Changes in concentration of pesticide residues in fruits and vegetables during household processing

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\section*{A R T I C L E  I N F O}

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\section*{A B S T R A C T}

Monitoring of pesticide residues in fruits and vegetables and their processed products like jams, pickles, juices, ketchup, dried products and canned products was undertaken. The study was conducted to assess the effect of washing, peeling, heating and cooking on concentration of various pesticides. The stability of various pesticides in samples and their products was assessed. Pesticide residues were extracted using QuEChERS method and analysed by GC-MS. It was observed that pesticides like mancozeb and carbofuran were found to be stable for tomato and potato while chloropyriphos, captan and mancozeb (in other samples) were found to be unstable. It was also observed that peels and pomace showed highest levels of pesticide residues. In this study, washing, peeling and heat processing (boiling and blanching) have been found to be the most effective ways of pesticide residue dissipation.

\section*{1. Introduction}

Pesticides are used globally to protect crops against pest infestation in transport and storage. However their excess use often leads to adverse health effects during long distance transports. Food being the basic necessity of life is often consumed in various forms and the presence of pesticides residues is evident in each of these. Therefore it is extremely important to find cost effective and easy strategies to dissipate residues available in the primary raw commodities. Food processing at domestic and industrial level is one the best methods to reduce the content of residues in fruits and vegetables.

The present study was done to evaluate the pesticide residue content in each of the primary raw commodities (before and after processing) in Kashmir valley.

\section*{2. Materials and methods}

\subsection*{2.1. Sample collection}

A total of 7 different types of fruits and vegetable samples were collected from September 2019 to February 2021 for pesticide residue analysis. These samples include apple, pear, peach, apricot, tomato, local collard greens (Khanyari Haakh) and potato. These are the representatives of the commonly consumed fruits and vegetables of the Kashmir valley. The fruit and vegetable samples were procured from the local market and were all locally produced. The sampling was done in accordance with (EC) directive 2002/63/EC \cite{1} for MRL regulation. The samples collected were of minimum 1–2 kg and were collected in a sterile bag to avoid contamination and deterioration. They were well labelled and transported to the laboratory for further processing.

\subsection*{2.2. Chemicals and reagents}

The pesticide reference standard (purity 99.5\%) were purchased from Sigma-Aldrich, USA. The Mancozeb (Indofil M-45), carbofuron (Carbo-G), chloropyriphos (Dursban 20 EC) and captan (Captaf) market formulation obtained from M/S Premium sales agency Srinagar were used for Dipping. Acetonitrile (high-performance liquid chromatography (HPLC) grade), sodium chloride and acetic acid were purchased from HIMEDIA, India and sorbents for QuEChERS analysis like primary secondary amines (PSA), anhydrous magnesium sulphate, sodium acetate were all purchased from Sigma-Aldrich, USA. All the reagents and sorbents were kept at 4 °C or as directed by the manufacturer. Blanks before samples were also run to test the reagents for purity.
Recovery percentage of pesticides.

### Table 1
Summary of sample preparation.

| S.no | Sample Used  | Pesticide to be analysed | Fortified by: |
|------|--------------|--------------------------|---------------|
| 1.   | Potato       | Carbofuron               | 3 g in 1000 ml |
| 2.   | Apple        | Mancozeb                 | 3 g in 1000 ml |
| 3.   | Collard greens | Carbofuron             | 3 g in 1000 ml |
| 4.   | Pear         | Chlorpyriphos            | 1 ml in 1000 ml |
| 5.   | Tomato       | Mancozeb                 | 3 g in 1000 ml |
| 6.   | Apricot      | Captan                   | 3 g in 1000 ml |
| 7.   | Peach        | Captan                   | 3 g in 1000 ml |

2.3. Sample preparation

Each of these samples were first analysed for interferences including the pesticide to be analysed, interferences being found negative, the samples were fortified with the pesticide to be analysed as discussed in Table 1.

The samples were washed with tap water and dipped in the diluted commercial formulations (not distilled water) of the respective pesticides at given concentration as summarised in Table 1. The samples were allowed to rest in the commercial formulation for 2 h to simulate the real-life use. The control samples for before processing (as soon as the solution dried up) were collected and analysed, while rest of the samples were stored for processing at 4 °C.

2.4. Processed samples

The representative fortified samples were processed as discussed in Table 2.

