Research Journal of Environmental Toxicology

ISSN 1819-3420

Academic Journals Inc.

www.academicjournals.com

OPEN ACCESS Research Journal of Environmental Toxicology

ISSN 1819-3420
DOI: 10.3923/rjet.2026.1.12

Research Article
Influence of Domestic Preparation Methods on Xenobiotic and Pesticide Residues in *Phaseolus vulgaris*

[1]Tamuno-Boma Grace Odinga-Israel, [1]Conquest Chivusalem Nodi, [1]Prince Aruchi Chikordi Amechi, [2]Oghenetekevwe Efekemo, [3]George Nnabugwu Anaero-Nweke, [4]Sarah Kelechi Enebeli and [5]Iyingiala Austin-Asomeji

[1]Department of Biochemistry, Faculty of Science, Rivers State University, River State, Nigeria
[2]Department of Environmental Management and Toxicology, College of Sciences, Federal University of Petroleum Resources, Effurun, Delta State, Nigeria
[3]Department of Animal and Environmental Biology, Faculty of Science, Rivers State University, River State, Nigeria
[4]Department of Pharmacology and Therapeutics, Faculty of Basic Clinical Sciences, College of Medical Sciences, Rivers State University, River State, Nigeria
[5]Department of Community Medicine, Faculty of Clinical Sciences, College of Medical Sciences, Rivers State University, River State, Nigeria

Abstract

Background and Objective: *Phaseolus vulgaris* (common beans) are a major dietary protein source globally, but pesticide residues from cultivation and preservation can persist in the food chain. Household cooking practices such as soaking, boiling and filtration can reduce or transform these residues. This study evaluated how common preparation methods influence the persistence, reduction and transformation of pesticide-derived residues in Phaseolus vulgaris using Gas Chromatography-Mass Spectrometry (GC-MS). **Materials and Methods:** Eight representative beans preparations (A-H) were designed to simulate household cooking conditions, including soaking, boiling with or without filtrate, filtrate-only extraction and raw controls. Samples (173 g beans and 50cl water) were extracted via a modified QuEChERS method and analyzed on an Agilent 7890A GC coupled with a 5675C Inert MSD detector and a 30 m × 0.25 mm × 0.25 µm HP-5MS column. Spectra were compared against the NIST 2017 library and validated per AOAC (2023) standards. Quantification used relative peak areas. **Results:** Seventy-seven xenobiotics were detected across all preparations, with notable variation. Filtrate-retained samples had higher diversity: A (14 compounds), B (11), E (7). Filtrate-discarded or dry-boiled samples (C, D) had fewer compounds (7 and 10), but some semi-volatile aromatics were higher, e.g., 4-dibenzofuranamine (21.93%) and 4-nitrophenyl laurate (11.12%) in D. Boiled filtrate (F) contained 25 residues, mostly 0.1-0.9%, with some up to 6.33%, showing partitioning of soluble xenobiotics. Persistent compounds included di-(2-ethylhexyl) phthalate, 1-octadecanesulphonyl chloride (0.37-4.83%), 1-chlorooctadecane (3.09-4.83%) and carbonic acid esters like eicosyl vinyl ester (0.26-27.4%). Thermal processing promoted partial transformation, esterification and condensation of nitrogen- and halogen-containing residues. Raw beans (G) had 7 xenobiotics and 3 thermal products; raw soaking filtrate (H) had 11. **Conclusion:** Domestic preparation strongly influences xenobiotic and pesticide residue retention in *Phaseolus vulgaris*. Soaking followed by filtrate discard (Sample C) effectively minimizes both water-soluble and lipophilic residues, whereas filtrate retention favors persistence of thermally stable and halogenated compounds. These findings provide practical guidance for reducing dietary exposure and underscore the need for further targeted quantitative studies.

Key words: *Phaseolus vulgaris*, xenobiotics, pesticide residues, thermal degradation, food safety

Citation: Odinga-Israel, T.G., C.C. Nodi, P.A.C. Amechi, O. Efekemo, G.N. Anaero-Nweke, S.K. Enebeli and I. Austin-Asomeji, 2026. Influence of domestic preparation methods on xenobiotic and pesticide residues in *Phaseolus vulgaris*. Res. J. Environ. Toxicol., 20: 1-12.

Corresponding Author: Tamuno-Boma Grace Odinga-Israel, Department of Biochemistry, Faculty of Science, Rivers State University, River State, Nigeria

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Beans (*Phaseolus vulgaris*) are a vital source of protein, fiber, vitamins and minerals consumed globally, especially in areas with limited access to animal-based proteins[1,2]. However, the common usage of pesticides in their cultivation can result in residue accumulation in beans, which poses risks such as endocrine disruption, cytotoxicity and cancer[3]. Various domestic food preparation methods, including soaking, boiling, peeling and removing filtrate, can affect residue levels. Some techniques significantly reduce pesticide residues, while others may convert these residues into new toxic compounds[4,5].

Recent research in Nigeria has found that samples of *Phaseolus vulgaris* consumed in Port Harcourt contained multiple pesticide residues, with some levels exceeding the Maximum Residue Limits (MRLs) set by the European Union. The study indicated that parboiling significantly reduced these pesticide residues compared to raw bean samples[6]. Similarly, a study conducted in the Western Highlands of Cameroon evaluated 99 different pesticides in agricultural products and discovered that many pesticide residues persisted in staple foods, even after standard washing and market handling[7]. These findings highlight the need to understand how household cooking processes not only reduce pesticide residues but may also lead to the formation of new harmful by-products.

Despite extensive research on pesticide contamination in food crops, there remains a paucity of studies specifically examining how different household preparation methods, such as boiling with retained filtrate, boiling after discarding filtrate, soaking and evaporating filtrate, influence both pesticide residues and thermally induced xenobiotic compounds in *Phaseolus vulgaris.* This knowledge gap is particularly important in regions where beans constitute a major dietary staple and cooking practices vary substantially.

Therefore, this study aims to evaluate the impact of various domestic preparation methods on the concentration and occurrence of both xenobiotic and pesticide-derived residues, as well as potentially harmful thermal products, in *Phaseolus vulgaris*. By comparing residue profiles across soaked, boiled, filtrate-retained and filtrate-discarded samples using GC-MS analysis, the research seeks to provide scientific evidence for safer domestic cooking practices and contribute to the formulation of improved regulatory frameworks for food safety.

MATERIALS AND METHODS

Study area and duration: The study was carried out in the Central Laboratory, University of Ilorin and the department of Biochemistry, Faculty of Science, Rivers State University, Nigeria, between June 2024 to November, 2024.

Study materials and equipment: The materials and equipment used for this study included *Phaseolus vulgaris* (common beans), a gas chromatography-mass spectrometer (Agilent 7890A GC system coupled with 5675C Inert MSD triple-axis detector), a heavy-duty grinder, analytical weighing balance, a filtration setup, a hot plate, bowls and other standard laboratory glassware. All reagents used were of analytical grade and all glassware was washed thoroughly and rinsed with deionized water before use to avoid contamination.

Sample collection: Samples of *Phaseolus vulgaris* (2 kg) were purchased from Mile 1 Market in Port Harcourt, Rivers State, Nigeria. The market serves as one of the largest retail points for food commodities in the Niger Delta, characterized by diverse agricultural produce such as maize, yams, cowpea and cereals. The samples were collected in clean polyethylene bags, labeled appropriately and transported to the laboratory for processing. Samples were stored at ambient temperature (25-28°C) before analysis to prevent moisture alteration or microbial degradation[8].

