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Assessment of some Insecticide Residues in Strawberry and Pear Fruits and their Risks on Consumer Health

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Abstract

Pesticide residues monitoring is an important method for protecting consumers from the possible adverse effects of pesticides. Therefore, this study aimed to assess the residues of four insecticides belonging to different chemical groups in strawberry and pear fruit. The impact of washing and some food processes on residue elimination and the potential health risks to consumers as a result of direct exposure to the consumption of these fruits were also studied. The initial deposit values of acetamiprid and lambda-cyhalothrin were 0.79 and 1.27 mg/kg in pear fruit; and 0.58 and 0.74 mg/kg for emamectin and spinosad in strawberry fruits. These insecticide residues lost 20.25, 33.85, 36.2, and 31.08 % of their amounts, respectively, one day after application. Moreover, the half-lives of the above insecticides were 3.96, 2.21, 1.93, and 2.19 days, with decomposition rates of 0.175, 0.313, 0.359, and 0.317, respectively. According to health risks, the EDI of pear fruits treated with lambda-cyhalothrin exceeded the ADI in fruits collected at 0, 1, and 3 days, and strawberry fruits treated with emamectin just after spraying; therefore, it was considered to be a risk for consumers. The results also showed that the wash-and-compote or jam processes played a significant role in removing most of the contaminated residues. For strawberries, wash and jam remove 100% of spinosad residues, so these fruits can be consumed safely immediately after insecticide application. In addition, processing factors (PF) for the tested insecticides were evaluated to perform an acute risk assessment of dietary exposure. This type of study is needed to more realistically determine the dietary intake of insecticides and assess their health risks.

Keywords: Pesticides, residues, health risk, strawberry, pear, processing

Introduction:

Pesticides play a major role in food production. They protect and increase yields and may increase the number of times a crop can be grown on the same land each year. This is particularly important in countries that face food shortages [1]. The proper use of pesticides improves the quantity and quality of crops. However, the increased use of these chemicals has resulted in contamination of the environment and also caused many associated adverse health effects on consumers [2, 3]. Vitamins, nutrients, and minerals in vegetables and fruits are important for a healthy diet and play a significant role in disease prevention. According to the World Health Organization (WHO), 30% of food (based on mass) comprises fruits and vegetables [4]. As they are usually semi-processed or raw, they contain higher pesticide residues than other food groups of plant origin [5, 6, 7], which negatively affects consumer health [8, 9]. According to the European Union [10], pesticide residues in food (with more than one pesticide) were found in 27.3% of strawberries, peaches, apples, and lettuce samples, while 45.5% of the analyzed samples (out of 84,657 samples) contained quantified residues not exceeding the maximum residue limits (MRLs). Frequently vegetables and fruits are eaten fresh without peeling or processing due to their high nutritional value and content of antioxidants, vitamins, minerals, and fiber [11, 12]. So, they are expected to contain higher pesticide residue levels than other food groups because most are eaten raw. Some fruits and vegetables are also processed into ready-made food products sold in the markets, such as producing fruit and vegetable juices, jams, sauces, ketchup, etc., considered one of the fastest growing industries for their significant role in global food consumption [13]. Therefore, surveying pesticide residues is a significant method to protect consumers from the prospected harmful effects of pesticides. This would help verify that the level of pesticides in food did not exceed the permissible or MRLs set by various international organizations such as the WHO and Food and Agriculture Organization (FAO) [14]. When evaluating chronic exposure, the level of pesticide exposure throughout life and the probable effects of such exposure on health are considered [15]. This

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evaluation method is well developed and considers the average levels of exposure to acceptable daily intake (ADI) amounts established for individual pesticides. If consumers were exposed to pesticide residues for a long period of time, their health would only be at risk if their daily dietary intake exceeds the ADI over time. The estimated acceptable daily intake (EDI) was assessed individually for each compound during exposure evaluation. A chronic consumer risk can be excluded if ADI is not exceeded for any commodity [16]. Knowledge about various mechanisms of pesticide interaction should be utilized in predicting the consumer's hazard of pesticides. The processing factor (PF) is the main factor that describes processing efficiency. Many PFs remain unknown; therefore, this value for a particular combination of pesticide/processing techniques/matrices needs to be determined. It is important for researchers to perform a risk assessment for a pesticide under specific treatment in a particular commodity. MRLs are often available only for uncooked products (pear, strawberry, etc.) and not for the corresponding processed commodities (juice, jam, compote, etc.) [17]. So, this study aimed to: 1) estimate residues of emamectin-benzoate and spinosad in strawberry; and acetamiprid and lambda-cyhalothrin in pear fruits; 2): the effect of some food processes of treated fruits on insecticide residue elimination; 3) to assess the extent of potential health risks to the health of consumers arising from direct exposure to the consumption of these fruits.

Materials and Methods

1. **Insecticides used:** The used insecticides, their common and trade names, chemical groups, and recommended rates were listed in Table 1.