Representative samples of potato were analysed for treatments T1 to T4 by washing them in the desired solution of acetic acid and sodium chloride. The solution were prepared in Millipore water (1000 ml) and 20 ml (for 2%) while as 60 ml (for 6%) were added to each respectively. Samples were extracted and then analysed for effect of washing with various solvents.

Representative samples of apple were analysed for treatment T5 to T11. Both Jam and Juice were prepared using standard BIS 3501 [3]. Pickled collard greens were then analysed for Pesticide residue presence.

Pear was analysed for treatment T13 and T14. Standard household juicer was used to extract juice from the fruit using a standard method of BIS 7732 [4]. Pomace obtained was oven dried for 2 h and was also analysed for residue presence.

Tomato was analysed for treatments T15 and T16. Tomato Ketchup was prepared using standard method of BIS 3882 [2] while as lye peeling was done by dipping the tomatoes in 76 °C of water with 5% caustic soda (NaOH) solution for 10 min. Both lyer peeled tomatoes and tomato ketchup were analysed for pesticide residue presence.

Apricots and peaches were both analysed for treatments T17 AND T18. Canning was done using standard method of BIS 9789 [6]. canned apricots and peaches were analysed for the presence of pesticide residues.

2.4.1. Sample extraction and clean-up

Fruit and vegetable samples were chopped on a simple chopping board and blended in an electric blender with 1000 rpm. The samples were then homogenised in a homogeniser.

Pesticide residues were then extracted using QuEChERS method with dispersive clean-up.

About 15 ml of homogenised sample was used during comminution and mixed with 6 g of anhydrous MgSO4 in a 15 ml centrifuge tube. 1.5 g of sodium acetate was used as a buffer and mixed with 15 ml of 1% acetic acid of acetonitrile for vegetables and ethyl acetate for fruits. The tubes were tightly closed and vigorously shaken for 1 min on a vortex mixer for 2 min. The samples were centrifuged at 1500 rcf for 1 min.

For d-SPE, 1–8 ml of supernatant was added to a centrifuge tube containing 150 mg anhydrous MgSO4 along with 50 mg of PSA (Use of GCB and C18 were done wherever necessary-mostly for Haakh). The tubes were shaken well for 2 min on a vortex mixer and then centrifuged for 1500 rcf for 1 min. About 1 ml of supernatant was collected using a micropipette and transferred to a auto sampler vial of GC/MS.

2.5. Solutions and standards

The stock standard solution of the four target pesticides (1 mg ml⁻¹) was prepared in HPLC grade acetonitrile for vegetables and ethyl acetate was used for fruits. The standard solutions were required for constructing a calibration curve (20, 50, 100, 200 ppb) from serial dilution with the respective solvent. All standard solutions were stored at refrigerated conditions (4 °C) before use. The recovery study for the calibration curve is as follows (Table 3).

The limit of detection was found to be 0.1 mg/kg and the limit of quantification was found to be 0.25 mg/kg for in samples analyzed.

### Table 3
Summary of treatments for processed sample.

| S.no | Samples Used | Treatments (Processed Samples) |
|------|--------------|-------------------------------|
| 1.   | Potato       | Washing                       |
| 2.   | Apple        | Jam (T5)                      |
| 3.   | Collard greens | Pickling                    |
| 4.   | Pear         | Pear peel (T12)              |
| 5.   | Tomato       | Tomato ketchup (T15)         |
| 6.   | Apricot      | Apricot peel (T16)           |
| 7.   | Peach        | Peach Canning (T18)          |

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Representative samples of apple were analysed for treatment T5 to T11. Both Jam and Juice were prepared using standard BIS 3501 [3] and BIS 7732 [4] respectively. Pomace obtained from juice was oven dried for 2 h to remove excess water and was then analysed. Apples were mechanically peeled using a standard household hand peeler (Y-type) that removed the peel up to 3 mm thickness. Both mechanically peeled apple and the apple peel were analysed for the presence of pesticide residue. Apple slices were cut using a standard commercial apple slicer (for uniform thickness of 1.5 cm) and were allowed to be oven dried (50 °C for 72 h) and sun dried for 20 days. Both oven dried and sun dried sample were analysed for residue presence.

Local collard greens (Khanyari Haakh) was analysed for treatment T12. Pickle was prepared using standard BIS 3501 [3]. Pickled collard greens were then analysed for Pesticide residue presence.

Pear was analysed for treatment T13 and T14. Standard household juicer was used to extract juice from the fruit using a standard method of BIS 7732 [4]. Pomace obtained was oven dried for 2 h and was also analysed for residue presence.