Experimental design: Eight representative beans samples (A-H) were prepared to simulate different household processing conditions and evaluate how variations in soaking, boiling and filtrate management affect pesticide residue persistence and transformation. The design ensured that all samples were treated under uniform analytical conditions for comparative evaluation. The processing conditions are summarized as follows:

- **Sample A:** Soaked beans boiled together with the soaking filtrate
- **Sample B:** Beans boiled directly without prior soaking (unwashed stock)
- **Sample C:** Soaked and boiled beans with filtrate discarded before boiling
- **Sample D:** Peeled beans boiled until complete evaporation of the filtrate (dry-boil method)
- **Sample E:** Soaked beans boiled while retaining the soaking stock throughout cooking
- **Sample F:** Filtrate (stock) obtained from boiled beans without the solid component

- **Sample G:** Ground raw beans analyzed without soaking or boiling
- **Sample H:** Filtrate derived from raw soaked beans (uncooked)

Each sample was analyzed separately using GC-MS under identical instrumental conditions. Resulting chromatograms were processed to identify and quantify compounds based on retention time and mass spectral library matches using the NIST 2017 reference database. Only xenobiotic residues, pesticide-derived compounds and potentially harmful thermal degradation products were retained for interpretation, excluding natural plant metabolites, volatiles and endogenous components.

Sample preparation: For each treatment, 173 g of *Phaseolus vulgaris* was weighed using an analytical balance and mixed with 50 mL of distilled water. The mixture was boiled on a hot plate at 100°C until the filtrate nearly evaporated (approximately 1 hr and 20 min). The cooked samples were allowed to cool, cleaned to remove impurities and homogenized using a decontaminated laboratory blender until uniform consistency was achieved. For the raw and filtrate samples, equivalent sample masses and water volumes were used to maintain uniformity across treatments. The preparation procedure was consistent across all eight experimental categories.

Sample extraction: Five grams of each homogenized bean sample was weighed into a 50 mL Teflon centrifuge tube. Subsequently, 5 mL of distilled water and 10 mL of acetonitrile were added and the mixture was shaken vigorously for 1 min. A QuEChERS extraction salt mixture containing 4 g magnesium sulfate ($MgSO_4$), 1 g sodium citrate dihydrate ($Na_3C_6H_5O_7{\cdot}2H_2O$) and 0.5 g sodium hydrogen citrate sesquihydrate ($Na_2HC_6H_5O_7{\cdot}1.5H_2O$) was added, followed by vigorous shaking. The mixture was centrifuged at 4,000 rpm for 1 min and the supernatant was decanted for cleanup.

This modified QuEChERS (Quick, Easy, Cheap, Effective, Rugged and Safe) procedure was adopted[9,10], they demonstrated its efficiency in isolating pesticide residues from plant matrices. The protocol has been widely applied in recent environmental residue studies due to its reliability and minimal solvent requirement[11].

Sample treatment for GC-MS analysis: To remove moisture, 2 g of the homogenized extract was mixed with 4 g of anhydrous sodium sulfate. The mixture was transferred into a 100 mL conical flask and extracted with 50 mL of n-hexane and methanol (60:40 v/v) for 3 hrs under continuous agitation. Approximately 5 mL of the filtrate was double-filtered using Whatman No. 1 filter paper and transferred into GC-MS vials for instrumental analysis.

GC-MS instrumental analysis: Residue quantification and compound identification were carried out using an Agilent 7890A GC system coupled with a 5975C Inert MSD triple-axis detector equipped with an auto-injector (10 µL syringe). Chromatographic separation was achieved on a capillary column (Agilent 19091-433HP-5MS; 30 m×0.25 mm×0.25 µm) coated with 5 % phenyl methyl siloxane. Helium (99.999 %) served as the carrier gas at a constant flow rate of 1 mL/min. The injector temperature was set at 280°C in split mode (split ratio = 1:50), with an injection volume of 1 µL.

The oven temperature was programmed as follows: Initial temperature 50°C (held for 2 min), ramped at 20°C/min to 100°C, then increased to 250 at 20°C/min and held for 5 min, yielding a total run time of 19 min. The ion source and interface temperatures were maintained at 250 and 300°C, respectively. The MS operated in electron ionization (EI) mode at 70 eV and spectral data were acquired over a mass range of 50-550m/z. Compound identification was achieved by comparing sample spectra to the NIST 2017 library with ≥ 80% match threshold[12].

Quality assurance: Procedural blanks and solvent blanks were analyzed alongside samples to detect potential contamination or carryover. The method performance (recovery, precision and repeatability) was validated according to the AOAC guidelines for pesticide residue analysis[13]. Data interpretation and compound classification were conducted using MS Solution Software (Agilent Technologies, USA). For this study, only xenobiotic contaminants, pesticide-derived residues and potentially harmful thermal degradation products were reported, while natural volatiles and plant metabolites were excluded from interpretation.

RESULTS AND DISCUSSION

The chromatographic analysis of the samples A-H is as seen in Fig. 1-8. The Chromatograms revealed a complex profile characterized by multiple peaks distributed across the retention time range. Several prominent peaks were observed, indicating the presence of diverse chemical constituents within the sample matrix. Notable peaks appeared at