Table (1): Insecticides common and trade names, chemical groups, recommended rates and crop protect

No.	Common name	Trade name	Chemical group	Recommended Rates *	Crop
1	**Acetamiprid**	**Mospilan 20 % SP**	**Neonicotinoid**	**25 g/ 100 L**	**Pear**
2	**Lambda-cyhalothrin**	**Icton 2.5 % EC**	**Pyrethroid**	**375 ml/ 100 L**	**Pear**
3	**Emamectin-benzoate**	**Proclaim 5% SG**	**Avermectin**	**60 g/ 200 L**	**Strawberry**
4	**Spinosad**	**Tracer 24 % SC**	**Spinosyn**	**20 ml/ 100 L**	**Strawberry**

***Recommended rates according to APC [18].**

2. **Reagents and solvents**: Authenticated insecticides reference analytical standards (>99% purity) were obtained from Dr. Ehrenstorfer GmbH (Augsburg, Germany). HPLC-grade methanol and acetonitrile were purchased from Sigma (Sigma GmbH Darmstadt, Germany). Primary secondary amine (PSA, 40 µm Bondesil) and graphitized carbon black sorbent were bought from Supelco (Bellefonte, Pennsylvania, USA). Analytical grade of trisodium citrate, disodium acetate, anhydrous magnesium sulfate and sodium chloride was obtained from CARLO ERBA Reagents S.A.S.

3. **Preparation of standard solutions:** To conduct an HPLC analysis, a 100 ml/L stock solution lambda-cyhalothrin, acetamiprid, emamectin benzoate, and spinosad was prepared in acetonitrile. To set up consecutive working dilution and spike standard solution, the stock solution was diluted accordingly. All standard and working solutions were stored at 4 ℃. To define the effectiveness of our technique, we established its linearity constructed on the concentration of the tested pesticides, which we diluted in a solvent. We evaluated the resulting correlation coefficient (R2) using a 6-point calibration curve series (0.01, 0.1, 0.5, 1.25, 2.5,5 and 10) µg/ml for HPLC analysis.

4. **Field experiment:** This study was conducted at a National Research Centre (NRC) farm, El-Nubaria region, El-Behara governorate, Egypt. The experimental design was randomized complete block (RCB). A motor sprayer was used to apply the tested insecticides.

   a. **Pear:** Pear trees, *Pyrus communis* var. Le-Conte about 15 years old. Forty-five trees of same size and height approximately, were selected for experimental purposes. The selected trees were distributed in three treatments; each divided into three replicates (5 trees/ replicate). Mature fruits were sprayed with lambda-cyhalothrin and acetamiprid once at the recommended rates according to APC [18], Table 1. Control plots were left unsprayed. Samples were taken (about 2 kg collected randomly) after 1 hour, 1, 3, 5, 7, 10 and 14 days. The samples were divided into three groups; the 1stunprocessed for residue determination; the 2nd for the effect of washing process on residue elimination, the 3rd for the effect of compote preparation on pesticide residue. Fruits were washed with tap water (1 min) and airs drying, also, samples were taken two hours after compote preparation process.

   b. **The strawberry** (*Fragaria ananassa* ver. festival)**:** For each pesticide, three plots were established (50 m^2 each) with a 2 m plot-to-plot distance. Mature plants were sprayed with emamectin benzoate and spinosad once at the recommended rates (according to APC [18], Table 1). The control plots were left unsprayed. Fruit samples were taken 1 h, 1, 3, 5, 7, 10, and 14 days later. The collected samples (1 kg collected randomly) were divided into three groups; the 1st unprocessedfor residue determination; the 2nd for the effect of washing process on residue removal, the 3rd for the effect of jam preparation on pesticide residue. Fruits were washed with tap water (1 min) and air drying. Fruit samples were taken after 2 h for the jam preparation [19].

5. **Residue analysis:**

a. **Sampling:** Samples were put in polyethylene bags after collection and transported immediately in an ice box to the Pesticide Lab and; kept at 4°C. The samples were homogenized and stored in a deep freezer at –20°C until analysis.

b. **Analysis of pesticide residues:**

Extraction and Clean-up: Pesticide residues are extracted and cleaned up in a wide range of matrices by using the QuEChERS method [20]. About 10 g of homogenized pear and strawberry fruit samples were weighed into 50 ml centrifuge tube; 10 ml of acetic acid 1% was added and shaken for 2 min then sonicated for 1 min. Ten ml of acetonitrile was added to the tube and shaken vigorously for 2 min, then centrifuged for 5 min at 4000 rpm. An aliquot of 3 ml was taken from the supernatant and transferred to 15 ml centrifuge tube containing 1g magnesium sulfate and 200 mg PSA, shaken energetically for 30 seconds and centrifuged (3000 rpm) for 2 minutes. 2 ml of the supernatant were filtered through a 0.2 µm PTFE Filter (Millipore, USA) and then analyzed using HPLC – DAD and GLC-ECD.

c. **Determination:**

1. **HPLC-DAD:** Final determination of acetamiprid, emamectin-benzoate, and spinosad samples were carried out in HPLC at Pesticide Residues and Environmental Pollution Dept., Central Agriculture Pesticide Laboratory, Agriculture Research Center. The HPLC instrument, an Agilent 1260 series equipped a quaternary pump, a variable wavelength diode array detector (DAD), an auto sample with an electric sample valve. The column was Nucleosil C18 (30 x 4.6 mm (i.d) x 5 µm) film thickness. The other conditions are summarized in Table 2.

