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Comparative Analysis of Phthalates Migration into Mayonnaise and Mustard Sauce from Polyethylene Terephthalate (PET) Containers

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ABSTRACT: The use of sauces packaged in Polyethylene terephthalate (PET) bottles is widespread in households, restaurants, and fast-food establishments. This research focuses on comparing the migration of phthalates from PET bottles into mayonnaise and mustard sauces, adhering to guidelines set forth by the British Standard, European Union (EU) Commission Regulations, and the FDA. The study employed food simulants and PET bottle samples directly sourced from production lines to measure the Overall Migration Limit (OML). In this investigation, the presence of five types of phthalates, namely DEHP, DBP, BBP, DINP, and DIOP were analyzed in PET bottles used for packaging these sauces. The OML levels in the PET bottle samples for both mayonnaise and mustard sauces were significantly below the EU regulation limit. Only DIOP was detected in the PET bottles used for mayonnaise sauce. For mustard sauce, both DEHP and DIOP were detected simultaneously. The levels of DIOP in mayonnaise and mustard sauces were well below the EU's specified SML. However, DEHP levels in mustard sauce slightly exceeded the specified SML value. The ratio of migrant milligrams per kilogram of sauce and the migration percentage of phthalates were calculated, providing a comprehensive analysis of phthalate migration dynamics. These results underscore the importance of continuous monitoring and stringent compliance with regulatory guidelines to ensure the safety of PET-packaged food products.

Keywords: *Mayonnaise, Migration, Mustard Sauce, Phthalates, Plasticizer, Polyethylene terephthalate*

Introduction

Packaging is widespread and necessary in modern day life. It improves, and safeguards the products from the stage of processing and manufacturing to the final consumer through storage and handling (Robertson, 2013). The packaging industry is the largest end-user industry, as it has the highest market share, primarily due to its applications in the food and beverage sectors, where it is used in bottles, jars, and containers (Mordorintelligence, 2023). Polyethylene terephthalate, usually abbreviated as PET, PETE, is one of the most widespread thermoplastic polymers. It is a popular choice for the safe packaging of food items in the food and beverage industry due to its exceptional

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physical and chemical properties (Nisticò, 2020; fnfresearch, 2023; Joseph *et al.*, 2024; Askar *et al.*, 2023; Conroy & Zhang, 2024). This poylmer was patented in 1941 and is currently owned by DuPont Teijin Films (fnfresearch, 2023). It has recently become the third most commonly used plastic in the packaging industry, and its demand continues to rise (Nisticò, 2020).

This indicates it is readily reprocessable at high temperatures. It is colourless and can be either semitransparent (if it is semicrystalline) or transparent (if it is amorphous). It is a noteworthy feature because it facilitates consumers to observe the contents of the container (Nisticò, 2020; fnfresearch, 2023). The demand for the plastic packaging industry is being driven by the growth prospects of end-user segments, including fast-moving consumer goods (FMCG), food and beverages, pharmaceuticals, and others (Figure 1) (mordorintelligence, 2023).

In 2021, the global market for polyethylene terephthalate (PET) was reported to be $37.25 billion. With a compound annual growth rate (CAGR) of approximately 10% from 2022 to 2030, it is expected that the market will reach $41 billion by 2030 (fnfresearch, 2023).

Interactions between the product and the packaging material is one of the most essential and extensively investigated fields of food packaging. These interactions can be categorised into three primary forms:

- Migration (the transfer of mass from packaging components to food)
- Absorption/Scalping (mass transfer of food constituents to packaging)
- Permeation (water vapor or oxygen transfer through plastic packaging to food) (Oromiehie, 2009; Hosseini *et al.*, 2016).

Plastic-forming monomers and additives (such as softeners, plasticisers, and antioxidants) penetrate the material in contact with them from the polymer structure during the migration process. This process leads to a variety of safety-related concerns, as numerous of these migrating compounds are toxicologically harmful and deleterious to the consumer's health (Oromiehie, 2009). The specific migration of plasticisers to food or food simulants has been the subject of numerous investigations. As of June 2017, Figure 2 illustrates the number of sources available regarding the migration of each plasticiser family into food (Nerin *et al.*, 2018).

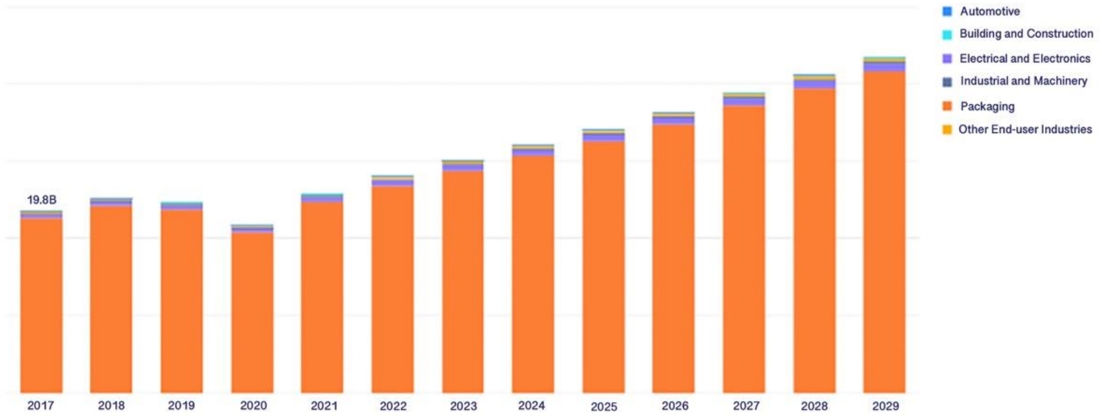

Fig. 1. Global Polyethylene Terphthalate (PET) market, by end user industry, value, USD, 2017-2029 (Mordorintelligence, 2023)