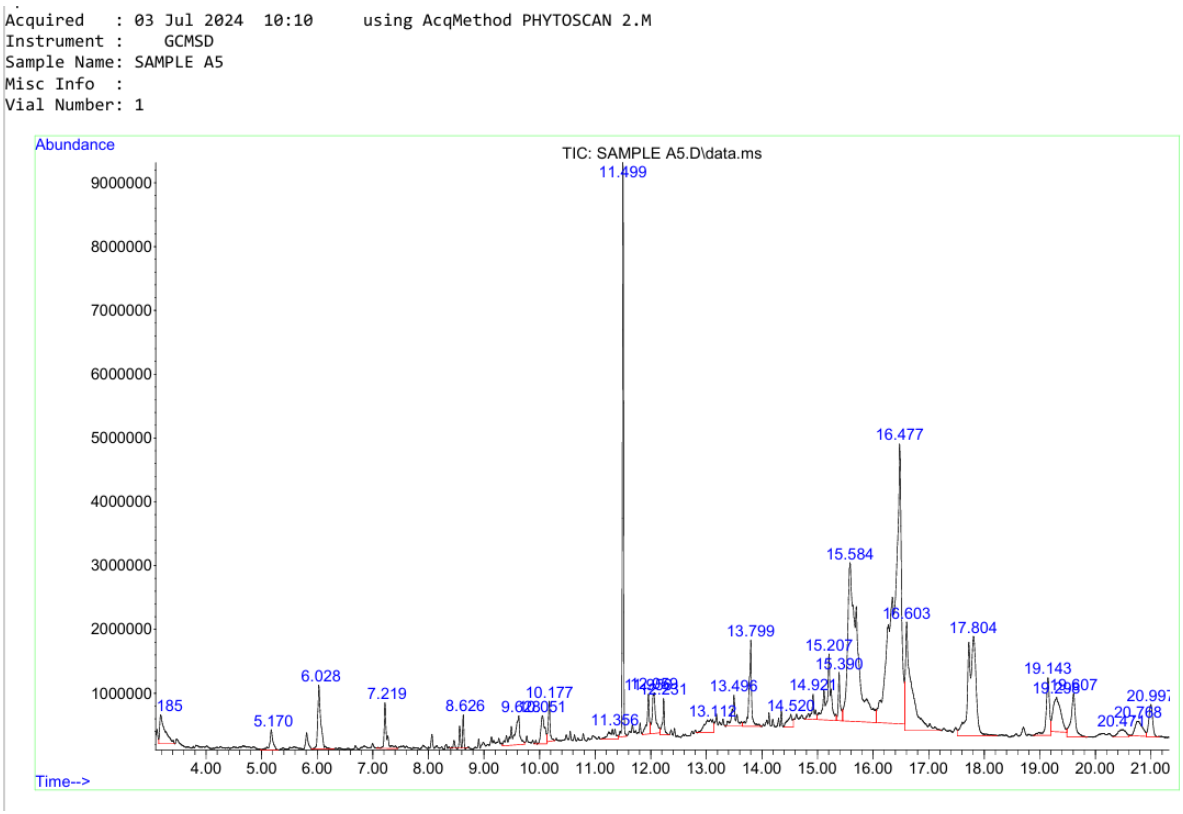

Fig. 1: GC-MS chromatogram of sample A showing pesticide residues in the sample

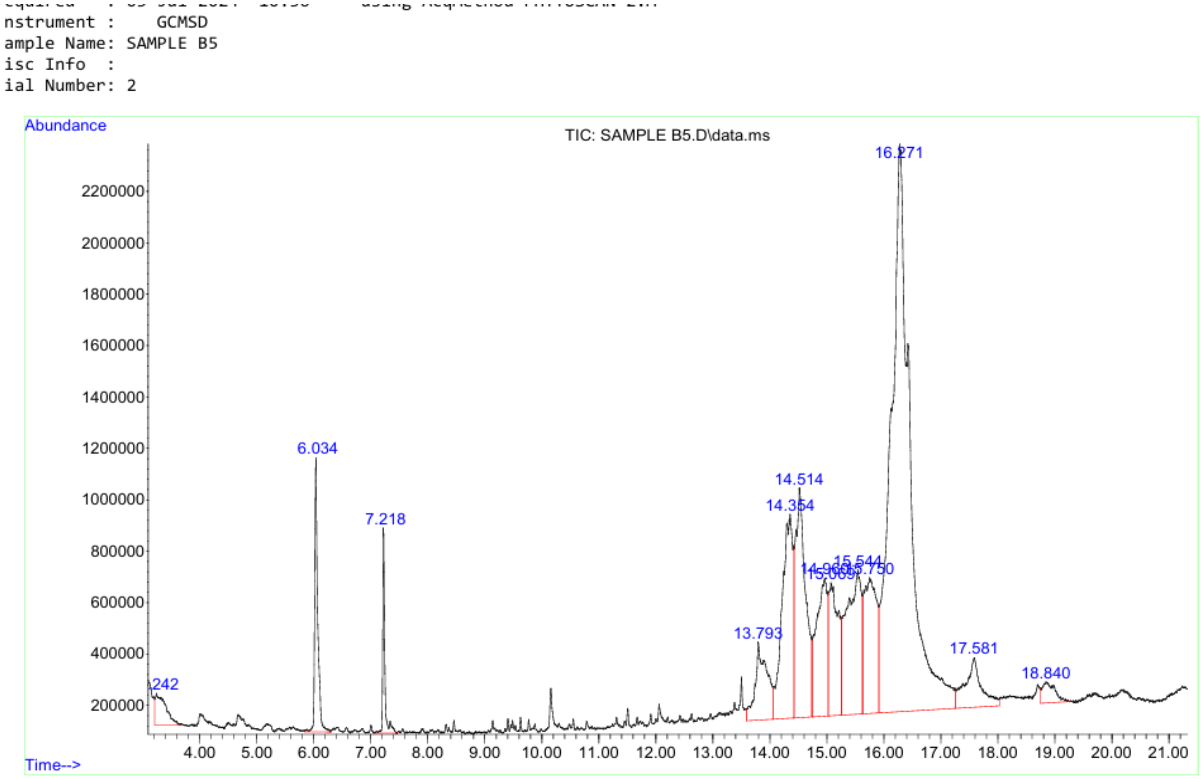

Fig. 2: GC-MS chromatogram of sample B showing pesticide residues in the sample

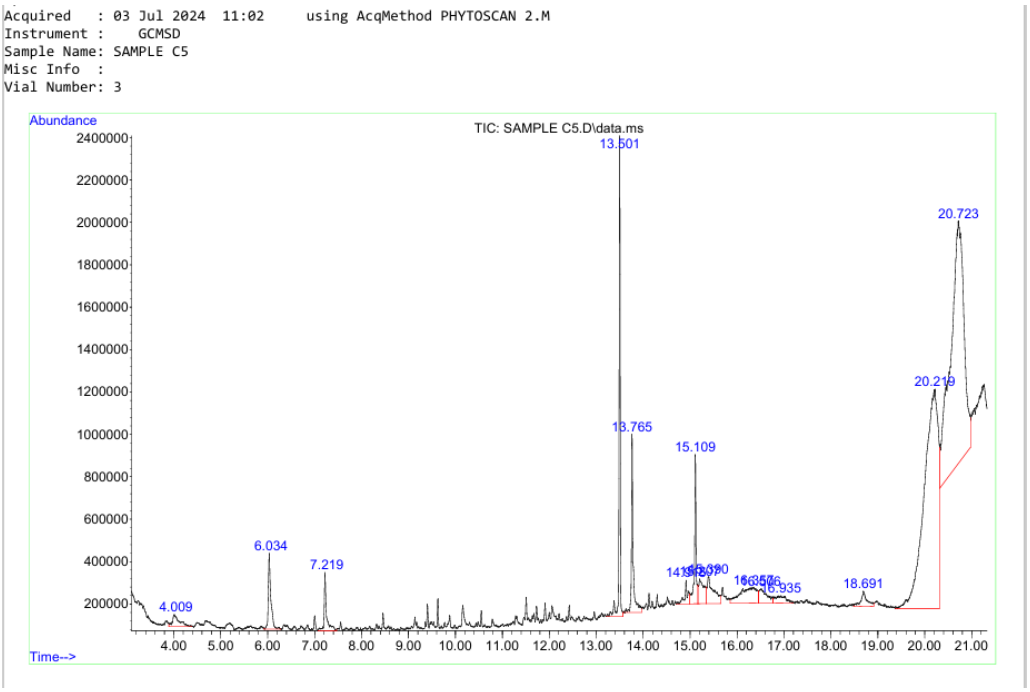

Fig. 3: GC-MS chromatogram of sample C showing pesticide residues in the sample

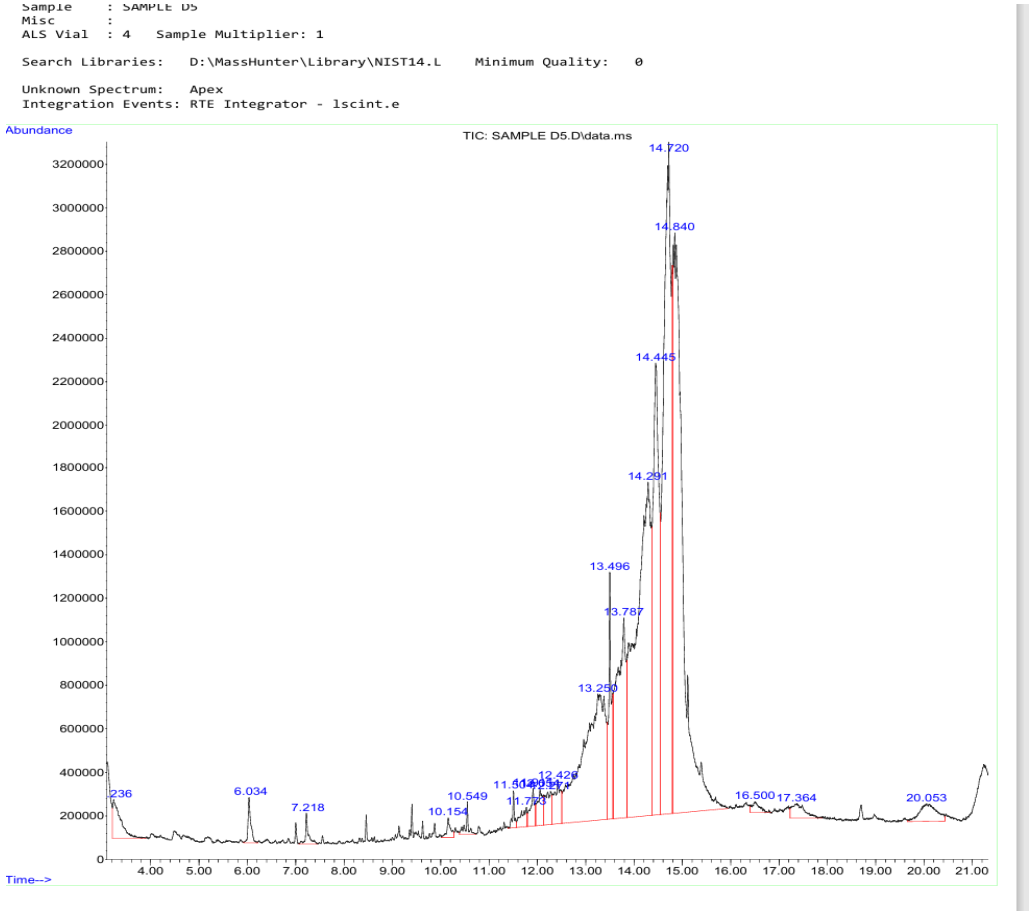

Fig. 4: GC-MS chromatogram of sample D showing pesticide residues in the sample