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The limit of detection was found to be 0.1 mg/kg and the limit of quantification was found to be 0.25 mg/kg for in samples analyzed.
Method validation was carried out for the samples by fortifying them with 20, 50, 100, 200 ppb in triplicate and were extracted by the same method as described above. The recovery percentage was found to be commendable in the range of 85.00–97.5%.

Relative standard deviation was calculated in % RSD and ranged between 1.64% and 2.44%.

2.6. Instruments

The detection of the target pesticides (mancozeb, carbofuron, captan and chloropyriphos) was done by gas chromatography-mass spectrosopy (Agilent 6890 N) equipped with nitrogen phosphoric detector (NPD AND NPD+).

2.6.1. GC-MS flow conditions

**2.6.1.1. Chloropyriphos.**
- GC-MS Conditions set:
  - GC system: Agilent 6890 N
  - Column: RTX-5MS x 0.25 mm
  - Carrier gas: Helium at 1 ml/min
  - Temp: 100 °C hold 1 min then 10 °C /min to 320 °C hold for 7 min.
  - Injection: 2 microlitres split less
- MS conditions Set: Ionisation Mode:
  - Positive Capillary Voltage: 3KV
  - Temp: 400 °C Gas temp: 800 L/H
  - Detector: NPD AND NPD+

**2.6.1.2. Carbofuron.**
- Carrier gas: He (30 cm.sec)
- Injector temp: 275 °C
- Injection type: splitless
- Oven: Temperature Hold Time Rate
  - 80 °C 0 min 20 °C
  - 290 °C 4.75 min end
- MS conditions
- Gc inlet temp: 275 °C
- Ion source temp: 275 °C
- Scan range: m/z 40–450
- Scan time: 0.2 s
- Inter scan delay: 0.1 s

**2.6.1.3. Mancozeb on sim mode.**
- Carrier Gas: He
- Injection: PTV.LVI (split mode)
- Injection temp: 40 °C
- Injection pressure: 50, 100,150,250,300,400 kPa for 0.1 min at 64 ml/min
- Evaporation phase temp: 80 °C at 10 °C for 0.3 min to 110 °C at 10 °C for 1.5 min
- Oven temp: 40 °C hold time for 5 min
- 40 °C at 200 °C
- MS SIM MODE
- Highest abundant ion: 75.8,75.9,76.0 amu
- Next highest abundant ion: 77.9,78.0,78.1 amu

**2.6.1.4. Captan.**
- Carrier: He at 1 ml/min
- Injection: 1 μl splitless at 250 °C
- Oven: 60 °C (1 min)
- 30 °C to 12 °C for 1 min
- 15 °C /min to 360 °C/min
- MS Conditions
- Ionisation: 70 ev
- Source temp: 225 °C
- Stored mass range: 45–550 u
- Acquisition rate: 10 spectra/s

Data compilation and analysis was performed by Mass Hunter Software under MRM mode. Simple probe homogeniser WiseTis® was used for homogenising the sample. For sample preparation eppendorf®5810 R centrifuge was used. Processing factor for the respective processes was also calculated as:

\[ \text{PF} = \frac{\text{level of residues in processed food (mg/kg)}}{\text{level of residues in primary raw commodity (mg/kg)}} \]

where in,

Processing factor (PF) is a ratio, calculated from the residue level in the processed food divided by the residue level in the primary raw commodities. A PF value lower than 1 indicates a reduction in the residue level and higher than 1 highlights a concentration effect [7].

3. Results

3.1. Potato

Samples of locally grown potato were analysed for the effect of
washing on carbofuron. Results are summarised in Table 4.

It was observed that washing with 6% acetic acid reduced the residue to the maximum possible extent and hence acidic solution were found to be more suitable for dissipation of carbofuron through washing (Fig. 1).

3.2. Tomato

Samples of locally grown tomato were analysed for the effect of peeling and heat processing on Mancozeb. Results are summarised in Table 5.

It was observed that although lye peeling reduced the pesticide residue content. Hardly any residue was found in the heat processed tomato ketchup (Fig. 2).