Table (2): HPLC conditions for determine the tested pesticide residues, mobile phase, retention time (Rt.), flow rate and wave length

Insecticide	Mobile phase	Rt. (min)	Flow rate (ml/min)	Wave length (nm)
Acetamiprid	**ACN: water (70:30)**	**4.8**	**1**	**230**
Emamectin-benzoate	**ACN: water (90:10)**	**4.2**	**1**	**245**
Spinosad	**ACN: MeoH: 2% Ammonium acetate (42:42:16)**	**A:6.9 D:7.8**	**1**	**250**

Rt. = retention time; CAN: Acetonitrile

2. **GLC-ECD:** Agilent GC Model 6890 equipped with a N^{i63} electron capture detector was used for the determination of lambda-cyhalothrin residues using the following conditions. The column was PAS-5 methyl silicone (length 30 m × 0.32 mm i.d. × 0.52 µm film thickness), detector temperature was 320 °C, and injector temperature was 300 °C. The initial oven temperature was 200 °C for 2 min, held at this temperature for 9 min, and then raised to 260 °C for another 9 min. The carrier gas was N2, and the flow rate was 3 ml/min. The retention time was 13.4 min for lambda-cyhalothrin.

6. **Half-life calculated:** The residual half-life (RL_{50}) of the tested pesticides was calculated using the equation of Moye et al [21].

7. **Health risk assessment:**

Health risk (HR) assessment was described by using the health risk index (HI). It was calculated according to the following equation:

$$HI = \frac{EDI}{ADI} \text{ X } 100$$

While, the estimated daily intake (EDI) was determined by using the following equation:

$$EDI = \frac{A \times B}{C}$$

where A represents the concentration of pesticide residues in vegetables (mg kg-1), B is the average daily vegetable intake for adults was considered to be 0.345 kg/person/day according to the previous report [22, 23], while C is the average body weight considered to be 70.8 kg for adults [24]. If the HI is less than 100 %, the food concerned is considered acceptable. If it is greater than 100 %, the food concerned is considered a risk to the consumer [25].

8. **Processing factors calculation:** the effect of washing process was estimated according to the equation 1; similar to processing factor (PF) and obtained by the division of the residue concentration of washed fruits to the residue concentration of the unprocessed fruits [26,27]

Equation 1): $$PF = \frac{PRP}{PRR}$$

PF= Processing factor; PRP= Pesticide residue of processed material (mg kg^{-1}); PRR= Pesticide residue of raw material (mg kg^{-1})

The PF value may indicate reduction (PF1) of the pesticide residues [26]. When residues were below the limit of quantification (LOQ) after processing, the PF value was accepted as zero [28].

When PF<1: reduction factor commodity; while PF>1: concentration factor of pesticide residue in the processed commodity [17].

Additionally, the residue reduction rate (%) was calculated by following equation 2:

Equation 2): $$RR = \frac{PRR-PRP}{PRR} \text{ X } 100$$

RR= Residue reduction rate (%); PRR= Pesticide residue of raw material (mg kg^{-1}); PRP= Pesticide residue of processed material (mg kg^{-1})

Results and Discussion

1. **Validation study:** Recovery was carried out on untreated samples spiked with acetamiprid and lambda-cyhalothrin at three concentrations for pear fruits and four levels for samples in five replicates. The method's trueness and precision parameters in terms of average recovery and relative standard deviation (RSD) were calculated and measured according to the European Union guidelines [29]. The percentage recovery and calibration curves of acetamiprid and lambda-cyhalothrin from the fortified pear samples are presented in Table 3. Data showed that the recovery percentage for acetamiprid ranged from 94.29 to 99.28 % with an average of 96.8%, whereas the RSD % was ranged from 1.53 to 2.54%. The recovery rate from lambda-cyhalothrin was in the range of 92.49 to 98.88 % with an average of 96.21%; while %RSD of 2.22 - 2.98%. The recovery and the %RSD for pear fruits were within the acceptable limits for routine analysis of acetamiprid and lambda-cyhalothrin residues leading to high precision. Furthermore, when analyzed in pure solvent matrix extract, these insecticides showed linearity in the concentration range used with a coefficient of determination (R2) greater than 0.99, demonstrating better analytical sensitivity and accuracy.

Table 3: Mean recovery and repeatability precision of acetamiprid and lambda-cyhalothrin in pears.