```
cquired   : 03 Jul 2024  15:19     using AcqMethod PHYTOSCAN 2.M
nstrument :    GCMSD
ample Name: SAMPLE E5
isc Info  :
ial Number: 13
```

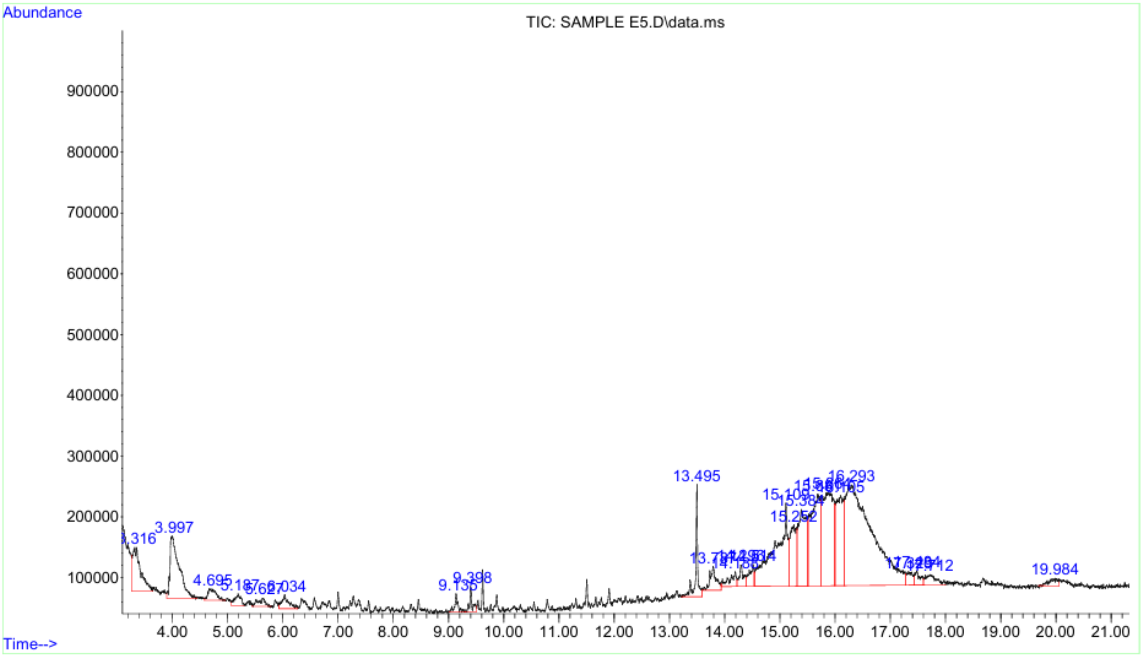

Fig. 5: GC-MS chromatogram of sample E showing pesticide residues in the sample

```
\cquired   : 03 Jul 2024  12:15     using AcqMethod PHYTOSCAN 2.M
[nstrument :    GCMSD
Sample Name: SAMPLE F5
Misc Info  :
/ial Number: 6
```