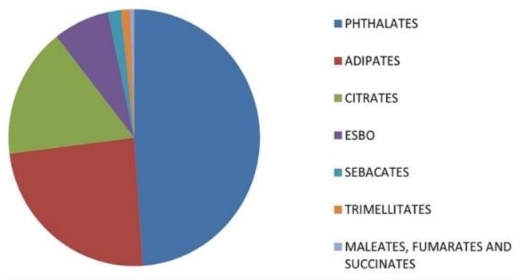

Fig. 2. Number of bibliographic references of each plasticizer family (Nerin et al., 2018)

It is clear that phthalates have been the subject of extensive research, with a total of 203 sources. Their importance originates not only from their abundance but also from their detrimental impacts on the health of both humans and animals. Phthalates account for more than 80% of the production of plasticizers due to their excellent plasticizing properties at low cost (Nerin *et al*., 2018).

Phthalates, or phthalic acid esters, are synthetic organic chemicals that were first introduced in the 1920s (Nerin *et al*., 2018). Figure 3 (R and R' = CnH2n+1) (SHEETS, 2007; Fan *et al*., 2017) illustrates the general chemical structure of phthalates:

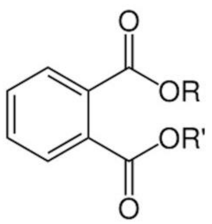

Fig. 3. Chemical structure of PAEs
(R_1 and R_2 represent the alkane or aromatic hydrocarbon group) (SHEETS, 2007; Fan et al., 2017)

Phthalates are widely used in various applications, such as food packaging, printing inks, pharmaceuticals, films, coatings, regenerated cellulose layers, paper-aluminium foil sheets, sealed bottles, paints, aroma preservation, nutritional supplements, glues, and adhesives (Heudorf *et al*., 2007; Gao *et al*., 2013; X.-L. Cao *et al*., 2015; Harunarashid *et al*., 2017; Kiani *et al*., 2018). The free mobile phase of phthalates, which are not chemically bound to plastic materials, has the potential to migrate, leak, or evaporate in a variety of environments, including the open air, indoor air, atmosphere, drinking water, food, soil, personal care, cosmetics, and other materials (Heudorf *et al*., 2007; Fan *et al*., 2017; Taghilou & Hosseini, 2015). These compounds may be released from soft plastic over time into the environment or in the food products (Gao *et al*., 2013; X.-L. Cao *et al*., 2015; Liu *et al*., 2020). The structures and characteristics of phthalates that are typically investigated in food and food packaging materials are summarised in Table 1 (Cao, 2010; CPSC, 2010; CPSC, 2011; IARC, 2013; NICNAS, 2014; NICNAS, 2015; ECHA, 2013; ECHA, 2014; Pubchem, 2024).

Food is the primary source of human exposure to phthalates, despite the fact that consumer products and other domestic appliances are the most significant sources of phthalate exeposure (Heudorf *et al*., 2007; Harunarashid *et al*., 2017). Consequently, it is advantageous to monitor the concentrations of phthalates in a variety of materials in order to evaluate human exposure (Cao, 2010). The presence of phthalates in food contact materials, including packaging materials,

Table 1. The structures and characteristics of phthalates (Cao, 2010; CPSC, 2010; CPSC, 2011; IARC, 2013; NICNAS, 2014; NICNAS, 2015; ECHA, 2013; ECHA, 2014; Pubchem, 2024)

Phthalates	CAS Number	Formula	Fw	Density (g/mL) (25 °C)	b.p. (°C)	m.p. (°C)	Vapor Pressure (Pa)	Water solubility (mg/L)	Log K_{ow}
Dimethyl phthalate (DMP)	131-11-3	$C_{10}H_{10}O_4$	194.19	1.19	283.7	2	0.41	2800-4300	1.6
Diethyl phthalate (DEP)	84-66-2	$C_{12}H_{14}O_4$	222.4	1.12	298	-3	0.279	1000	2.21-3.27
Dipropyl phthalate (DPP)	131-16-8	$C_{14}H_{18}O_4$	250.29	1.078	303.8-305 (760mmHg)	-31	1.75×10^{-2}	108.1 (20 °C)	3.4
Di-iso-butyl phthalate (DIBP)	84-69-5	$C_{16}H_{22}O_4$	278.35	1.039	327	-64	634.61	0.01	4.27
Di-n-butyl phthalate (DBP)	84-74-2	$C_{16}H_{22}O_4$	278.35	1.045 (20 °C)	340	-35	4.73×10^{-3}	11.2	4.27
Butyl benzyl phthalate (BBP)	85-68-7	$C_{19}H_{20}O_4$	312.4	1.119	370	<-35	0.00112	3.8	4.84
Dicyclohexyl phthalate (DCHP)	84-61-7	$C_{20}H_{26}O_4$	330.4	1.383	222 to 228 (0.5 kPa)	66	13.3 (150 °C)	4.0 (24 °C)	3-4
Di-n-hexyl phthalate (DHP)	84-75-3	$C_{20}H_{30}O_4$	334.46	1.011	350	-27.4	3.45×10^{-4}	0.159	6
Di-2-ethylhexyl phthalate (DEHP)	117-81-7	$C_{24}H_{38}O_4$	390.56	0.981	384	-55	0.0255 (KPa)	0.27	7.73
Di-n-octyl phthalate (DOP)	117-84-0	$C_{24}H_{38}O_4$	390.6	0.985	390	-25	189.32	2.49×10^{-3}	7.73
Di-iso-octyl phthalate (DIOP)	27554-26-3	$C_{24}H_{38}O_4$	390.6	0.983	370 / 230 (0.53 kPa)	-45	1330 (200 °C)	0.27	8.39
Di-iso-nonyl phthalate (DINP)	68515-48-0; 28553-12-0	$C_{26}H_{42}O_4$	418.6	0.972	370	-48	0.0547	<0.001	9.37
Di-iso-decyl phthalate (DIDP)	68515-49-1; 26761-40-0	$C_{28}H_{46}O_4$	446.7	0.966	>400	-50	5.1×10^{-5}	1.19	9.46