### Table 4
Summary of results for potato washing.

| Potato Washing (Carbofuron) | Before Processing | After Processing | Processing Factor (Pf) | Mean Pf | % Reduction |
|-----------------------------|-------------------|------------------|------------------------|---------|-------------|
| MRL: 0.1 mg/kg              |                   |                  |                        |         |             |
| 2% sodium chloride          | 0.3               | 0.29             | 0.9667                 | 0.8417  | 3.33%       |
| 6% sodium chloride          | 0.3               | 0.27             | 0.9000                 | 10%     |
| 2% acetic acid              | 0.3               | 0.23             | 0.7667                 | 23.33%  |
| 6% acetic acid              | 0.3               | 0.22             | 0.7333                 | 26.66%  |

![Fig. 1. Effect of washing on pesticide residue in potato for carbofuran.](image)

### Table 5
Summary of results for tomato washing.

| Tomato processing (Mancozeb) MRL: 2 mg/kg | Before Processing | After Processing | Processing Factor (Pf) | Mean Pf | % Reduction |
|------------------------------------------|-------------------|------------------|------------------------|---------|-------------|
| Control sample                           | 0.00615 mg/kg (6.15ppb) | 0.00 mg/kg | 0.167 | 0.167 | 37.5758% decrease |
| lye peeling                              | 0.00615 mg/kg (6.15ppb) | 0.00103 mg/kg (1.03ppb) | 0.00615 mg/kg (6.15ppb) | 0.00 mg/kg (ND) | 0.167 |
| ketchup                                  |                   |                  |                        |         |             |

![Fig. 2. Effect of processing on pesticide residue in tomato for mancozeb.](image)
3.3. Pear

Samples of locally grown pear were analysed for the effect of Juicing on Chloropyriphos. Results are summarised in Table 6.

![Effect of processing in Pear for Chloropyriphos](image)

**Table 6**
Summary of results for pear processing.

| Processing (Chloropyriphos) MRL: 1 mg/kg | Before Processing | After Processing | Processing Factor (Pf) | Mean Pf | % Reduction |
|----------------------------------------|-------------------|------------------|------------------------|---------|-------------|
| Juicing                                | 0.02              | 0                | 0                      | 0       | 100         |
| Pear Pomace                            | 0.02              | 0.01             | 0.5                    | 0       | 50          |

![Effect of processing on carbofuron in collard greens](image)

**Table 8**
Summary of results for collard green processing.

| Collard green processing (carbofuron) MRL: 0.1 mg/kg | Before Processing | After Processing | Processing Factor (Pf) | Mean Pf | % Reduction |
|-----------------------------------------------------|-------------------|------------------|------------------------|---------|-------------|
| Pickling of collard greens                          | 16.56             | 0                | 16.56                  | 0       | 100         |

3.4. Apricot and peaches

Samples of locally grown apricot were analysed for the effect of canning on apricots and peaches. Results are summarised in Table 7.

It was observed that although no residue was found in the canned apricots and peaches after optimum heat processing (Fig. 4).

![Effect of processing on pesticide residue in pear for chloropyriphos](image)

**Table 7**
Summary of results for apricot and peach processing.

| Apricot and Peach processing (Captan) MRL: 15 and 20 mg/kg resp. | Before Processing | After Processing | Processing Factor (Pf) | Mean Pf | % Reduction |
|-----------------------------------------------------------------|-------------------|------------------|------------------------|---------|-------------|
| Apricot                                                         | 0.047             | 0                | 0                      | 0       | 100%        |
| Peach                                                           | 1.25              | 0                | 0                      | 0       | 100%        |

3.5. Collard greens

Samples of locally grown Collard greens were analysed for the effect of Pickling on Collard greens (Table 8). Results are summarised in Table 8.

3.6. Collard greens

Samples of locally grown Collard greens were analysed for the effect of Pickling on Collard greens. Results are summarised in Table 8.

It was observed that although no residue was found in the pressed pear juice however a minute content of pesticide was found in Pear Pomace even after drying (Fig. 3).
of pickling on Carbofuron. Results are summarised in Table 8.

It was observed that a no residue was found in the pickled collard greens after optimum fermentation (Fig. 5).

3.6. Apple

Samples of locally grown Apples were analysed for the effect of jamming, juicing, peeling and drying on Carbofuron. Results are summarised in Table 9.