Spiking level (mg/kg) (n*=5)	Acetamiprid		Lambda-cyhalothrin	
	% Recovery ±SD	RSD%	% Recovery ±SD	RSD%
0.01	94.29±2.39	2.54	92.49±2.76	2.98
0.1	96.86±1.48	1.53	97.26±2.41	2.48
1.0	99.28±1.69	1.7	98.88±2.2	2.22
Average	96.8		96.21	

***= number of replicates; RSD= relative standard deviation**

The results showed also, the recovery % for emamectin-benzoate ranged from 88.89 to 93.08 %, with an average of 90.56%, while the RSD % for strawberry fruits ranged from 1.4 to 3.33%. In the same concept, the recovery rate of spinosad ranged from 84.29 to 88.28 %, with an average of 86.08 %, and the RSD percentage ranged from 2.44 to 3.67% (Table 4).

Table 4: Mean recovery and repeatability precision of emamectin-benzoate and spinosad in strawberry fruits

Spiking level (mg/kg) (n*=5)	Emamectin-benzoate		Spinosad	
	% Recovery ±SD	RSD%	% Recovery ±SD	RSD%
0.01	88.89±2.96	3.33	84.29±2.56	3.05
0.1	89.71±1.25	1.4	85.66±3.15	3.67
1.0	93.08±2.04	2.2	88.28±2.15	2.44
Average	90.56		86.08	

***= number of replicates; RSD= relative standard deviation**

2. Acetamiprid and lambda-cyhalothrin dissipation in pear fruits:

The results presented in Table 5 showed that the acetamiprid residue amount after 1 hour of application was 0.79 mg/kg, this value decreased to 0.63 mg/kg after 1 day with a loss rate of 20.25% of the initial deposit. These amounts decreased gradually over time till reached 0.47, 0.33, 0.29, 0.13, and 0.09 mg/kg after 3, 5, 7, 10, and 14 days after insecticide application. The corresponding values of residue degradation rate were 40.5, 58.22, 63.29, 83.54, and 88.6 %. In addition, the persistence of acetamiprid residues (100% after 1 hour) was decreased in pear fruits by time to 79.75, 59.5, 41.78, 36.71, and 16.46 and, reached 11.4% after 14 days of treatment. Washing processes have been found to reduce the acetamiprid residues in fruits significantly, the amount of acetamiprid residues detected in washed fruits were 0.31, 0.22, and 0.11 mg/kg after 1 h, 1, and 3 days for treatment, representing processing factors 0.607, 0.65, 0.766 and 0.818. While no residues were found during 5 to 14 days. Also, data in the same Table showed that compote process for pear fruits eliminates 100% of acetamiprid residues during all experiment intervals. According to the maximum residue limits (MRL of acetamiprid = 0.4 mg/kg according to the EU Codex, [30]), the estimated pre-harvest interval (PHI) of treated pear fruit by acetamiprid was less than 5 days. While in the case of washed and compote pear fruits treated with acetamiprid, it could be safely consumed just after spray. Results also showed that the half-life ($t_{1/2}$) of acetamiprid in pear fruits was almost 3.96 days, and the rate of decomposition (K) was 0.175 mg day^{-1}.

When assessing chronic exposure, the level of pesticide exposure over a lifetime and the likely effects of such exposure on health are considered [31]. This method is well-developed and considers the average levels of exposure to the ADI values established for individual compounds. If consumers were exposed to chronically toxic pesticide residues, their health would only be at risk if their dietary intake exceeded the ADI every day for an extended period. The EDI was evaluated separately for each pesticide during the exposure evaluation. A chronic consumer risk can be excluded if the acceptable daily intake (ADI) is not exceeded for any commodity. Data in Table 5and Fig. 1revealed that the hazard index (HI) for acetamiprid contaminated pear samples decreased with time elapsed, its value was 15.2 % of acetamiprid ADI in samples collected just after spray (zero time) and decreased to reached 1.6 % at 14 days for application. When the HI is less than 100%, the food concern is considered acceptable [25], and it is clear from the data obtained from the risk assessment of pesticide residues in pear fruits that no risk will be found from consuming these fruits.