food processing machinery, and contaminated food and beverages, is suspected to be the primary cause of this exposure. Phthalates are typically found in fatty and acidic environments (Anggarkasih *et al*., 2018), and their solubility in water is limited (Sungur *et al*., 2015).

Mayonnaise is an emulsion of oil droplets in water, despite the fact that the oil concentration is often more than 80% (Featherstone, 2015; Morley, 2016). The compositional standards vary widely, but there is joint agreement on the critical ingredients of vegetable oil, acidifying agents, and egg components (Morley, 2016).

Mustard sauce is typically made by combining ground, defatted mustard seeds with water, vinegar, salt, oil, and other seasonings to form a slurry (Garcıa-Casal *et al*., 2016).

The migration of additives and degradable products from plastic packaging materials to food in mixed-use environments has become a global issue as a result of the excessive human exposure to these toxic pollutants. It is imperative to identify the migration of additives in various conditions and to thoroughly recognise the interaction between food and packaging in order to guarantee the quality and shelf life of food, as a result of the excessive use of additives in materials (Wang *et al*., 2020).

This study set out to achieve the following objectives: 1) Establishing a practical and appropriate method for measuring the migration rate of phthalates in mustard sauce and mayonnaise in a laboratory setting 2) Examining the migration rate of the phthalates that were evaluated to mayonnaise and mustard sauce in polyethylene terephthalate packaging 3) Examining the impact of pH value and fat content on the quantity of phthalates that migrate from packaging to mayonnaise and mustard sauce at a specific temperature and time. 4) Assessing the suitability of this packaging for the storage of mustard sauce and mayonnaise.

Materials and Methods

- ***Materials***

Polyethylene terephthalate (PET) unfilled bottles used for mayonnaise and mustard sauce were prepared from one of the well-known food industry factories in Iran. The sample bottles were kept at room temperature and away from direct sunlight. Acetic acid and ethanol, used for the preparation of food simulant solutions, were purchased from Merck, Germany. Phthalate’s standards including di(2-ethylhexyl) phthalate (DEHP), dibutyl phthalate (DBP), benzyl butyl phthalate (BBP), diisononyl phthalate (DINP), and diisooctyl phthalate (DIOP) were also obtained from Merck, Germany.

- ***Methods***
- ***Food Simulants Preparation***

Migration tests were conducted using food simulants in accordance with the European Union Commission Regulation No 10/2011 and Regulation No 2020/1245, Directive 2005/84/EC, British Standard EN 1186-1:2002 and 1186-3:2002, and the American Food and Drug Administration (FDA) (British Standard, 2002a; British Standard, 2002b; FDA, 2007; European Commission, 2011a; European Commission, 2020b). This was necessary due to the complexity of the food matrix and the microstructures of packaging materials.

The food simulants were selected as follows:

1. Acidic food simulant: A simulant solution with a pH of 4.5 or less, such as 3% acetic acid, has been

chosen due to the pH of mayonnaise and mustard sauce (4.1 and 3.8, respectively).

2. Fatty food simulants: Olive oil (simulant D2) was selected to test these samples. However, previous studies suggest that the dissolution of DBP in olive oil makes this type of simulant D2 unsuitable for the analysis of DBP residues. Therefore, Anggarkasih *et al*. (2018) suggested that 95% ethanol be employed as a food simulant for fatty food products. In addition, this simulant was the best option to provide acceptable results without temperature restrictions and approved by the European Union and the US Food and Drug Administration (FDA).
3. Fatty-acidic food simulant: an intermediate-natured simulant was also necessary. The most similar state to the combined nature of fatty-acidic foods was determined to be 10% ethanol. This solution has been classified by the US Food and Drug Administration as an acidic-aqueous substance. It may contain either salt, sugar, or both, as well as oil-in-water emulsions with either low or high fat content.

- ***Overall Migration Test***

The migration tests were conducted according to the European Union Commission Regulation No 10/2011 and Regulation No 2020/1245, Directive 2005/84/EC, British Standard EN 1186-1:2002 and 1186-3:2002, and the American Food and Drug Administration (FDA) guidance document, at ambient temperature (24.6 °C) and 40% humidity as follows:

At first, the bottle samples of mayonnaise and mustard sauce were cut into strips with a scale of 10 cm x1 cm x 0.00543 cm and 10 cm x1 cm x 1.026 cm, respectively (Figure 4). Then, the test tubes were filled with three selected food simulants, and the pre-cut pieces of polyethylene terephthalate (PET) bottles were placed in each tube and tightly closed. For each type of food simulant, six test tubes were prepared for mayonnaise and six for mustard sauce PET bottles. Considering 4 repetitions to measure the overall migration test, 1 repetition to measure the number of migrated phthalates by gas chromatography (specific migration test), and 1 for blank simulant. The test tubes were kept at a temperature of 40°C in an oven (Fanazmagostar model CM55) for a period of 10 days before being used for further analysis (Figure 5).

