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Assessment of Total UV-Absorbing Contaminants in LDPE Food Packaging from Philippine Markets

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Abstract

This study evaluated the migration of total UV-absorbing contaminants (TACs) from commercially available low-density polyethylene (LDPE) bags commonly used by local eateries and street stalls in the Philippines to package fatty and oily foods. Forty-six (46) LDPE samples composing fifteen (15) brands were collected from public markets across Metro Manila and analyzed using a validated UV-Vis spectrophotometric method. Preliminary screening identified samples with low, mid, and high TACs absorbance levels for method validation. The method demonstrated limits of detection (LOD) and quantification (LOQ) of 0.009 and 0.021 AU, respectively, with repeatability and intermediate precision metrics meeting established criteria. Results revealed significant variability in TACs levels across brands and locations with 58.7% of samples exceeding the Philippine Food and Drug Administration's maximum allowable limit of 0.100 AU. The high non-compliance rate highlights possible inconsistencies in material quality and handling practices. These findings underscore the need for stricter regulatory oversight and enhanced quality control measures for LDPE materials used as food packaging. This study provides a reliable method for monitoring TACs migration and offers critical insights for ensuring the safety of food contact materials in the Philippine market, contributing significantly to food protection efforts.

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Abbreviation

AU	absorbance unit
EU	European Union
FCAs	food contact articles
FDA	Food and Drug Administration
FTIR-ATR	Fourier Transform Infrared Spectroscopy - Attenuated Total Reflectance
IAS	intentionally added substances
LDPE	low-density polyethylene
LOD	limit of detection
LOQ	limit of quantification
MAL	maximum allowable limit
NIAS	non-intentionally added substances
PAHs	polycyclic aromatic hydrocarbons
PET	polyethylene terephthalate
PFAS	per- and polyfluoroalkyl substances
RH	relative humidity
RSD	relative standard deviation
TACs	total UV-absorbing contaminants

Introduction

The use of Low-Density Polyethylene (LDPE) plastic food contact articles (FCAs) such as plastic *labo* bags has become a ubiquitous practice in the Philippines.[1] The average Filipino uses 163 plastic *labo* yearly,[2] particularly in the packaging of street food and locally-inspired dishes often sold in eateries called *carinderia*.[3] These plastics are favored for their affordability, transparency, and versatility, enabling convenient storage and transport of a wide variety of products.[4-6]

However, concerns have arisen regarding the use of plastic packaging due to the potential migration of chemical compounds such as unreacted monomers, plasticizers and lubricants from the packaging into the food.[7–11] This migration is influenced by several factors, including the chemical characteristics of the monomers, the type of plastic material, and environmental conditions such as temperature, pH, and the food's composition.[12-14] Contamination of food through packaging can stem not only from intentionally added substances (IAS) but also from non-intentionally added substances (NIAS) such as by-products, impurities, and degradation product.[15-17]

To safeguard public health, regulatory bodies like the Commission on Regulation (EU) and United States Food and Drug Administration (US FDA) have established guidelines to limit the migration of contaminants from packaging materials.[18,19] In the Philippines, FDA Circular No. 2022-0011 specified voluntary testing and compliance with migration limits for packaging materials used for consumable products, particularly for items prone to higher contamination risks such as fatty and oily foods. Meanwhile, previous studies have emphasized the migration of specific contaminants such as bisphenols, phthalates, and PFAS, while relatively few have explored broad-spectrum screening approaches such as the release of total UV-absorbing contaminants (TACs), which can serve as a preliminary rapid indicator of multiple potentially hazardous migrating substances.[20–27] Currently, based on existing studies and to the knowledge of the authors, there are no published studies that determines the total UV-absorbing contaminants in oligomer-based food packaging.

The research aims to address these gaps by profiling the migration of TACs from LDPE plastic bags used in Philippine food settings. By simulating contact with fatty and oily foods and applying a screening-based approach using UV-Vis spectrophotometry, the study offers a relevant and accessible method for assessing packaging-product compatibility. It also provides locally grounded data that contribute to the limited body of research on food contact article safety in the region.

The novelty of this work lies in its contextual relevance—targeting widely used but under-researched packaging materials in the Philippine market—and its application for TACs profiling to assess chemical migration. The findings not only support compliance with regulatory recommendations but also offer actionable insights for manufacturers, regulators, and food vendors seeking to improve food safety. Ultimately, this research contributes to strengthening local food safety standards and informs policy decisions regarding the use of plastic FCAs in the Philippines.

Materials and Methods

Sample Collection and Identification

Unused LDPE plastic bag samples were collected to represent a range of plastic *labo* packaging available in Metro Manila. Different commercial brands were targeted. The sampling was conducted across 16 cities and 1 municipality. Within each location, one public market was purposively selected based on criteria such as high consumer accessibility and volume of food packaging transactions. In each selected market, plastic bag samples were acquired by randomly approaching different vendors or stalls and purchasing the most frequently bought or vendor-recommended plastic bags. This represents the generally used samples. Following collection, all samples were stored in clean, dry containers conditioned at ambient laboratory conditions (25 ± 3°C, 50 ± 10% RH) to prevent environmental contamination or degradation. To verify the polymer type of the collected samples, each was subsequently analyzed using Fourier Transform Infrared Spectroscopy with Attenuated Total Reflectance (FTIR-ATR) (Shimadzu IR-Prestige-21).