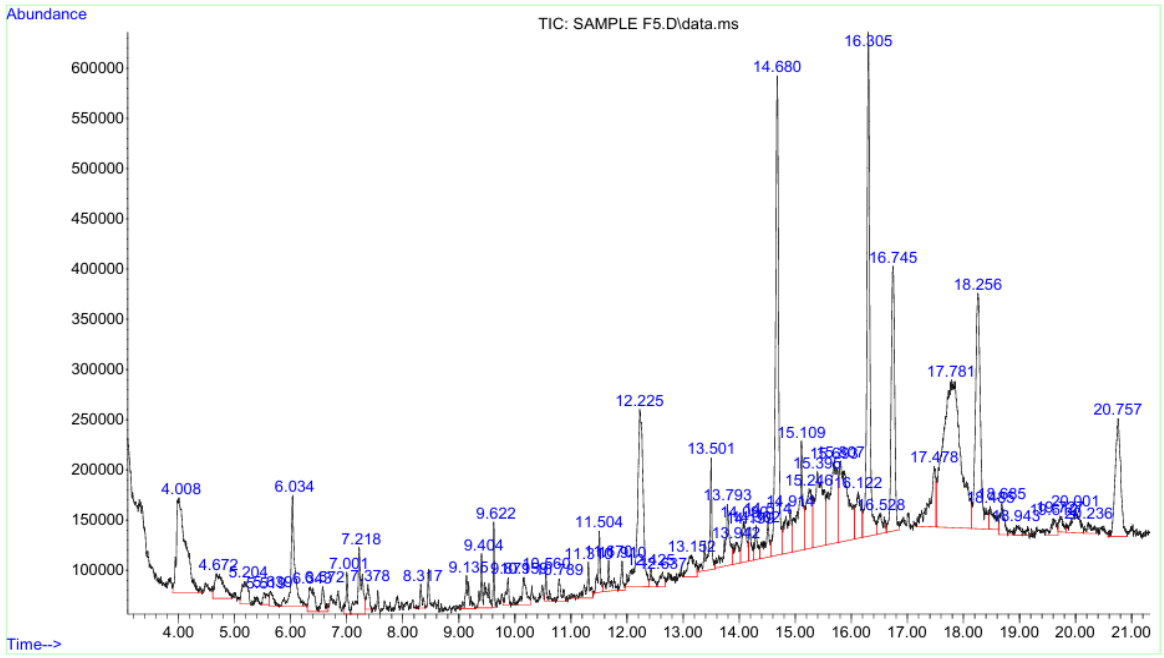

Fig. 6: GC-MS chromatogram of sample F showing pesticide residues in the sample

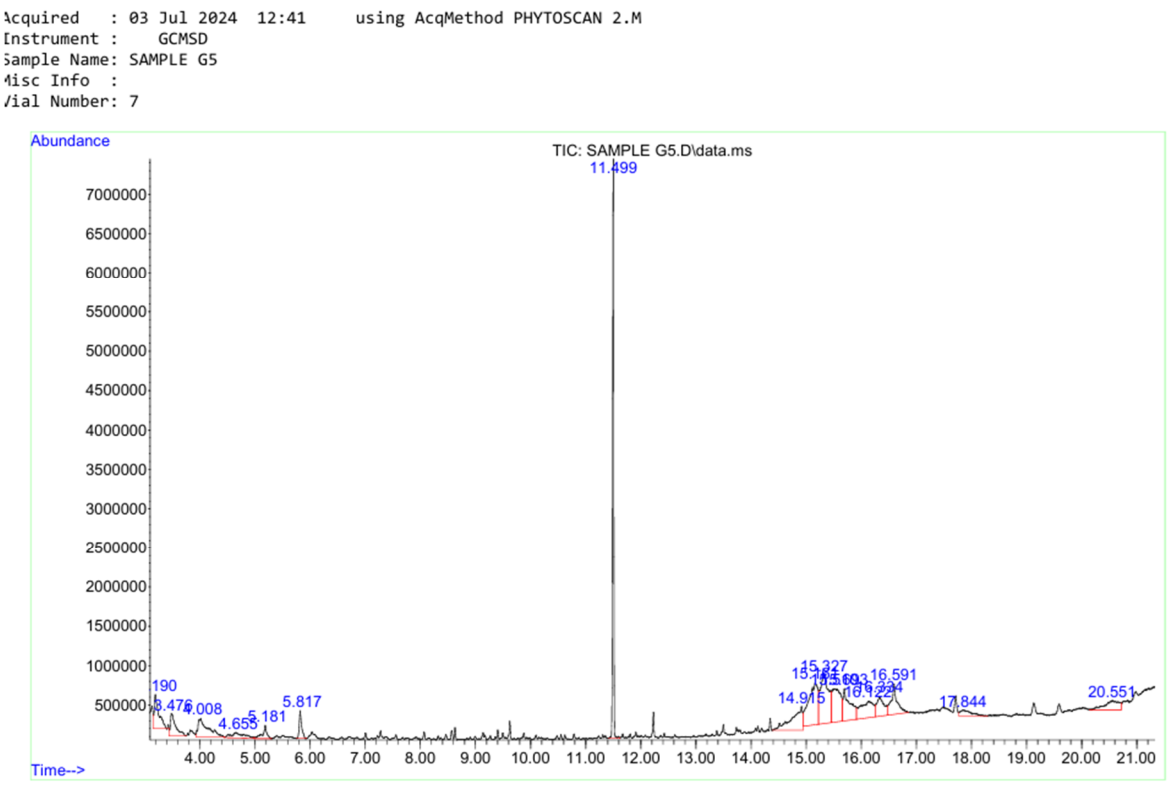

Fig. 7: GC-MS chromatogram of sample G showing pesticide residues in the sample

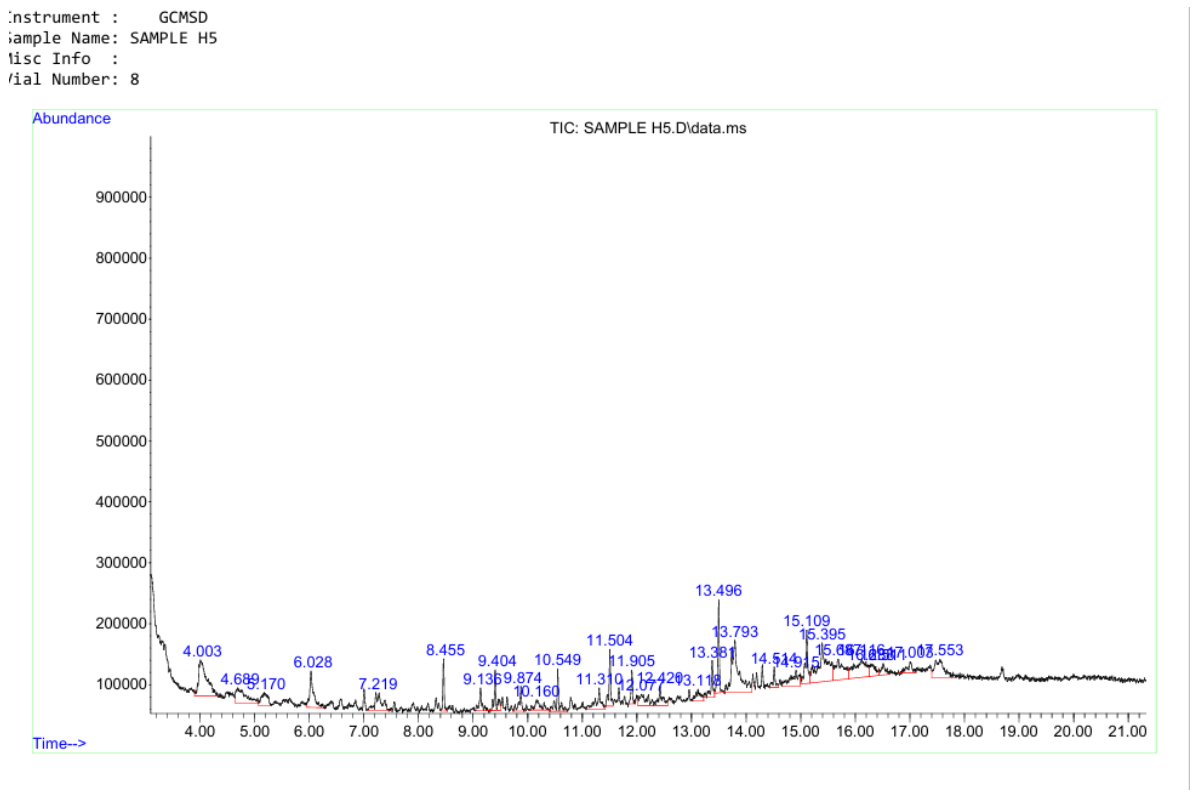

Fig. 8: GC-MS chromatogram of sample H showing pesticide residues in the sample

Table 1: Xenobiotic and contaminant residues in *Phaseolus vulgaris*

Compound	A	B	C	D	E	F	G	H
2-Piperidinone, N-[4-bromo-n-butyl]-	0	6.76	0	0.31	0.79	0	1.71	0
Pyrrolidine-3-carboxamide	0	6.76	0	0	0	0	0	0
1-Isopropyl-5-oxo-N-(2-thiazolyl)-tetracosanoic acid, isobutyl ester	0	6.76	0	0	0	0	0	0
Carbonic acid, Octadecyl prop-1-en-2-yl ester	0	3.55	0	0	0	0	4.04	0
Carbonic acid, eicosyl vinyl ester	0	3.55	0	0.26	27.45	1.02	0	0
Chloroacetic acid, hexyl ester	0	1.29	0	0	0	0	0	0
N-[(1,5-Dimethyl-3(2H)-oxo-2-phenyl-4-pyrazolyl)aminomethyl]-4-fluorophthalimide	0	1.29	0	0	0	0	0	0
1-Chlorooctadecane	0	3.09	0	0	0	3.41	4.83	0
Decanoyl chloride	0	42.32	0	0	0	0	0	0
1,3-O-Benzylidene glyceryl-2-myristate	0	8.31	0	0	0			
2-Piperidinone, N-[4-bromo-n-butyl]-disparlure			2.02					
4-Nitrophenyl laurate			37.38	11.12				
Oxalic acid, dodecyl 3,5-difluorophenyl ester			1.06					
4-dibenzofuranamine			35.46	21.93				
Piperidine			0.98					
3-MethylPiperidine			0.98					
3-Methylimidosulfurous difluoride			0.98					
Dodecanoic acid, pentafluorophenyl ester				11.12				
1,3,5-Triazin-2(1H)-one, 4,6-bis(ethylamino)-				21.93				
Myristoyl chloride				0.8				
2-dibenzofuranamine				9.88				
8H-Thiazolo[5,4-c]azepin-8-one, 2-amino-4,5,6,7-tetrahydro-1,15-Pentadecanedioic acid				20.5				
Sulfurous acid, dodecyl 2-propyl ester				0.57				
Benz[b]-1,4-oxazepine-4(5H)-thione, 2,3-dihydro-2,8-dimethyl-					0.64			
Urea					3.56			
Carbonic acid, monoamide, N-(2-ethylphenyl)-, propyl ester					0.96			
1,2,5-Oxadiazol-3-amine, 4-(4-methoxyphenoxy)-					0.96			
Hexahydropyridine, 1-methyl-4-[4,5-dihydroxyphenyl]-					0.79	1.84		
1,2-Benzisothiazol-3-amine, TBDMS derivative						1.16		
2-(Piperazin-1-yl)-5,6,7,8-tetrahydroquinoline-3,4-dicarbonitrile						1.16		
3,4-Dimethyl-5-phenyloxazolidine						0.43		
Sulfurous acid, 2-propyl tetradecyl ester						1.48		
o-(p-Tolyl) 1-azetidine carbothioate						0.33		
Methyl 3-bromo-1-adamantane acetate						0.63		
1-Iodo-2-methylundecane						1.02		
1-octadecanesulphonyl chloride						0.37	4.83	2.02
9H-Fluorene-2-carboxylic acid, 9-oxo-, (2-hydroxyethyl)(methyl)amide						0.63		
Thiophene-2-methylamine, N-(2-fluorophenyl)-						0.66		2.64
2-Thiophenemethanethiol						0.66		2.64
Acetamide, N-(4-fluorophenyl)-2,2,2-trifluoro-						0.8		
1-methyl-4-phenyl-5-thioxo-1,2,4-triazolidin-3-one						0.8		
Benzo[h]quinoline, 2,4-dimethyl-						0.61		
Carbonic Acid, Octadecyl Vinyl Ester						3.6		
4-Cyanobenzoic Acid, Tridecyl Ester						3.85		
2-Quinoxalinamine, 3-Chloro-N-ethyl-						3.85		
Octatriacontyl pentafluoropropionate						2.03		
Octacosyl trifluoroacetate						2.03		
Heptacosane, 1-chloro-						6.33		
1-methyl-4-phenyl-5-thioxo-1,2,4-t 30 triazolidin-3-one						0.75		
Benzene, 2-ethyl-1,3-dimethyl-							1.84	
Benzene, 1-ethyl-2,4-dimethyl-							1.84	
Benzene, 1-ethyl-2,3-dimethyl-							1.84	
N-(Trifluoroacetyl)-N,O,O',O''-							1.52	
3-Butylthiophene							17.93	
5-Bromo-4'-chlorosalicylanilide							8.05	
Piperidine, 3-methyl-								8.1
Imidosulfurous difluoride, methyl-								8.1
Acetamide, 2-(2-thiophenyl)-N-ethyl-N-2-ethylhexyl-								3.38
Benzeneacetaldehyde, α-(methoxymethylene)-4-nitro-								1.71
Formic acid, 1-(4,7-dihydro-2-methyl-7-oxopyrazolo[1,5-a]pyrimidin-5-yl)-, methyl ester								1.71
2-Thiopheneacetic acid, decyl ester								2.64

Table 1: Continue

Compound	A	B	C	D	E	F	G	H
Carbonic acid, hexadecyl prop-1-en-2-yl ester								9.42
Eicosane, 1-iodo-								9.42
Benzonitrile	0.67							
Phosphine oxide	0.67							
Sulfurous acid	7.27							
Bibenzyl	0.74							
Benzene	0.74							
(Z)- 2-Piperidinone	1.16							