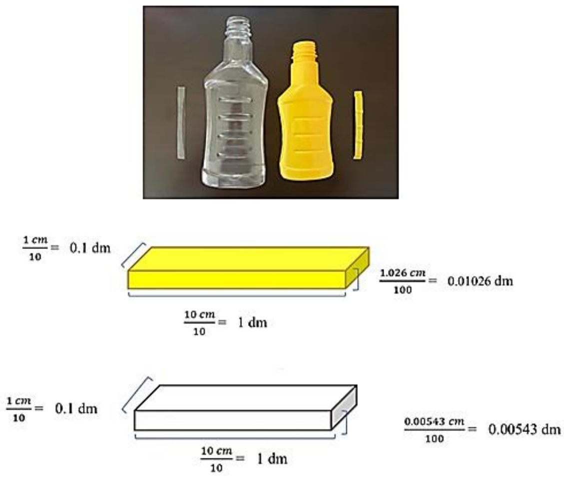

Fig. 4. Pre-cut pieces of PET bottles used for mayonnaise and mustard sauces

The test tubes were taken out from the oven after 10 days, and the overall migration measurement was determined based on four treatments of each food sample. In addition, the contents of each tube were transferred to a pre-weighed beaker. The beakers were then heated to evaporate the food simulants, and subsequently placed in an oven at 70°C for 2 hours to ensure complete drying. Finaly, the beakers were placed in a desiccator for a minimum of 24 hours to reach a constant weight (Figure 5). All 30 beakers were re-weighed and the overall migration was calculated for each treatment according to BS EN 1186-1:2002 and 1186- 3:2002 (British Standard, 2002a, 2002b) through equation 1:

$$M = \frac{(m_a - m_b) \times 1000}{S} \left(\frac{mg}{dm^2}\right) \quad \text{(Eq 1)}$$

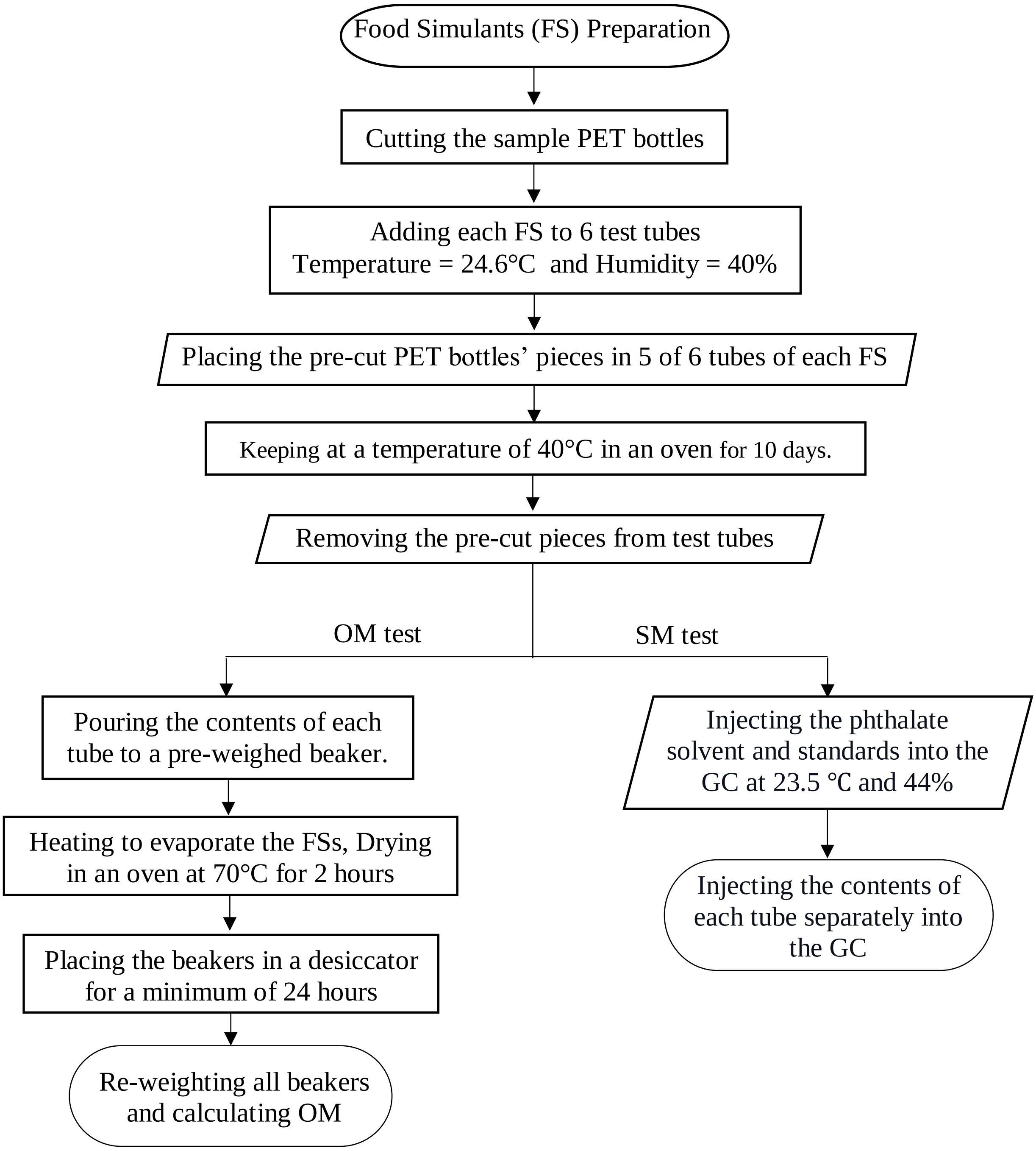

Fig. 5. Step-by -step illustation of overall and specific migration tests for both PET bottle samples of mayonnaise and mustard sauce

