exposure to residues of pesticides in food, but no carcinogenicity risk assessment study is available in Iran up to date [26, 27]. the type of pesticide, carcinogenic potency of pesticide, age and the body weight of the person, can be used to estimate the excess risk from ingestion of food contaminated with these pesticides. In health risk assessment, target hazard quotients (THQ) is defined as the ratio of estimated dose to reference dose and it is used to estimate the non-carcinogenic risk due to the exposure to contaminants. THQ > 1 is an indication of potential health risk and less than 1 indicating that the daily exposure to this level of contaminant is unlikely to

cause any carcinogenic effects during a person life-time [27, 28]. In this work, the health risks (non-carcinogenic) were also estimated for the adults and children via Monte Carlo simulation (MCS) method that could occur due to the bread content of pesticide ingestion.

2. Materials and Methods

2.1. Reagents

All reagents including methanol, acetonitrile, carbon tetrachloride, chloroform and chlorobenzene were analytical grade, purchased from Merck (Germany) and used without further purification. deltamethrin, permethrin and malathion (analytical standards) () were purchased from Dr. Ehrenstorfer GmbH (Augsburg, Germany). Methanol (HPLC grade, Merck) was used to prepare 1000 mg/L stock standard solutions of pesticides and stored at −20°C. Working standard solutions daily were prepared from the stock solution using deionized (DI) water as solvent and stored at 4°C prior to analysis.

2.2. Sample collection

The wheat flour samples (n=27) used in this study included bakery flour and samples from different kinds of bread such as Lavash, Barbari, baguette, and Sangak (Iranian whole wheat leavened flat bread) and also pastry flour. Samples were collected from Kermanshah (n=10), Kangavar (n=4), Songhor (n=4), Ravansar (n=4) and Sar-polezahab (n=5) cities (province of Kermanshah, Iran). It is important to know that the different climate has different effect on pesticide residual and their degradation rate. Kermanshah province with its vast area is located between Iranian Plateau and Mesopotamian Plain and is divided to three climatic regions including tropical, cold and humid. Samples were procured from local bakery and market.

2.3. Extraction and analytical method

Extraction and analytical method were based on our previous work [23] with some modification. To extract the pesticide from the samples, firstly 200 g of flour and bread (dry) samples were milled and homogenized in a multifunction grinder to prepare a representative sample. These samples were transferred into plastic bags. After wards, 2 g of milled sample (bread or flour) was transferred into a 10 mL centrifuge tube. An extractant, here, 5.0 mL of acetonitrile was added to extract the sample after 30 min sonication by an ultrasonic bath (Erosonic 4D, Vicenza, Italy) for 30 min at 30˚C.. Then 150 µL of 1-undecanol, which is a microextraction solvent in DLLME, was added to the tube and then was gently mixed for few second to homogenized 1-undecanol and acetone mixture. Consequently, the sample is simultaneously in contact with acetone and 1-undecanol, but1-undecanoldoes does not have any role as extraction solvent here and for further DLLME-SFO was added to aceton. Then the solution was centrifuged at 5000 rpm for two min. DLLME-SFO was performed by rapid injection of 1.0 mL of acetone extract containing spyrethroids, malathion and 1-undecanol (approximately 30 µL) to 5.0 mL ultra-pure water (gastight, Hamilton, Nevada, USA). In the test tube, a cloudy solution was formed by dispersion of fine droplets of 1-undecanol in aqueous solution. Therefore, within few seconds the OPPs in acetone were extracted into the fine droplets of 1-undecanol. The mixture was further centrifuged for 4 min at 5000 rpm and due to density difference, the fine droplets of organic solvent float at the top of the test tube. The test tubes were cooled down in a beaker containing ice. The extraction solvent solidified within 5 min and was transferred into a conical vial which quickly melts at room temperature. The samples were injected into a HPLC for analysis. Separations were carried out on a H5-ODS C18 column (15 cm × 4.6 mm, with 5 µm particle size) from Anachem (Luton, UK) anda mixture of HPLC grade water and methanol (10:90) was used as a mobile phase with a flow rate of 1.0 mL/min. The analytes were detected at wavelength ranged 245-470 nm.

2.4. Validation studies of the analytical method

The practical application of the proposed method was evaluated and the parameters validation was carried out under the most favorable conditions using spiked samples of flour and bread for the selected pesticides. Mean recovery (as a measure of trueness), calibration curve suitability, intra- and inter-assay precision, sensitivity, the limit of quantification (LOQ) and limit of detection (LOD) were evaluated as the analytical characteristics. For validating of a method, mean recoveries of 67–81% with a repeatability RSD ≤ 10% are considered acceptable. The spiked samples of flour and bread were used to determine the mean recoveries, which previously analyzed to ensure the absence of pesticide residues, at two concentration levels (10 and 100 µg/L) with five replicates for each level. LOQ was considered as the lowest concentration which was tested and established for S/N = 10. LOD was determined with signal to noise ≥3. LOD, LOQ and both were determined by analyzing spiked extracts of flour and bread. Repeatability of data were assessed using five consecutive analyses at the same operational condition. Linearity was determined by assessing the signal responses of target analytes in the standard within the concentration range from 0−10000 µg/L. The method precision was determined based on our previous work elsewhere [29].