N-[4-bromo-n-butyl]- 6-Nitroundec-5-ene	1.16							
Carbonic acid, tetradecyl vinyl ester	0.76							
Carbonic acid, tridecyl vinyl ester	0.76	3.09						
1-[p-Bromophenyl]-4-nitro-1,3-butadiene	25.15							
Diethylmalonic acid, 3,4-difluorobenzyl heptyl ester	25.15							
Pentadecafluorooctanoic acid, octadecyl ester	0.64							
Sulfurous acid, 2-propyl undecyl ester	1.35					6.33		
Fenproporex	0.85							

Black text color: Xenobiotics/Contaminants, Red text color: Potentially harmful thermal product

Sample A: Soaked beans boiled together with the soaking filtrate, Sample B: Beans boiled directly without prior soaking (unwashed stock), Sample C: Soaked and boiled beans with filtrate discarded before boiling, Sample D: Peeled beans boiled until complete evaporation of the filtrate (dry-boil method), Sample E: Soaked beans boiled while retaining the soaking stock throughout cooking, Sample F: Filtrate (stock) obtained from boiled beans without the solid component, Sample G: Ground raw beans analyzed without soaking or boiling and Sample H: Filtrate derived from raw soaked beans (uncooked)

various retention times with varying peak intensities suggesting differences in compound abundance. The chromatogram showed a gradual increase in baseline intensity, with clusters of peaks observed particularly between 12 and 18 min, indicating a higher concentration of eluting compounds within this region. The most intense peak was recorded, suggesting the predominance of a major constituent in the sample. Additionally, several smaller peaks were detected throughout the chromatogram, reflecting the presence of minor components or possible degradation products. The spectral pattern demonstrates a heterogeneous mixture of compounds, consistent with the presence of multiple pesticide residues or related chemical substances. The variation in retention times and peak intensities highlights the complexity of the sample and suggests differential physicochemical properties among the detected compounds.

Table 1 presents only xenobiotics/contaminants and potentially harmful thermal products detected (Concentration %) across all preparation methods (A-H). Natural plant metabolites and harmless volatiles have been excluded.

Table 1 above summarizes all compounds identified as xenobiotics, contaminants, or potentially harmful thermal products. These compounds were detected across various bean preparation methods (A-H). The retention time (RT) values confirm consistency of identification across samples, while concentration (Conc, %) represents the relative abundance based on GC-MS peak area normalization. The comparative GC–MS analysis of *Phaseolus vulgaris* processed using eight domestic preparation methods revealed notable differences in the persistence and distribution of xenobiotic compounds as shown in Tables 1 and 2. These variations were largely influenced by pre-soaking, boiling duration and the handling of the cooking filtrate. Across all treatments, residues belonging to organosulfur, organochlorine and phthalate-based chemical classes were predominant.

The most frequently detected contaminants included di-(2-ethylhexyl) phthalate, 1-octadecanesulphonyl chloride, 2-piperidinone N-[4-bromo-n-butyl], n-hexadecanoic acid derivatives, 1-chlorooctadecane and several carbonic acid esters.

The comparatively higher proportion of 2-piperidinone N-[4-bromo-n-butyl] observed in samples B (6.76%), D (0.31%), E (0.79%) and G (1.71%) likely reflects a brominated degradation product of carbamate or organonitrogen pesticides. Brominated amides and alkylamines are thermally stable and can undergo condensation to yield mutagenic intermediates[14]. It also indicates possible thermal formation or partial transformation of nitrogen-containing pesticide residues above trace levels (<0.1%), under moist-heat conditions. Similar concentrations have been associated with hepatic enzyme induction, oxidative stress and DNA damage in experimental models[15].