Where M represents the overall migration in milligrammes per square decimetre of surface area of the sample, m_a is the mass of the residue from the test specimen after evaporation of the simulant in which it was immersed in grammes, and m_b is the mass of residue from the blank simulant in grammes (British Standard, 2002b).

The final overall migration was calculated using the average of the overall migrations in all of the three food simulants, which was measured separately for each PET pre-cut samples.

- ***Specific Migration Test***

The specific migration tests were accomplished on pre-cut pieces of PET bottle samples as illustrated in Figure 5. The prepared samples were injected in gas chromatography equipped with flame ionization (GC-FID) [Varian CP 3800 (Palo Alto, California, USA), and Agilent capillary column (5 µm × 0.53 mm × 30 m, HP-5), using helium carrier gas with a pressure of 45 psi. The oven temperature was first set at 150 ºC and then increased to 280 ºC at a rate of 5 ºC / min, and finally kept constant for 5 min. The injector and detector temperatures were both set at 300 ºC. The injection mode was split with a split ratio of 1:5, and the injection volume was 1 µl.

- ***Identification and quantification of phthalates in PET bottle samples of mayonnaise and mustard sauce***

The method of Chacon *et al*. 2020 was implemented to quantify and identify the phthalates that migrated from packaging into food simulants. The phthalate solvent was used as a 60:40 mixture of phenol and tetrachloroethane. The test samples of mustard sauce and mayonnaise bottles were first crushed into powder, and then 5 grams of it were poured into a 50 ml volumetric flask, setting the volume by the solvent. The volumetric flask were subsequently heated to a temperature of 40℃ for 2-3 hours to ensure that the phthalates were very readily soluble. This investigation was conducted under a fume hood due to the toxic and hazardous nature of phenol. Finally, the solution was analyzed by the gas chromatography with the same settings as above mentioned (Chacon *et al*., 2020).

Results and Discussion

- ***Pre-cut samples of mayonnaise and mustard sauce' bottles***

According to the dimensions of the pre-cut samples of PET bottles of mayonnaise and mustard sauce, the surface areas calculated were 0.2119 dm² and 0.2226 dm², respectively. Table 2 represent the overall migration results.

Table 2. Overall migration in selected food simulants for mustard sauce and mayonnaise PET samples by total immersion method

PET bottle type	Simulant Type	Overall Migration (mg/dm^2)
Mustard Sauce	95% Ethanol	1.24 ± 0.31
	10% Ethanol	1.65 ± 0.26
	3% Acetic Acid	1.46 ± 0.43
Mayonnaise	95% Ethanol	2.83 ± 0.82
	10% Ethanol	1.18 ± 0.27
	3% Acetic Acid	1.89 ± 0.54

The European Union Commission's regulations, No. 10/2011, pointed out the rule requiring that plastic materials and articles not transfer their constituents to foodstuffs in quantities that exceed 10 milligrammes per square decimetre of the surface area of the materials or articles (overall migration limit) (European Commission, 2011) and the results presented in Table 2 indicate that the overall migration in this study is lower than the limit established by the European Union.

Ashby *et al*. 1988 analysed the impact of varying the surface-to-volume ratio by exposing a biaxially oriented 125-micrometre PET film to 110 cm³ of olive oil as a fatty food simulant at 40°C for 10 days, using contact areas of 1, 2, and 4 dm². The results indicate that there is no significant difference in migration levels. Agiotti *et al*. 2022 analyzed the release of selected non-intentionally added substances (NIAS) from PET food contact materials using 3% acetic acid as an aqueous food simulant at 60°C for 10 days, using a contact area of 4 dm². The amount of overall migration was lower than 0.1 mg/dm2. Satish *et al*. 2013 carried out a study on the migration aspects of food-contact materials using aqueous food-simulating solvents, in accordance with various international standards. A 10% ethanol solution was used as an aqueous food simulant at 40°C for 10 days with a contact area of 5 dm². The amount of overall migration was determined to be 0.38 ± 0.05 mg/dm². Hosseini *et al*. 2016 analyzed the migration of dibutyl phthalate and dimethyl phthalate into rose water packaged in PET containers using 3% acetic acid and 10% ethanol as acidic and aqueous food simulants, respectively, at 4, 25, and 42 °C for 2 days, 2 weeks, and 2 months, using a contact area of 1 dm². 1.1 mg/dm² was the overall migration for aqueous food with a pH greater than 4.5, while 2.3 mg/dm² was the migration for aqueous food with a pH less than 4.5.

Therefore, the overall migration in all four above mentioned investigations is lower than the amounts obtained from the current study (Table 2), and the value approved by the EU Commission regulations, with the exception of the data results from Hosseini *et al*. 2016.

Despite the minor differences in the time and temperature conditions, the values for aqueous food with a pH higher than 4.5 were comparable to our findings for 10% ethanol (food simulant: mayonnaise PET bottle).