It was observed that jamming and juicing hardly leave any detectable residues in the samples however apple Pomace (obtained after juicing) showed traces of residue content in it. Mechanically peeled apple showed reduced traces of residues while as apple peel showed a good content of residue available. Drying reduced the residue content to the maximum possible extent (Fig. 6):

4. Discussion

It was observed that due to washing a large amount of pesticide residues are dissipated. It may be due to the fact that acetic acid has the potential to act as a strong chelating agent that makes the residues unavailable as compare to the salt water washing. The results are supported by the findings of [16] where the Acidic solutions were found to be more effective that the salt water solutions for organo chlorine pesticides in potatoes. Also Soliman [8] confirmed that washing with acidic solution is more effective in case of pirimiphosmethyl HCB, p,p-DDT, lindane, dimethoate, pirimiphosmethyl and malathion from potatoes. In case of tomato the residues were dissipated by peeling and heating. It was due to the fact that Mancozeb being a non systemic fungicide it can be easily dissipated by peeling off the outer skin or peel. However in case of heating/boiling, the organic compounds of the pesticide tend to break down due to heat instability over 100 °C and thus undergo thermal degradations. Hence no traces of residues where found in case of processed tomato ketchup. The results are supported by the findings of [9] in which the percentage of pesticide residues dissipated from tomatoes by peeling were 70% for pyridaben and 100% for pyrifentox and tralomethrin. Also in [10], 77% percentage reduction for procymidone was seen. Pear processing involved pressing of juice and development of Pomace from the same, in case of juice processing due to the partitioning properties of the skin/pulp/fibre from fruits and vegetables, it was observed that residues of moderate to highly hydrophobic pesticides hardly transfer to the juice. Post juicing operations like clarification/filtration further reduce the residue presence in the same. However since Pomace contains majority of the fibre/pulp, residue presence in the same is evident. Same was observed in [11] when in concentrated apple juice about 90% of fenitrothion residue was removed also in [12] where multiple residues of apple juice like azinophos-methyl, chlorpyrifos, fenvalerate were reduced to about 97.6%, 100%, 97.8% and 78.1% respectively.

Process of canning is an elaborate process which involves multiple steps like boiling, steaming, sterilisation etc. Therefore hardly any traces of residues were analysed in canned apricots and peaches that were sterilised at 121 °C for 15 min. Evaporation and thermal degradation are the possible physico-chemical processes responsible for this dissipation as seen by maneb reduction in tomatoes at 121 °C for 15 min by [13]. Apple processing involved multiple steps like drying, jamming, juicing, peeling. Residue dissipation was analysed in each. In case of drying, evaporation was found to be the primary physicochemical process responsible for dissipation because of the strong volatility of the compounds Therefore, Lee stated in his study both sun and hot air drying are effective in case of pesticide residue dissipation for about 20–30% of chlorpyrifos and fenitrothion residues from red pepper and in case of industrial dehydration, the phosalone levels in apples was found to be reduced to over 80%. Mergnat et al. [14] Fermented collard greens were analysed for residue dissipation. The scenario for pesticide residue dissipation in case of fermentation is mainly because of three reasons. Firstly, it is assumed that the pesticides get adsorbed to the polysaccharides in the cell walls of the microorganisms. Secondly, they consume the residue available as nutrition for their growth as it is a rich source of nitrogen, carbon and phosphorous. Lastly, microorganisms tend to produce pesticide degrading enzymes which are responsible for this biological degradation same was observed during kimchi fermentation where chlorpyrifos was degraded rapidly (83.3%) [15].

4.1. Risk assessment

Risk Assessment for each of the processing treatment was calculated by taking into consideration the TMRC (Theoretical maximum residue contribution) values for each. It was observed that the TMRC (After processing) was less than the TMRC (Before processing) in all processing treatments which thus concludes the fact that, processed food samples

Table 9
Summary of results for apple processing.

| Apple processing                  | Before Processing | After Processing | Mean PF | % Reduction |
|-----------------------------------|-------------------|------------------|---------|-------------|
| Simple fortified Apple            | 0.894             | 0                | 0       | 100%        |
| Apple Jam                         | 0.894             | 0.754            | 0.84    | 15.66%      |
| Apple peel                        | 0.894             | 0.245            | 0.27    | 72.50%      |
| Mechanically Peeled Apple         | 0.894             | 0.674            | 0.75    | 24.60%      |
| Oven Dried Apple                  | 0.894             | 0                | 0       | 100%        |
| Sun Dried Apple                   | 0.894             | 0                | 0       | 100%        |
| Apple Juice                       | 0.894             | 0.674            | 0.75    | 24.60%      |

Fig. 6. Effect of processing on pesticide residue in apple for mancozeb.
as fit to be consumed (Table 10).