Among the processed beans samples, A, B and E, which retained their soaking or cooking filtrate, contained 14, 11 and 7 compounds, respectively. Samples C and D, where the liquid phase was discarded or evaporated, showed fewer detected species (7 and 10 compounds), indicating that removal of the aqueous medium reduces the retention of soluble contaminants. This trend is reinforced by the exceptionally high burden observed in the cooked filtrate (F), which contained 21 xenobiotics and 4 thermal products. The raw samples showed moderate diversity, with ground raw

Table 2: Xenobiotic and thermal-derived contaminant matrix

Compound	A	B	C	D	E	F	G	H
Halogenated & persistent contaminants								
Pentadecafluorooctanoic acid, octadecyl ester (PFAS)	0.64	0	0	0	0	0	0	0
1-[p-Bromophenyl]-4-nitro-1,3-butadiene	25.15	0	0	0	0	0	0	0
5-Bromo-4 -chlorosalicylanilide	0	0	0	0	0	0	8.05	0
1-Iodo-2-methylundecane	0	0	0	0	0	1.02	0	0
Eicosane, 1-iodo-	0	0	0	0	0	0	0	9.42
Nitrogen-containing toxicants								
4-Dibenzofuranamine	0	0	35.46	21.93	0	0	0	0
2-Dibenzofuranamine	0	0	0	9.88	0	0	0	0
Piperidine, 3-methyl-	0	0	0	0	0	0	0	8.10
Imidosulfurous difluoride, methyl-	0	0	0	0	0	0	0	8.10
Fenproporex	0.85	0	0	0	0	0	0	0
Sulfur-containing/Chlorinated residues								
Sulfurous acid	7.27	0	0	0	0	0	0	0
Sulfurous acid, 2-propyl undecyl ester	1.35	0	0	0	0	6.33	0	0
Sulfurous acid, dodecyl 2-propyl ester	0	0	0	0.57	0	0	0	0
1-Chlorooctadecane	0	3.09	0	0	0	3.41	4.83	0
Heptacosane, 1-chloro-	0	0	0	0	0	6.33	0	0
Thermal processing products †								
Carbonic acid, eicosyl vinyl ester	0	3.55	0	27.45	1.02	0	0	0
Carbonic acid, octadecyl vinyl ester	0	0	0	0	0	3.60	0	0
Carbonic acid, hexadecyl prop-1-en-2-yl ester	0	0	0	0	0	0	0	9.42
Carbonic acid, tridecyl vinyl ester	0.76	3.09	0	0	0	0	0	0
Aromatic hydrocarbons								
Benzene	0.74	0	0	0	0	0	0	0
Bibenzyl	0.74	0	0	0	0	0	0	0
Benzo[h]quinoline, 2,4-dimethyl-	0	0	0	0	0	0.61	0	0

beans (G) containing 7 xenobiotics and 3 thermal products and the raw soaking filtrate (H) containing 11 xenobiotics. The lowest overall counts were found in samples C and E, further supporting the interpretation that discarding or minimizing the liquid phase limits xenobiotic retention.

1-Octadecanesulphonyl was detected in the cooked filtrate (F, 0.37%) as well as in ground raw beans (G, 4.83%) and raw soaking filtrate (H, 2.02%), indicating its presence in both raw and processed matrices. The markedly higher abundance in the raw samples suggests partial loss or dilution during cooking, while its persistence in the filtrate demonstrates chemical stability under thermal processing. These findings are consistent with previous reports indicating that sulfonyl chlorides resist hydrolysis and can persist as organosulfonate intermediates[16], supporting the observation that 1-Octadecanesulphonyl may remain in edible beans despite domestic cooking procedures.

Several carbonic acid esters were identified in processed and raw bean samples. Specifically, carbonic acid eicosyl vinyl ester occurred in B (3.55%), D (0.26%), E (27.4%) and F (1.02%), carbonic acid octadecyl prop-1-en-2-yl ester appeared in B (3.55%) and G (4.04%) and carbonic acid tridecyl vinyl ester was detected in A (0.76%) and B (3.09%). These compounds were predominantly detected in boiled samples, with minimal presence in raw beans or filtrates, suggesting that thermal processing likely promotes their formation. The notably high abundance of eicosyl vinyl ester in sample E, where the soaking filtrate was retained throughout cooking, suggests that liquid retention may facilitate the accumulation of these esterified products. These observations align with general findings that cooking and heat treatments do not always eliminate pesticide residues, but in some cases lead to persistence, partitioning, or transformation depending on compound properties and processing conditions[17-19]. Given the plausible chemical pathways under heat, the data support the hypothesis of esterification between native fatty acids and pesticide-derived alcohols during heating, in line with transesterification reactions described in chemical processing contexts[20]. The variation in compound distribution across raw, soaked and boiled beans underscores the influence of both matrix composition and processing method on contaminant fate.

The halogenated compound, 1-Chlorooctadecane, listed as an active chemical in pesticide-related industry sectors according to the EPA TSCA Chemical Data Reporting, was detected in samples B (3.09%), F (3.41%) and G (4.83%). Its presence in both raw and processed samples indicates persistence through domestic processing. Halogenated compounds are known to induce oxidative stress and alter lipid metabolism in plants and human cells[21,22], suggesting potential toxicological relevance. The comparatively higher levels in filtrate-retained samples (B, F) suggest that liquid

retention during boiling may favor persistence or redistribution of these compounds, consistent with the behavior of water-soluble xenobiotics in processed beans.

Sample D, which was subjected to dry boiling until complete filtrate evaporation, showed the lowest number of detectable polar residues but a clear dominance of semi-volatile aromatic compounds, including 4-nitrophenyl laurate (11.12%), 4-dibenzofuranamine (21.93%) and 2-dibenzofuranamine (9.88%). The formation of these compounds could result from thermal rearrangement or Maillard-type condensation reactions between residual pesticides and native bean constituents under dry-heat conditions[23]. Although Sample D recorded the highest total xenobiotic peak area, this likely reflects a smaller number of compounds at higher concentrations rather than indicating extensive contamination. This indicates that pre-soaking and filtrate disposal effectively reduce xenobiotic intake, similar to Anaemene *et al.*[24], who reported up to 85% pesticide reduction in soaked Vigna unguiculata seeds compared to raw and unsoaked controls.

In contrast, Sample F, representing the filtrate of boiled beans, contained the highest number of detected residues (25), although many occurred at relatively low abundances (<1%), with a few compounds reaching higher relative concentrations (up to 6.33%). This pattern indicates that soluble xenobiotics preferentially partition into the aqueous phase during boiling, supporting the conclusion that removing the filtrate during cooking reduces contaminant retention in the edible portion. The persistence of phthalates and carbonic acid derivatives in the filtrate highlights potential environmental risks if such cooking effluents are discharged untreated.

The results show that discarding the soaking or cooking filtrate, as practiced in Samples C and D, is the most effective method for reducing overall xenobiotic residues in the edible portion of domestically prepared beans. In contrast, filtrate-retained methods (A, B and E) showed higher xenobiotic diversity, emphasizing the role of filtrate removal in lowering contaminant exposure. The persistence of chlorinated derivatives even after prolonged boiling underscores their chemical stability and potential dietary risk. Phthalates are recognized endocrine disruptors associated with reproductive toxicity and metabolic syndrome[25,26].

Soaking followed by boiling with filtrate discard, as represented by Sample C, therefore provides the most balanced approach to decontamination, effectively reducing both lipophilic and water-soluble xenobiotics while minimizing thermal degradation by-products. These findings have clear public health relevance, offering practical guidance to reduce dietary exposure to persistent pesticide residues.

Although quantification was based on relative GC-MS peak areas rather than absolute concentrations, this semi-quantitative approach reliably captures comparative residue distribution among domestic preparation methods, consistent with AOAC guidelines.

CONCLUSION

This study demonstrated that domestic preparation methods markedly influence the persistence and transformation of xenobiotic and pesticide residues in *Phaseolus vulgaris*. Retaining cooking or soaking filtrate, as seen in samples A, B and E, resulted in higher residue levels, whereas discarding the filtrate (samples C and D) effectively reduced both the number and concentration of contaminants. Persistent compounds such as di-(2-ethylhexyl) phthalate, 1-octadecanesulphonyl chloride and chlorinated hydrocarbons were most prominent in filtrate-retained samples, reflecting their lipophilic and thermally stable nature.

The study revealed that soaking followed by discarding the cooking filtrate is the most effective practical method to reduce xenobiotic residues in beans. This practice is recommended for households and food vendors to minimize dietary exposure to persistent contaminants.