- ***Specific migrations from PET bottle samples into food simulants***

The chromatograms for phthalate standard solutions including DEHP, DBP, BBP, DINP, and DIOP are illustrated in Figure 6. The chromatograms for the migration of pre-cut segments into food simulants (3% acetic acid, 10% ethanol, and 95% ethanol) for mayonnaise and mustard sauce are presented in Figures 7 and 8, respectively.

The results show that DEHP and DIOP, as phthalates, migrated from PET bottles of mayonnaise and mustard sauce into food simulants. Table 3 reports the specific migration quantities. The European Union Commission (2011/10) determined a special migration limit of mg/kg (mg/l) for the migrated DIOP, which is much lower

Table 3. The specific migration of phthalates from mustard sauce and mayonnaise PET bottles into food simulants

PET bottle type	Food Simulants	Phthalate compound	Specific Migration (mg/l)
Mustard Sauce	3% Acetic Acid	DEHP	2.4
		DIOP	6.7
	10% Ethanol	DEHP	3.6
		DIOP	3.4
	%95 Ethanol	DIOP	1.3
Mayonnaise	3% Acetic Acid	DIOP	1.7
	10% Ethanol	DIOP	4.8
	%95 Ethanol	DIOP	3.4

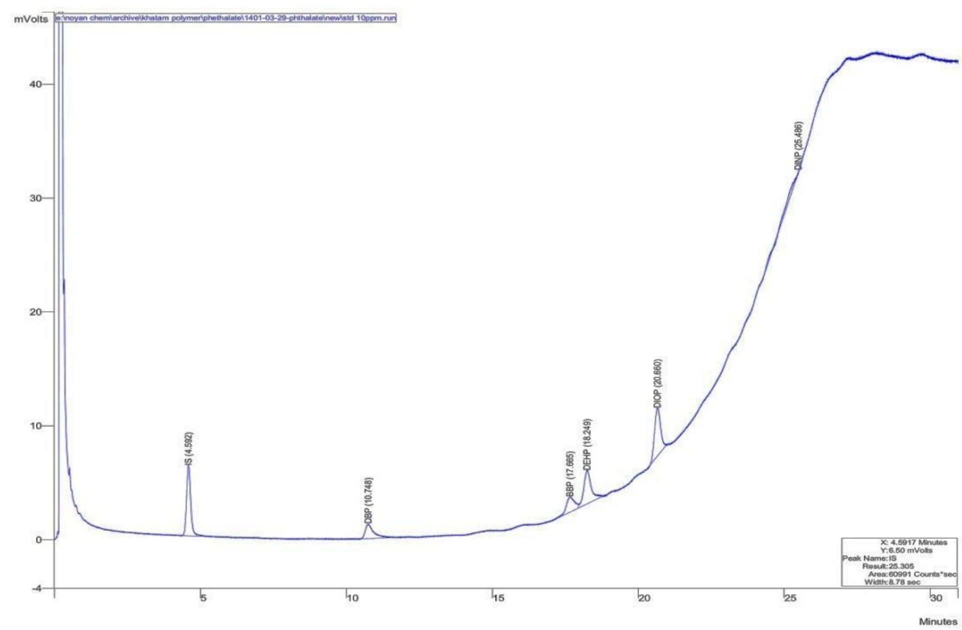

Fig. 6. Gas chromatogram of the examined phthalate standard with following retention times (minutes): DBP = 10.748, BBP = 17.665, DEHP = 18.249, DIOP = 20.660, and DINP = 25.486