Data in Table 6 showed the behavior of lambda-cyhalothrin insecticide in pear fruits after different intervals and the effect of washing and compote processing for fruits on insecticide dissipation. The initial deposit value of lambda-cyhalothrin was 1.27 mg/kg, this amount was decreased to 0.84 mg/kg after 1 day with a dissipation rate of 33.85 % of the initial deposits. The residue of lambda-cyhalothrin was dropped to 0.67, 0.52, 0.18, and 0.01 mg/kg after 3, 5, 7, and 10 days, respectively; while no residues were detected after 14 days for application. Also, results revealed that the residue loss continued over time, where the percent of residue reduction amounted to 33.85, 47.24, 59.05, 85.81, 99.21, and 100 %; after 1, 3, 5, 7, 10, and 14 days, respectively. Also, the persistence of lambda-cyhalothrin residues (100% after 1 hr) was decreased in contaminated pear fruits by time to 66.15, 52.76, 40.95, and 14.18 and reached 0.79 % after 10 days; while this insecticide residue disappearance after 14 days. The data in Table 6 reveal that the EDI values exceeded the ADI values of lambda-cyhalothrin in pear fruits collected at 1 h, 1 d, and 3 d after spraying. This indicates that the health index amounts were greater than 100 (Fig. 1); therefore, pear fruits were considered to be a risk to consumers during these intervals. The HI values reached 100 after 5 days and dropped to 1.6 at the end of the experiment, these fruits were considered to be acceptable. In the same trend, the maximum residue limit (MRL) for lambda-cyhalothrin was 0.08 mg/kg, on pear fruits established by the EU Codex for pesticide residues (EU Codex, [30]). In addition, pear fruits previously treated with this insecticide should be harvested after 10 days at least (PHI less than 10 days) to ensure that they contain residue levels below their MRL.

Our results also revealed that the half-life ($RL_{0.5}$) value in pear fruits was 2.21 days for lambda-cyhalothrin, and the rate of decomposition or degradation (K) was 0.3134 mg day^{-1}. The increasing use of chemical insecticides to control the economic pests which attack field crops has increased the pollution of the environment with their toxic residues. Therefore, the need for efficient treatments to reduce or remove such residues has become urgent. There was an effect of washing pear fruits under tap water on reducing the contamination by lambda-cyhalothrin residues (Table 6). The initial deposit of this insecticide was 1.27 ppm and its amount was 0.84 ppm after 1 day; the washing process reduced these amounts to 0.30 and 0.14 ppm representing the PF of 0.763 and 0.833; of their residue on pear fruits. No residues were found in washed fruit in other periods; therefore, these fruits could be consumed safely during these periods. Our results are in accordance with those obtained by Lozowicka et al. [17], who reported that washing with tap water could be useful for the partial removal of several pesticide residues from pear and strawberry fruits under both industrial and household conditions. The effectiveness of any decontamination method varies with the type of pesticide, location, and period of the residue in fruits and vegetables. Peeling was found to be an effective method for fruits and vegetables, in which most residues accumulate in the peel layer. Also, washing is effective for the decontamination of pesticide residues, but its effectiveness depends on the water solubility of the pesticide, temperature, and washing solution [32].

Table 5: Residue levels and dissipation behavior of acetamiprid in pear fruits under field conditions

intervals (days)	Residues (mg/kg)	RR (%)	% Persistence	Wash (mg/kg)	PF	Compote (mg/kg)	PF	EDI (mg/kg)	HI
initial*	**0.79±0.02**	**0**	**100**	**0.31±0.02**	**0.607**	**ND**	**0.0**	**0.0038**	**15.2**
1	**0.63±0.07**	**20.25**	**79.75**	**0.22±0.03**	**0.65**	**ND**	**0.0**	**0.0030**	**12**
3	**0.47±0.007**	**40.5**	**59.5**	**0.11±0.02**	**0.766**	**ND**	**0.0**	**0.0022**	**8.8**
5	**0.33±0.03**	**58.22**	**41.78**	**0.06±0.01**	**0.818**	**ND**	**0.0**	**0.0016**	**6.4**
7	**0.29±0.01**	**63.29**	**36.71**	**ND**	**0.0**	**ND**	**0.0**	**0.0014**	**5.6**
10	**0.13±0.02**	**83.54**	**16.46**	**ND**	**0.0**	**ND**	**0.0**	**0.0006**	**2.4**
14	**0.09±0.007**	**88.6**	**11.4**	**ND**	**0.0**	**ND**	**0.0**	**0.0004**	**1.6**
$t_{1/2}$ (day)	**3.961 / k=0.175**								
EU MRL	**0.4***								
ADI	**0.025**								

ND= non-detected * according to EU codex [30]; EDI= estimated daily intake; HI = health index; ADI= acceptable daily intake (according to EU Codex [30]); RR= Residue reduction rate (%); PF= Processing factor; k= rate of decomposition.

Table 6: Residue levels and dissipation behavior of lambda-cyhalothrin in pears fruits under field conditions

20intervals (days)	Residues (mg/kg)	RR (%)	% Persistence	Wash (mg/kg)	PF	Compote (mg/kg)	% Loss by compote	EDI (mg/kg)	HI
initial*	**1.27±0.09**	**0**	**100**	**0.30±0.02**	**0.763**	**ND**	**>99.9**	**0.0061**	**244**
1	**0.84±0.04**	**33.85**	**66.15**	**0.14±0.01**	**0.833**	**ND**	**>99.9**	**0.0040**	**160**
3	**0.67±0.007**	**47.24**	**52.76**	**ND**	**0.0**	**ND**	**>99.9**	**0.0032**	**128**
5	**0.52±0.10**	**59.05**	**40.95**	**ND**	**0.0**	**ND**	**>99.9**	**0.0025**	**100**
7	**0.18±0.02**	**85.82**	**14.18**	**ND**	**0.0**	**ND**	**>99.9**	**0.0008**	**32**
10	**0.01±0.01**	**99.21**	**0.79**	**ND**	**0.0**	**ND**	**>99.9**	**0.00004**	**1.6**
14	**ND**	**100**	**0**	**ND**	**0.0**	**ND**	**>99.9**	**-**	**-**
$t_{1/2}$ (day)	**2.21 / K= 0.313**								
EU MRL	**0.08***								
ADI	**0.0025**								