2.5. Health risk assessment

The pesticides health risk for the bread consumers (adults and children) were estimated via Monte Carlo simulation (MCS) method [30-33]. The chronic daily intake (CDI) (mg/kg-day) was estimated using the Eq. (2) [34-36].

$$CDI = \frac{C \times IR_i \times EF_i \times ED_i}{BW_i \times AT} \qquad (1)$$

where, C, is the concentration (mg/L) of pesticides in the breads. IR_i is the ingestion rate and these value are 0.452 and 0.271 kg/n-day for the adults and children, respectively. EF_i is the exposure frequency, 350 days/year in both groups; Ed_i is the exposure duration, 70 years for the adults and 6 years for children; BWi is the body weight, 70 kg and 20kg for the adults and children, respectively; AT, is the average life span which is 25550 days for adults and 2190 days for children. Potential adverse effects are likely when THQ is higher or equal to 1; but adverse effects are not likely if the value of THQ is less than 1 [37-39].

The Non-carcinogenic risk of pesticide due to direct ingestion of bread was estimated using Eq. (1) [34, 40, 41] as follow:

$$THQ = \frac{CDI}{RfD} \qquad (2)$$

Where, THQ is target hazard quotient and RfD is reference dose of pesticides (mg/kg-day) by oral exposure rout. Based on some reports RfD for deltamethrin and malathion is 0.01 and 0.02 mg/kg-d, respectively [42, 43].

To estimate the health risk of multiple pesticides in the breads, the sum of THQ for each pesticide was estimated separately using Eq.(3) [44, 45].

$$TTHQ = \sum_{i=1}^{n} THQ_i \qquad (3)$$

where, TTHQ is total target hazard quotient and THQ_i is THQ for individual pesticide.

2.6. Monte Carlo simulation (MCS) method

During risk assessment many uncertainties can occur [46]. If single-point values are used for the estimation of exposure risk, high uncertainty will be observed. Therefore, in this study, MCS was

used as a probabilistic method to reduce uncertainties [47, 48]. Health risk was estimated using MCS in the Crystal Ball (version 11.1.2.4, Oracle, Inc., USA). In MCS model in this study, IR_i, EF_i, Ed_i, BW, AT, and RfD have normal distribution but concentration of pesticides (C) have triangular distribution. The repetition number for each model was set on 10,000 and benchmark for risk was percentile 95% of the THQ [49].

3. Results and Discussion

3.1.Analytical method validation

The linearity of calibration plots was obtained for the range of 10–1000 µg/L with high coefficient of determinations (r^2)>0.9958 for all analytes (Table 1). Repeatability and reproducibility, as shown in Table 1, were lower than 6.5% and 9.3%, respectively and both presented as relative standard deviations (RSDs). The mean recoveries for the residues ranged from 62% to 81% and this indicates that the method used is reproducible. LODs were in the range of 3–7 µg/kg and indicating that the HPLC at its operation conditions was sensitive to analytes [9]. LOQ for each analyte was determined at S/N = 10 and ranged from 9.5–18.5 µg/kg. Shamsipur and colleagues demonstrated that the broad linear dynamic range combined with the low detection limit suggested a high potential for quantification of pesticides residues in various samples by applying the proposed UA−DLLME–SFO method [50].

3.2.Occurrence of pesticides in flour and bread samples

Table 2 presents the sample type, climate condition and mean concentrations (µg/kg) of selected pesticides residues measured in flour and bread. The amount of barn in bakery flour, and different breads including Lavash, Barbari, sangak, baguette and pastry flour were 11%, 13.5%, 16%, 12, 13.5, 0.0, respectively. According to Table 2, permethrin was no detected in any samples. This could be due to storage duration of wheat in silos before transferring it to milling and flour making

process. The wheat storage duration in silos is about 20 days (at ambient conditions) which is much greater than preharvest interval for permethrin, 7 days, so the residue amount of permethrim decreased quickly and reached below detection limit. These finding are in agreement with previous report which studied the persistence and activity of permethrin in stored wheat and found that permethrin was not present in flour after 274 days of wheat grain storage under ambient conditions [51]. They found that the residue of permethrin decreased from 1.378 ± 0.190 (day 1) to 0.247 ± 0.026 mg/kg (day 427) in the wheat treated at 2 mg a.i. permethrin/kg. On the other hand, Bengston et al. [52] reported that during the wheat storage and milling, pesticides like deltamethrin, fenvalerate, permethrin and phenothrin are highly persistent. They also found that these pesticides were not significantly reduced during baking. This is because the residues of pesticides accumulated in the bran fractions and finally it reduces in white flour [53]. In another report, the distribution of residues in milled fractions of treated wheat in case of permethrin was 61.7 and 12.0% for bran and flour, respectively [52]. However, permethrin could be removed easily by raining and washing, and have higher instability and in one case almost all the permethrin (19 ppm) in rice was washed and removed by water [54, 55].