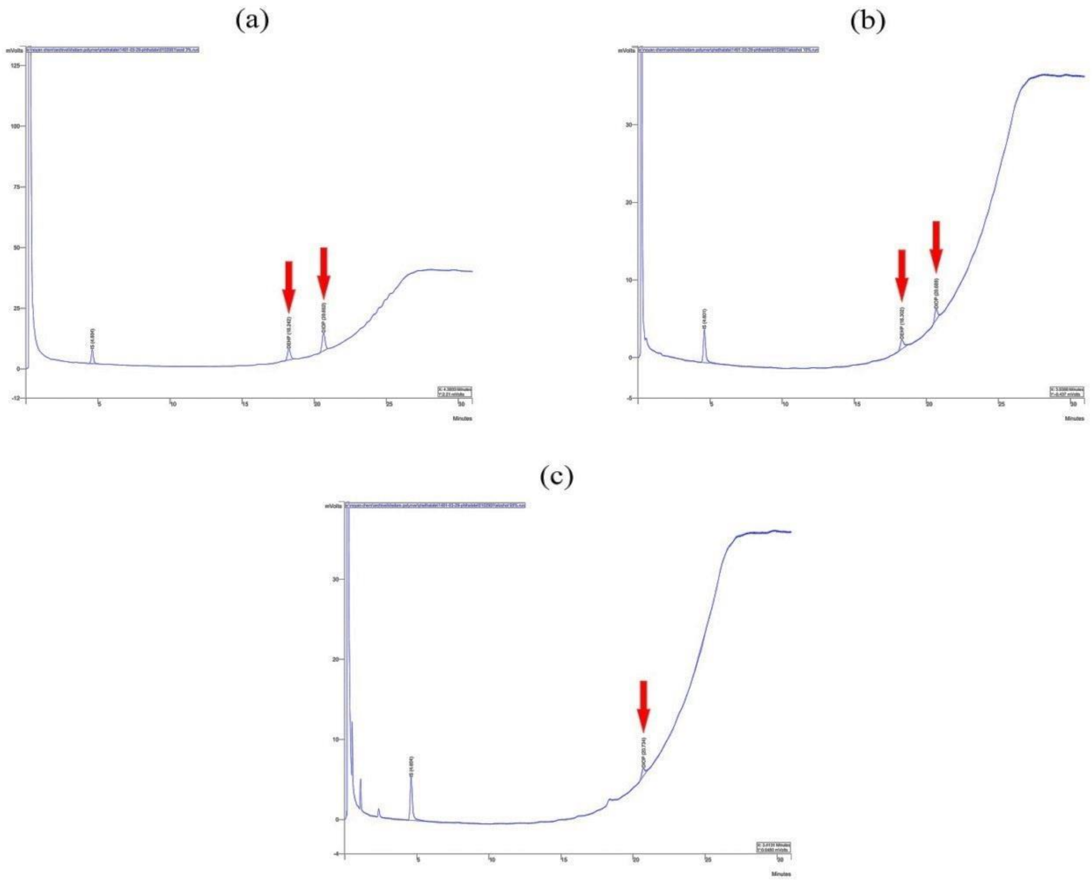

Fig. 7. Identification of phthalates migrated into 3 food simulants including: a) 3% acetic acid, b) 10% ethanol, and c) 95% ethanol from mustard sauce PET bottles

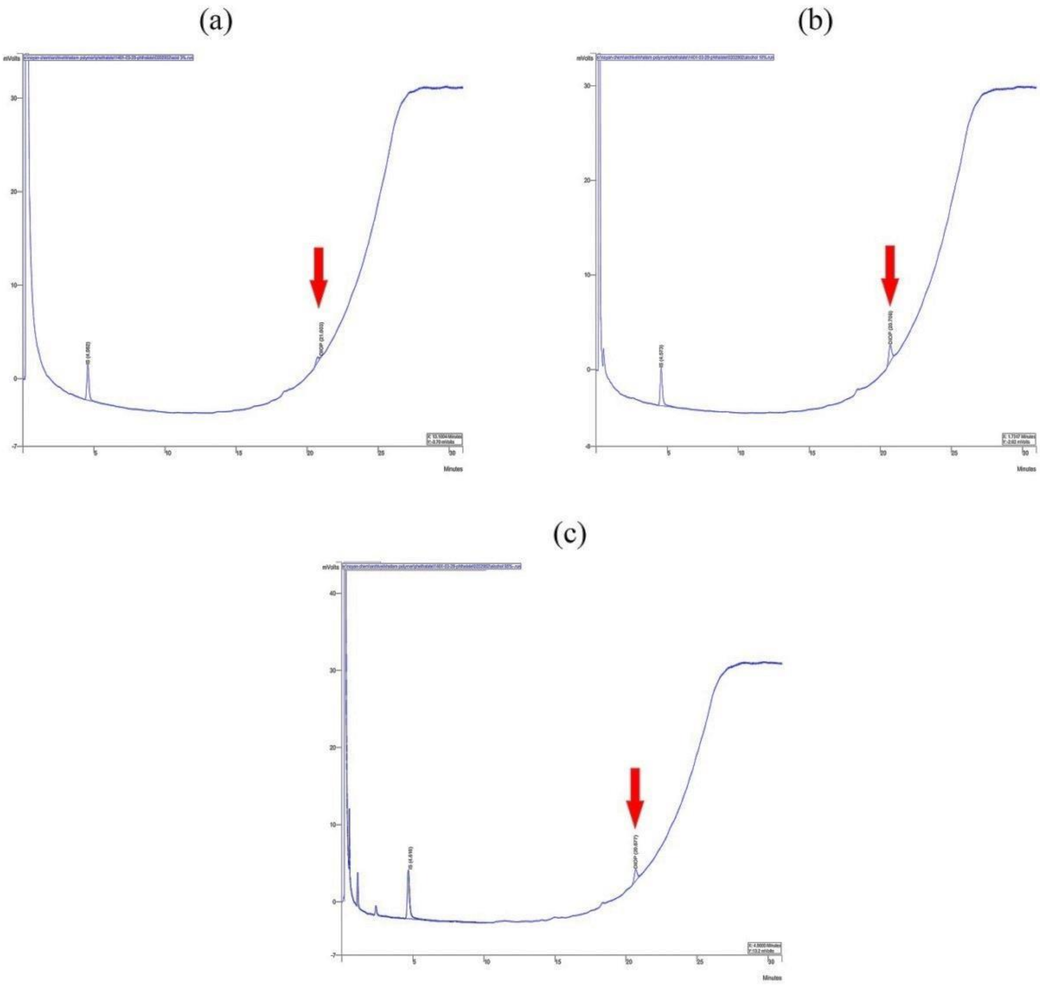

Fig. 8. Identification of phthalates migrated into 3 food simulants including: a) 3% acetic acid, b) 10% ethanol, and c) 95% ethanol from mayonnaise PET bottles

than this limit. However, the value of DEHP is slightly higher than the specified limit of 1.5 mg/kg (mg/l) for this compound, which is identified as the main plasticizer of PET bottles (Mukhopadhyay *et al*. 2022).

- **Identification and quantification of phthalates presented in the PET bottle samples**

Figure 9 illustrate the two chromatograms that were obtained from analyzing the PET bottle samples. The quantity of different phthalate compounds detected in the PET bottle samples, are given in Table 4.