5. Conclusion

The levels of pesticide residue that remain in the various food commodities both pre and post harvest could be effectively reduced by various household processing treatments. Therefore treatments like juicing, fermentation, heating etc were found to be one of the most common and cost effective methods for pesticide residue dissipation in various fruits and vegetables.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

[1] European Commission, Establishing community methods of sampling for the official control of pesticide residues in and on products of plant and animal origin and repealing directive, Off. J. Eur. Union 187 (2002) 30–43.
[2] IS 3882: Tomato Ketchup: Bureau of Indian Standards: Free Download, Borrow, and Streaming: Internet Archive, 2021. (https://archive.org/details/gov.in.is.3882.1966).
[3] IS 3501: Pickles: Bureau of Indian Standards: Free Download, Borrow, and Streaming: Internet Archive, 2021. (https://archive.org/details/gov.in.is.3501.1966).
[4] IS 7732: Apple Juice Preserved Exclusively by Physical Means: Bureau of Indian Standards: Free Download, Borrow, and Streaming: Internet Archive, 2021. (https://archive.org/details/gov.in.is.7732.2003).
[5] IS 5861: Jams, Jellies and Marmalades: Bureau of Indian Standards: Free Download, Borrow, and Streaming: Internet Archive, 2021. (https://archive.org/details/gov.in.is.5861.1993).
[6] IS 9789: Canned Apricot: Bureau of Indian Standards: Free Download, Borrow, and Streaming: Internet Archive, 2021. (https://archive.org/details/gov.in.is.9789.1981).
[7] Moo-Hyeg Im, Yu-Jeong Ji, A review on processing factors of pesticide residues during fruits processing, J. Appl. Biol. Chem. 59 (2016) 189–201, https://doi.org/10.1021/jf040455y.
[8] K.M. Soliman, Changes in concentration of pesticide residues in potatoes during washing and home preparation, Food Chem. Toxicol. 39 (2001) 887–891, https://doi.org/10.1016/S0278-6915(00)00177-0.
[9] M.F. Cengiz, M. Certel, B. Karakas, H. Gocmen, Residue contents of captan and procymidione applied on tomatoes grown in greenhouses and their reduction by duration of a pre-harvest interval and post-harvest culinary applications, Food Chem. 100 (2007) 1611–1619, https://doi.org/10.1016/j.foodchem.2005.12.059.
[10] M. Boulaid, A. Aguilera, F. Camacho, M. Soussi, A. Valverde, Effect of household processing and unit-touint variability of pyrifoxin, pyridaben, and tralomethrin residues in tomatoes, J. Agric. Food 53 (2005) 4054–4058, https://doi.org/10.1021/jf040455y.
[11] T. Lipowska, K. Szymczyk, B. Danielewska, B. Szteke, Influence of technological process on fenitrothion residues during production of concentrated apple juice - short report, Pol. J. Food Nutr. Sci. 7 (1998) 293–297.
[12] M.J. Zubik, M.F.A. El-Hadidi, J.N. Cash, M.E. Zabik, A.L. Jones, Reduction of azinphos-methyl, chlorpyrifos, esfenvalerate and methomyl residues in processed apples, J. Agric. Food Chem. 48 (2000) 4199–4203, https://doi.org/10.1021/jf9913559.
[13] S. Kontou, D. Tsipi, C. Tzia, Stability of the dithiocarbamate pesticide maneb in tomato homogenates during cold storage and thermal processing, Food Addit. Contam. 21 (11) (2004) 1083–1089, https://doi.org/10.1080/0265203040019372.
[14] T. Mergnat, P. Frisch, C. Saint Joly, E. Truchot, G. Saint Blanquat, Reduction of phosalone residue levels during industrial dehydration of apples, Food Addit. Contam. 12 (1995) 759–767, https://doi.org/10.1080/02652039509374336.
[15] K.M. Cho, R.K. Math, S.A. Islam, W.J. Lim, S.Y. Hong, J.M. Kim, H.D. Yun, Biodegradation of chlorpyrifos by lactic acid bacteria during Kimchi fermentation, J. Agric. Food Chem. 57 (2009) 1882–1889, https://doi.org/10.1021/jf803649p.
[16] A. Zohair, Behaviour of some organophosphorus and organochlorine pesticides in potatoes during soaking in different solutions, Food Chem. Toxicol. 39 (2001) 751–755, https://doi.org/10.1016/S0278-6915(01)00016-3.