Deltamethrin was the most frequent detected residue in all samples and out of all 27 analyzed samples, 4 samples with concentration ranged 16.6 to 47.2 µg/kg, were detected. This level of deltamethrin is less than the 0.3 mg/kg, MRL set by the WHO [56]. The highest deltamethrin concentration was observed in Barbari bread due to higher amount of bran. However, about 66% of deltamethrin could be distributed in bran and large proportion of the lipophilic insecticide migrate through the bran [52]. Deltamethrin is stable against heat, light, and air, but unstable in alkaline conditions. Deltamethrin is highly soluble in organic solvents but almost insoluble in water [57]. It has acceptable daily intake (ADI) of 0.01 mg/kg and its half-life is about 1 day [58,

59]. According to Paramasivam and Chandrasekaran[60], 68.47% of deltamethrin dose dissipated after 7 days of their field application in green tea leaves. Srivastava and Sehgal [61] reported that 93.2 % of deltamethrin residue reduced within 7 days on treated chickpea leaves and pods by 0.005 percent deltamethrin. However, no pesticide residues were detected at the time of harvesting. In this study, storing of wheat reduced deltamethrin residue significantly and also physical or chemical processes such as milling, washing and baking reduced deltamethrin carry-over from wheat to flour and from flour to bread.

Malathion occurred in 11.1% of the samples at a concentration ranged from 15.20 to 40.40 µg/kg. This level of malathion is lower than 0.1 mg/kg MRL. Most of malathion residual concentration are reduced during wheat milling to flour and more than 95% reduction form initial concentration of 8.89 ppm was reported [62]. Sharma et al. [63] reported that the dissipation residue of deltamethrin and malathion were 63 and 60%, respectively through bread making from wheat flour. The malathion residues quantity which were measured in that survey were higher than those reported in other work [9], and it is in agreement with Soliman[64] report which was lower than another reported value [65]. According to Darko and Akoto [9], levels of malathion in tomatoes (0.120 ± 0.101 mg kg^{-1}) and pepper (0.143 ± 0.042 mg kg^{-1}) exceeded the MRL of 0.1 mg kg^{-1}. The low level of malathion could be due to decay during wheat storage, bread processing and carrying of product. For example, washing and peeling removes 99% of malathion residues from tomatoes [66]. In bread production process, flour is subjected to fermentation and baking and therefore pesticide residue is dissipated [63]. Kaushik and colleagues reported that 60% of malathion was dissipated during bread making when the level of fortification was 4 ppm [54]. In general, for comparison, the results of this study is comparable with Pirsaheb et al [23] whose

found deltamethrin, permethrin and malathion in ranges of n.d.–73.6, n.d. – 74.5 and n.d. –167.4 µg/kg of stored wheat in silos of Kermanshah province, Iran.

3.3.Health risk assessment

The percentile 95% of THQ in the adults and children caused by bread ingestion content of deltamethrin was 0.033 and 0.070; and malathion, was 0.015 and 0.030, respectively (Figure 1). The THQ in the children due to deltamethrin and malathion was ~ 2.33 times higher than the adults. Since the BW of the children was less than adults [67], THQ in the children was higher than adults. The THQ in both adults and children due to deltamethrin was ~2.22 higher than malathion (Figure 1). Because of higher concentration and lower RfD of deltamethrin, its THQ was higher than malathion[42, 43, 67]. The percentile 95% of THQ in the adults and children was lower than 1 value caused by both deltamethrin and malathion. In general, about 85% of pesticide residue occurred in tropical and mild weather which is due to the fact that the pest growth rate is higher in mild and tropical climate, therefore the higher usage of pesticides for crop preservation. Moreover, additional pesticide may also be used during wheat storage in silos in tropical and mild condition to prevent pest attack.

4. Conclusion

In this study, the pesticide residues of 3 pesticides namely permethrin, deltamethrin and malathion in flour and bread obtained from Kermanshah province, Iran was investigated. A simple, precise and rapid UA–DLLME-SFO combined with HPLC-UV was developed and optimized for the quantitative determination of pesticides in flour and bread samples. The method had high recovery and inter and intraday precision. Permethrin was not detected in any sample, which is due to low pre-harvest interval needed for permethrin (7 days) and wheat storage in silos. About 85% of pesticide residue detections were in tropical and moderate weather due to higher consumption rate

of insecticides. Finally, it was found that all 3 pesticides were occurred at concentration lower than the MRL set by the WHO. The health risk assessment also indicated that Kermanshah's consumers, adults and children, are not at significant non-carcinogenic health risk (THQ < 1) which could be due to presence of deltamethrin and malathion in bread.

Conflict of interest statement

The authors declare that there are no conflicts of interest.

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