At present, there is no established regulation that governs the permissible level of phthalates in PET containers. The only published investigation to date was the annex of the 2005/84/EC European Union Directive, which specified the permissible level of phthalates in toys and equipment for children. This document encompassed two groups of phthalates: three types DEHP, DBP, and BBP, and DINP, DIDP, and DNOP were mentioned in the first and second groups, respectively, with the maximum level of 0.1% by weight for each group.

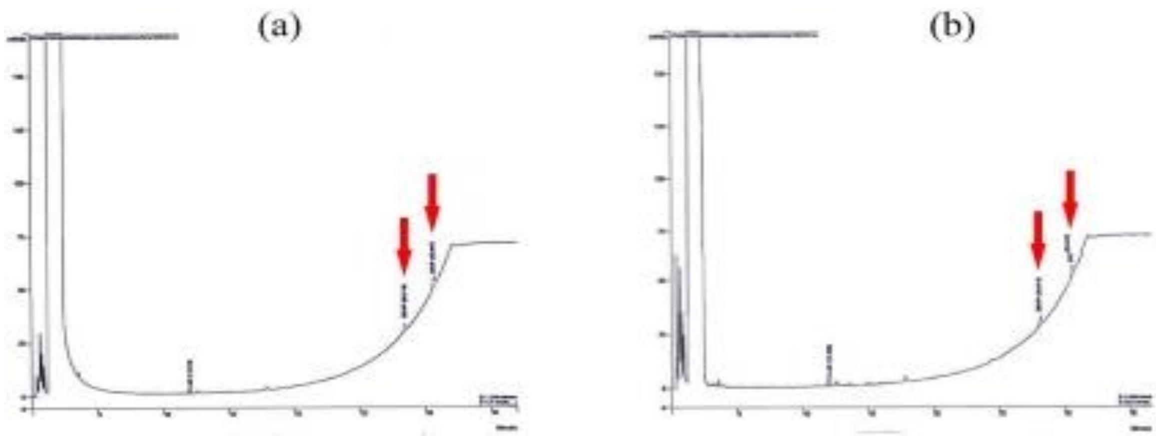

Fig. 9. Identification of the phthalates presented in a) Mustard sauce and b) Mayonnaise PET bottles

DEHP was the only phthalate compound detected in both the mustard sauce and mayonnaise PET bottles with concentrations of 61.3 mg/l (0.00613%) and 49.7 mg/l (0.00497%), respectively (Table 4). Consequently, the quantity of DEHP that was identified in the PET bottle samples is substantially lower than the permissible limit specified in this document.

Table 4. The quantity of phthalates detected in PET bottle samples

PET bottle type	Phthalate type	Phthalate Amount (mg/l)
Mustard Sauce	DEHP	61.3
	DIOP	92.1
Mayonnaise	DEHP	49.7
	DIOP	83.2

- ***The amount (%) of migrated phthalates into food simulants as compared to the quantity presented in the PET bottles***

Table 5 shows the results of making a comparison between the quantity of phthalate compounds potentially presented in PET bottle samples with the values migrated into different food simulants.

The milligram amount of migrants per kilogram of the food simulants can be determined separately for PET bottles of each type of sauce by taking into account the size of the surface area of the PET bottle, the volume of each food sample that is in contact with this surface area, and the overall migration in each food simulant (Table 6).

Conclusion

It may be concluded that:

- Overall migration is significantly less than what the European Union Commission specified.
- The DIOP levels in both sauce were significantly lower than the EU's specific migration limit, while the DEHP level in mustard sauce slightly exceeded it.
- The permissible limit was not exceeded by the levels of DEHP and DIOP that were detected in both PET bottles.

In order to obtain a more precise and exhaustive interpretation of phthalate migration, it is imperative to investigate the solubility of phthalates, as indicated by the findings of this study. The nature and structure of the food matrix, as well as pH, temperature, and time, all have an impact on phthalates during the migration process. Consequently, it is essential to study solubility in the environment where migration takes place. As a result, the solubility of phthalate compounds should be assessed under the appropriate

Table 5. The amount (%) of phthalates migrated to food simulants as compared to the phthalates in the PET bottles

Sauce type	The type and amount of phthalates in polyethylene terephthalate (PET) bottles (mg/l)	The type and amount of phthalates migrated to the food simulants (mg/l)		The ratio of phthalates migrated from packaging to food simulants (%)
Mustard Sauce	DEHP = 61.3	3% Acetic Acid	DEHP = 2.4	DEHP = 3.91
			DIOP = 6.7	DIOP = 7.27
	DIOP = 92.1	10% Ethanol	DEHP = 3.6	DEHP = 5.87
			DIOP = 3.4	DIOP = 3.69
		%95 Ethanol	DIOP = 1.3	DIOP = 1.41
Mayonnaise	DEHP = 49.7	3% Acetic Acid	DIOP = 1.7	DIOP = 2.04
		10% Ethanol	DIOP = 4.8	DIOP = 5.77
	DIOP = 83.2	%95 Ethanol	DIOP = 3.4	DIOP = 4.09

Table 6. The milligram amount of migrants per kilogram of the food simulant

Volume of Simulant / Surface Area	Type of food Simulants	Calculations (mg Migrant/Kg simulant)
Mustard Sauce PET Bottle: 25 cc (Kg) Simulant Surface Area = 0.226 dm^2	3% Acetic Acid	13.19
	10% Ethanol	14.89
	%95 Ethanol	11.17
Mustard Sauce PET Bottle: 25 cc (Kg) Simulant Surface Area = 0.2119 dm^2	3% Acetic Acid	16.00
	10% Ethanol	9.99
	%95 Ethanol	23.99

conditions in order to plan for future advances.

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