$T_{1/2}$ = the half-life period (day); ND= non-detected * according to EU codex [30]; EDI= estimated daily intake; HI = health index; ADI= acceptable daily intake (according to EU Codex [30]); RR= Residue reduction rate (%); PF= Processing factor; k= rate of decomposition.

Fruit compote is fruit cooked with a little juice or water which produces a syrupy fruit mixture; the compote food process of pear fruits caused the elimination of total lambda-cyhalothrin residues, so these fruits could be consumed safely just after spray.

There are significant factors that influence insecticide dissipation in the environment such as physicochemical properties, the frequency and the rate of insecticide used, mode of application, occurrence of insect pests, biotic and a biotic characteristic of the environment and weather conditions, plants or fruit characteristics, e.g., roughness and content of cuticular waxes [33].Also, the rate of used insecticide, the nature of the recipient surface, the used spraying equipment and the climatic conditions, especially the ambient temperature during pesticide application [34]. In addition to these factors, the type of insecticide used can have an impact on its dissipation in the environment, with some insecticides being more persistent than others [35]

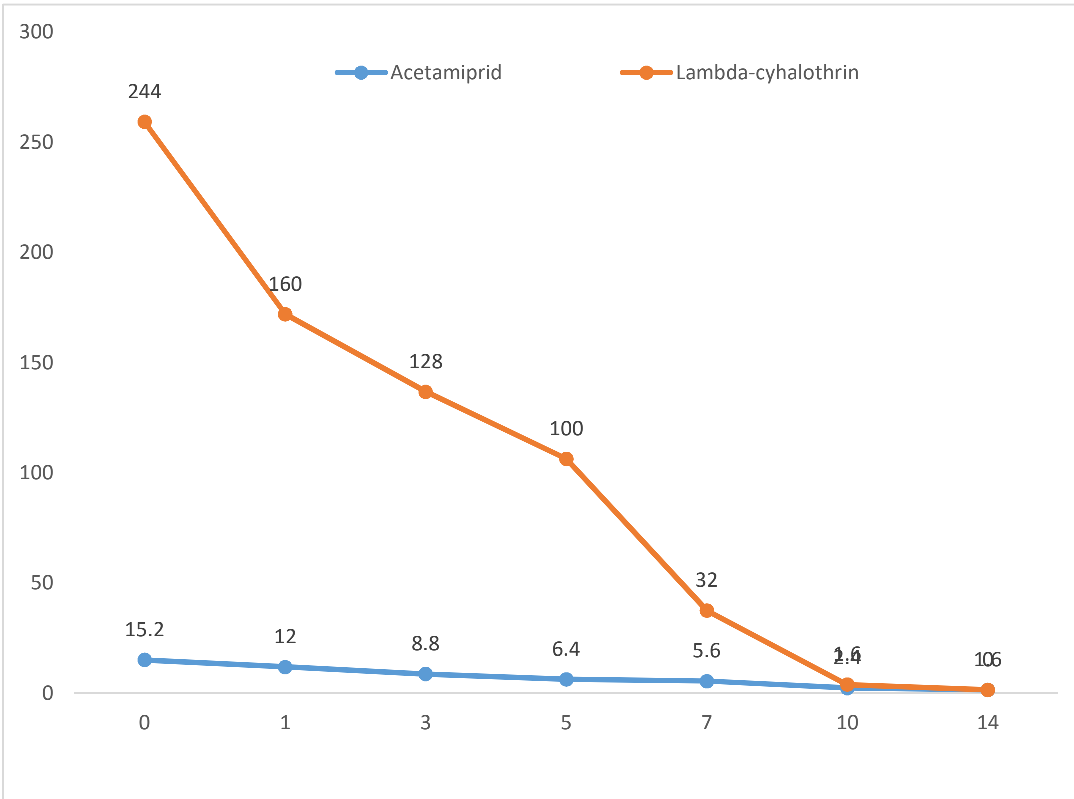

Figure 1: Health index values for acetamiprid and lambda-cyhalothrin residues in treated pear fruits