SIGNIFICANCE STATEMENT

This study demonstrates that simple household preparation methods significantly alter pesticide-derived xenobiotic residues in Phaseolus vulgaris. Soaking followed by filtrate discard reduced residue diversity from 14 to 7 compounds, while filtrate retention increased persistence of halogenated and thermally stable compounds. These findings provide practical, evidence-based guidance for consumers to minimize dietary exposure and highlight the importance of optimizing domestic processing techniques.

REFERENCES

1. LISCIANI, S., S. Marconi, C. le Donne, E. Camilli and A. Aguzzi *et al.*, 2024. Legumes and common beans in sustainable diets: Nutritional quality, environmental benefits, spread and use in food preparations. Front. Nutr., Vol. 11. 10.3389/fnut.2024.1385232.
2. Uebersax, M.A., K.A. Cichy, F.E. Gomez, T.G. Porch and J. Heitholt *et al.*, 2023. Dry beans (*Phaseolus vulgaris* L.) as a vital component of sustainable agriculture and food security-a review. Legume Sci., Vol. 5. 10.1002/leg3.155.

3. Mostafalou, S. and M. Abdollahi, 2017. Pesticides: An update of human exposure and toxicity. Arch. Toxicol., 91: 549-599.
4. Yigit, N. and Y.S. Velioglu, 2020. Effects of processing and storage on pesticide residues in foods. Crit. Rev. Food Sci. Nutr., 60: 3622-3641.
5. Marican, A. and E.F. Durán-Lara, 2017. A review on pesticide removal through different processes. Environ. Sci. Pollut. Res., 25: 2051-2064.
6. Kalu, S.N., C.O. Ujowundu, A.A. Emejulu, F.N. Ujowundu, V.A. Onwuliri, T.O. Ukwueze and M.A. Akpaki, 2023. Risk assessment of residual pesticides of *Phaseolus vulgaris* L. consumed in Port Harcourt, Rivers State, Nigeria. Annu. Res. Rev. Biol., 38: 1-10.
7. Galani, J., M. Houbraken, A. Wumbei, J. Djeugap, D. Fotio and P. Spanoghe, 2018. Evaluation of 99 pesticide residues in major agricultural products from the western highlands zone of cameroon using QuEChERS method extraction and LC-MS/MS and GC-ECD analyses. Foods, Vol. 7. 10.3390/foods7110184.
8. Wainaina, I., E. Wafula, D. Sila, C. Kyomugasho, T. Grauwet, A. van Loey and M. Hendrickx, 2021. Thermal treatment of common beans (*Phaseolus vulgaris* L.): Factors determining cooking time and its consequences for sensory and nutritional quality. Compr. Rev. Food Sci. Food Saf., 20: 3690-3718.
9. Varela-Martínez, D.A., J. González-Sálamo, M.Á. González-Curbelo and J. Hernández-Borges, 2020. Quick, Easy, Cheap, Effective, Rugged, and Safe (QuEChERS) Extraction. In: Liquid-Phase Extraction, Poole, C.F. (Ed.), Elsevier, Amsterdam, Netherlands, ISBN: 978-0-12-816911-7, pp: 399-437.
10. Rahman, M., A.M. Abd El-Aty, S.W. Kim, S.C. Shin, H.C. Shin and J.H. Shim, 2017. Quick, easy, cheap, effective, rugged and safe sample preparation approach for pesticide residue analysis using traditional detectors in chromatography: A review. J. Sep. Sci., 40: 203-212.
11. Li, X., F.L. Dorman, P.A. Helm, S. Kleywegt, A. Simpson, M.J. Simpson and K.J. Jobst, 2021. Nontargeted screening using gas chromatography-atmospheric pressure ionization mass spectrometry: Recent trends and emerging potential. Molecules, Vol. 26. 10.3390/molecules26226911.
12. Termopoli, V., G. Famiglini, P. Palma, M. Piergiovanni and P. Rocio-Bautista *et al*., 2019. Evaluation of a liquid electron ionization liquid chromatography-mass spectrometry interface. J. Chromatogr. A, 1591: 120-130.
13. Latimer Jr., G.W., 2023. Official Methods of Analysis of AOAC International. 22nd Edn., AOAC International, New York, USA., ISBN: 9780197610145.
14. Mnif, W., A.I.H. Hassine, A. Bouaziz, A. Bartegi, O. Thomas and B. Roig, 2011. Effect of endocrine disruptor pesticides: A review. Int. J. Environ. Res. Public Health, 8: 2265-2303.
15. Billieux, J., P. Maurage, O. Lopez-Fernandez, D.J. Kuss and M.D. Griffiths, 2015. Can disordered mobile phone use be considered a behavioral addiction? An update on current evidence and a comprehensive model for future research. Curr. Addict. Rep., 2: 156-162.
16. Chen, D., G. Hao and B. Song, 2022. Finding the missing property concepts in pesticide-likeness. J. Agric. Food Chem., 70: 10090-10099.
17. Keikotlhaile, B.M., P. Spanoghe and W. Steurbaut, 2010. Effects of food processing on pesticide residues in fruits and vegetables: A meta-analysis approach. Food Chem. Toxicol., 48: 1-6.
18. Bajwa, U. and K.S. Sandhu, 2014. Effect of handling and processing on pesticide residues in food-a review. J. Food Sci. Technol., 51: 201-220.
19. Phopin, K., S. Wanwimolruk, C. Norkaew, J. Buddhaprom and C. Isarankura-Na-Ayudhya, 2022. Boiling, blanching, and stir-frying markedly reduce pesticide residues in vegetables. Foods, Vol. 11. 10.3390/foods11101463.
20. Naseef, H.H. and R.H. Tulaimat, 2025. Transesterification and esterification for biodiesel production: A comprehensive review of catalysts and palm oil feedstocks. Energy Convers. Manage.: X, Vol. 26. 10.1016/j.ecmx.2025.100931.
21. Akande, B., O. Fatoki, J. Odendaal, J. Marnewick and P. Ndakidemi, 2016. The halogen effects of disinfectant by-products on nutrient concentration, oxidative stress, fatty acids and α-tocopherol concentrations in membrane lipids of two *Solanum lycopersicum* cultivars. Theor. Exp. Plant Physiol., 28: 255-271.
22. Yang, L., Z. Jiang, L. Yang, W. Zheng and Y. Chen *et al*., 2024. Disinfection byproducts of haloacetaldehydes disrupt hepatic lipid metabolism and induce lipotoxicity in high-fat culture conditions. Environ. Sci. Technol., 58: 12356-12367.
23. Wang, J., X. Weng, S. Liu, H. Zhang and Q. Zhu *et al*., 2023. Occurrence, fate, and reduction measures of phthalates in the cooking process: A review. Environ. Health, 1: 300-314.
24. Anaemene, D., D. Nwude, F. Bamson and C. Udenigwe, 2025. Effects of processing methods on pesticide residue contents and proximate composition of cowpea (*Vigna unguiculata*) seeds. Food Humanity, Vol. 4. 10.1016/j.foohum.2024.100483.
25. Dubey, P., S.Y. Reddy, V. Singh, T. Shi, M. Coltharp, D. Clegg and A.K. Dwivedi, 2022. Association of exposure to phthalate metabolites with sex hormones, obesity, and metabolic syndrome in US women. JAMA Netw Open, Vol. 5. 10.1001/jamanetworkopen.2022.33088.
26. Haverinen, E., M.F. Fernandez, V. Mustieles and H. Tolonen, 2021. Metabolic syndrome and endocrine disrupting chemicals: An overview of exposure and health effects. Int. J. Environ. Res. Public Health, Vol. 18. 10.3390/ijerph182413047.