3. Dissipation and behavior of emamectin-benzoate and spinosad in strawberry fruits:

The data presented in Table 7 show the amounts of emamectin-benzoate residues in strawberry-treated fruits and the effect of the washing and jam processes on the decrease or elimination of this insecticide residue. The initial deposit (one hour after application) was 0.58 ppm and dropped to 0.37 ppm after the 1st day, with a residue reduction rate of 36.2%. The amount of emamectin-benzoate decreased to 0.22, 0.12 and 0.05 ppm after 3, 5 and 7 days. The residue loss continued over time, with reduction rates of 62.06, 79.31, and 91.37% after the same period. No residues were detected after 10 and 14 d in the treated strawberry fruits. In addition, the persistence of emamectin-benzoate residues (100 % after 1 h) decreased in strawberries fruits by the time to 63.8, 37.94, 20.69%, and 8.63 %, reaching 0.0 % after 10 days. According to MRL for emamectin-benzoate (0.05 mg/kg according to EU-Codex, [30]), the pre-harvest interval (PHI) was 7 days for treated strawberry fruits. While the half-life period of this insecticide was 1.93 days in strawberry fruits, and the rate of decomposition (K) was 0.359 mg day^{-1}. The health index value was 112 because the estimated daily intake (EDI=0.0028 mg/kg) exceeded the ADI (0.0025 mg/kg according to EU Codex, [30])for emamectin-benzoate in treated fruits just after spray, and consuming these fruits may cause adverse effects on consumers. The HI values decreased with time elapsed (Fig. 2), also the EDI values were lower than ADI values in the other periods, no risk will be found from consuming these fruits.

The washing process of strawberry fruits under tap water reduced emamectin-benzoate residues collected after 1h and 1 day to 0.37 and 0.26 mg/kg, representing processing factors 0.362 and 0.297. In contrast, no residues were detected in the washed fruits during the other periods. Accordingly, the washed fruits collected 3 days after insecticide application could be safely consumed. In addition, the jam process of strawberry fruits removed approximately all residues of this insecticide; no residues were detected during any of the experiment periods. Therefore, these fruits could be consumed safely after the jam is processed. The processing factor (PF) is the main factor that describes processing efficiency. Many PFs remain unknown;

therefore, this value for a particular combination of pesticide/processing techniques/matrices needs to be determined. It is important for researchers to perform a risk assessment for a pesticide under specific treatment in a particular commodity. MRLs are often available only for uncooked products (pear, strawberry, etc.) and not for the corresponding processed commodities (juice, jam, compote, etc.) [17].

Data in Table 8 revealed the behavior of spinosad residues in strawberry fruits and the effect of the wash and jam processing on these residues. The initial deposit (1 h after application) of this insecticide in strawberry fruits was 0.74 mg/kg, this amount was decreased to 0.52 mg/kg with a residue reduction rate of 30.08 % after the 1st day. The spinosad residues dropped to 0.32 and 0.15 mg/kg after 3 and 5 days, with a 56.75 and 79.72 % reduction rate, respectively. While no residues were found after seven days in strawberry fruits treated with spinosad. According to EU-Codex [30], the maximum residue limit of spinosad in strawberry fruits was 0.3 mg/kg, so the pre-harvest period (PHI) for treated plants was less than 5 days, and the rate of decomposition or degradation (K) was 0.3165 mg day^{-1}. While, the half-life period of this insecticide was 2.19 days in treated fruits. In addition, the estimated daily intake (EDI) of spinosad does not exceed the acceptable daily intake (ADI= 0.02 mg/kg according to EU-Codex, [30]), so the health index (HI) amount was less than 100; its value was 18 in strawberry fruits collected just after spray and decreased with time elapsed to reach 3.5, after 5 d. Accordingly, no risk was found when consuming these fruits.

Our data also revealed that washing fruit under the tap water and jam process was sufficient to remove all spinosad residues in strawberry fruits after all collection periods. These results accordance with those obtained by Lozowicka et al. [36], who reported that washing with tap and ozone water significantly eliminates pesticide residues present in unprocessed strawberries, while boiling was adequate for the removal of most pesticide residues except the alpha-cypermethrin, deltamethrin, and lambda-cyhalothrin.

These results are agreement with those of other researchers Liang et al. [37], who reported that the washing process yielded a lower PF when the time after pesticide application increased. Also, El-Sheikh et al. [38], reported that some home processing of fortified tomato (sauce) and strawberry (jam) samples had a major effect on decreasing residues of seven pyrethroid insecticides in tomato and strawberry processed, where the reduction reached 100%.

Table 7: Residue levels and dissipation behaviour of emamectin-benzoate in strawberry fruits under field conditions

Periods (days)	Residues (mg/kg)	RR (%)	% Persistence	wash (mg/kg)	PF	Jam (mg/kg)	% Loss by Jam	EDI (mg/kg)	HI
initial*	**0.58±0.01**	**0**	**100**	**0.37±0.007**	**0.362**	**ND**	**>99.9**	**0.0028**	**112**
1	**0.37±0.02**	**36.2**	**63.8**	**0.26±0.02**	**0.297**	**ND**	**>99.9**	**0.0018**	**72**
3	**0.22±0.03**	**62.06**	**37.94**	**ND**	**0.0**	**ND**	**>99.9**	**0.0010**	**40**
5	**0.12±0.02**	**79.31**	**20.69**	**ND**	**0.0**	**ND**	**>99.9**	**0.0006**	**24**
7	**0.05±0.03**	**91.37**	**8.63**	**ND**	**0.0**	**ND**	**>99.9**	**0.0002**	**8**
10	**ND**	**100**	**0**	**ND**	**0.0**	**ND**	**>99.9**	**-**	**-**
14	**ND**	**100**	**0**	**ND**	**0.0**	**ND**	**>99.9**	**-**	**-**
$t_{1/2}$ (day)	**1.93 / K = 0.359**								
EU MRL	**0.05***								
ADI	**0.0025**								

$T_{1/2}$ = the half-life period (day); ND= non-detected * according to EU codex [30]; EDI= estimated daily intake; HI = health index; ADI= acceptable daily intake (according to EU Codex [30]); RR= Residue reduction rate (%); PF= Processing factor; k= rate of decomposition.

Table 8: Residue levels and dissipation behaviour of spinosad in strawberry under field conditions

intervals (days)	Residues (mg/kg)	RR (%)	% Persistence	Wash (mg/kg)	Jam	EDI (mg/kg)	HI
initial*	0.74±0.07	0	100	ND	ND	0.0036	18
1	0.52±0.03	31.08	68.92	ND	ND	0.0025	12.5
3	0.32±0.01	56.75	43.25	ND	ND	0.0016	8
5	0.15±0.07	79.72	20.28	ND	ND	0.0007	3.5
7	ND	>99.9	>99.9	ND	ND	-	-
10	ND	>99.9	>99.9	ND	ND	-	-
14	ND	>99.9	>99.9	ND	ND	-	-
$t_{1/2}$ (day)	2.19/ K= 0.317						
EU MRL	0.3*						
ADI	0.02						

$T_{1/2}$ = the half-life period (day); ND= non-detected * according to EU codex [30]; EDI= estimated daily intake; HI = health index; ADI= acceptable daily intake (according to EU Codex [30]); RR= Residue reduction rate (%); k= rate of decomposition.

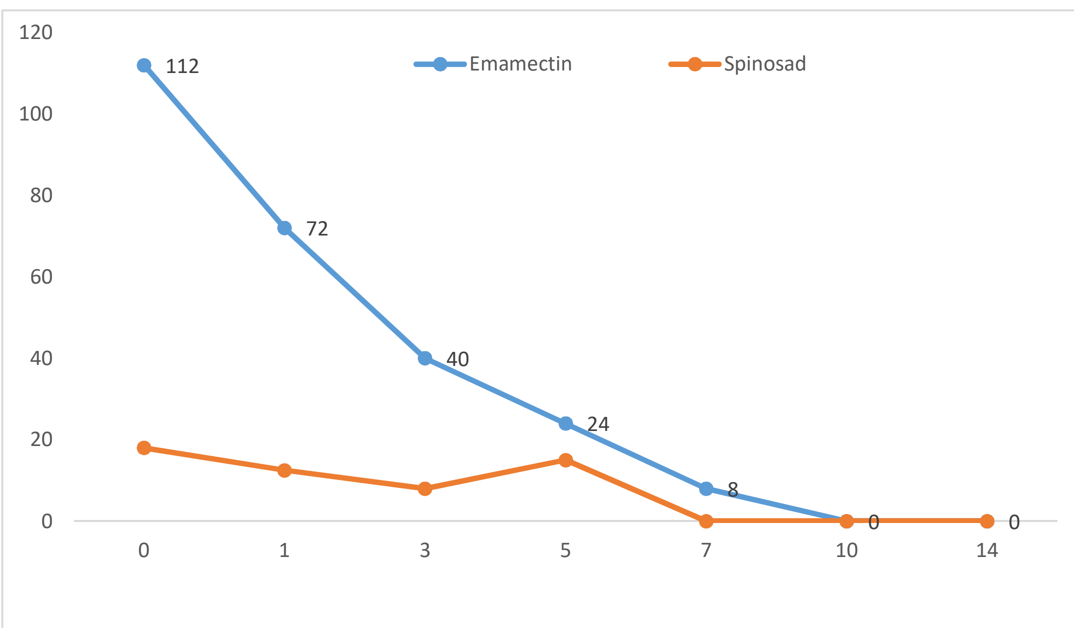

Figure 2: Health index values for emamectin-benzoate and spinosad residues in treated strawberry fruits

Conclusion: Nevertheless, monitoring pesticide residues should continue to provide up-to-date information for exporters of agricultural products, and regulators should take timely action to ensure the safe and effective use of pesticides, if necessary, and to avoid their adverse effects on consumers and the environment. With the increasing need to characterize the safety hazards of food, this type of study is required to determine the dietary intake of insecticides more realistically and assess their health risks.

Conflicts of Interest: The authors declare no conflict of interest.

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