Sample Extraction

Each unique brand was tested in duplicate (n = 2). The samples were cut into 5 cm x 10 cm films, wiped with lint-free paper, and placed in separate beakers using tweezers. Approximately 100 mL of n-Heptane was added to each beaker, ensuring total immersion of samples. The beakers were covered with petri dishes and left to stand for 30 minutes at 25 ± 3°C. After extraction, the plastic films were removed using tweezers.

Preliminary Screening of Selected Samples

The extracting solutions were analyzed using Shimadzu UV-1800 UV/Vis Spectrophotometer across the range of 220–360 nm. From these results, samples exhibiting the lowest and highest absorbance values were identified. Additionally, a sample with an absorbance level closest to the maximum allowable limit (MAL) or 0.100 AU (absorbance units) set by FDA Philippines for chemical migrations to fatty and oily food products was selected for method validation.

Method Validation

Limit of Detection (LOD) and Limit of Quantification (LOQ)

To confirm that the method is sensitive enough to reliably detect trace levels of TACs, the method was validated for both the Limit of Detection (LOD) and Limit of Quantification (LOQ). At least ten (10) replicates of the method reagent blanks were analyzed, following the same procedure used for the actual test samples.[28] This was performed under conditions where the reagent blanks produced absorbance readings above 0.000 AU, representing the TACs that migrated from 50 cm² of packaging material. The LOD is determined by adding three times the corrected standard deviation to the average absorbance, while the LOQ adds ten times the corrected standard deviation to the average absorbance.[29]

Repeatability and Intermediate Precision

To evaluate the precision of the method, both repeatability and intermediate precision were assessed. Three (3) representative LDPE samples exhibiting low, mid, and high TACs absorbance values from the survey were selected for this purpose. For repeatability testing, each sample was extracted and analyzed in at least eight (8) replicates by a single analyst under the same experimental conditions and on the same day. The percentage relative standard deviation (%RSD) for each concentration level was calculated to determine the method's precision under repeated conditions.

Intermediate precision was assessed by having two independent analysts perform the same extraction and analysis procedures on the selected samples, using the same instruments and reagents. The absorbance values generated by both analysts were combined, and pooled averages and %RSDs were calculated for each concentration level. These values served as the benchmark for acceptable precision, as established during method validation.

Sample Profiling and Statistical Analysis

After validation, all LDPE samples collected across Metro Manila were tested using the validated method. Each sample was analyzed in triplicate (n = 3) to ensure the reliability and repeatability of results across multiple measurements. Statistical analysis was performed to assess variability and compliance of TACs levels among and within LDPE brands.

Descriptive statistics (mean, median, standard deviation, range, and coefficient of variation) were computed for all brands with more than three (3) samples. Normality of data distribution for each brand was assessed using the Shapiro-Wilk test. For brands with normally distributed data ($p > 0.05$), a one-sample t-test was conducted to evaluate whether mean absorbance values differed significantly from the FDA's maximum allowable limit (0.100 AU). For brands with non-normally distributed data ($p < 0.05$), a Kruskal-Wallis rank sum test was used to determine whether absorbance values varied significantly across sampling locations. These tests were selected to ensure appropriate evaluation of both intra-brand variability and compliance with regulatory thresholds, aligning with the study's objective to assess safety and consistency of LDPE packaging.

Results

Sample Collection and Identification

A total of 46 unused LDPE plastic bags, representing 15 distinct commercial brands, were collected from public markets across the 16 different cities and one (1) municipality of Metro Manila. The locations (in alphabetical order) are Caloocan, Las Piñas, Makati, Malabon, Mandaluyong, Manila, Marikina, Muntinlupa, Navotas, Parañaque, Pasay, Pasig, Pateros (municipality), Quezon City, San Juan, Taguig, and Valenzuela. FTIR-ATR analysis revealed that 100% of the samples are primarily LDPE in composition.

Table 1: Preliminary Screening of TACs from Randomly Selected LDPE Samples

Location	Code		Absorbance (AU)
	Polymer Classification	Brand	
Taguig	LDPE	0001	0.190
Pasig	LDPE	0002	0.246
Valenzuela	LDPE	0003	0.201
Manila	LDPE	0004	0.246
Makati	LDPE	0005	0.179
Quezon City	LDPE	0006	0.096
Malabon	LDPE	0007	0.116
Paranaque	LDPE	0008	0.121
Valenzuela	LDPE	0009	0.044
Caloocan	LDPE	0010	0.130
Muntinlupa	LDPE	0011	0.105
Pasig	LDPE	0012	0.111
Caloocan	LDPE	0013	0.121
Valenzuela	LDPE	0014	0.072
Makati	LDPE	0015	0.250

Preliminary Screening

Approximately a third of the samples (15 out of the 46, and each a different brand) were randomly selected for preliminary screening. The locations, polymer classification and codes, and absorbance values of the initial survey are summarized in Table 1. The sample with the lowest absorbance value was LDPE-0009 from Valenzuela with 0.044 AU, and intended for low level repeatability and intermediate precision. In contrast, LDPE-0015 from Makati produced the highest absorbance value of 0.250 AU, and intended for high level precision measurements. LDPE-0011 from Muntinlupa gave an absorbance value closest to the MAL set by FDA Philippines and was chosen for mid-level repeatability and intermediate precision.

Method Validation

Because the absorbance value of LDPE-0009 during the screening was already above 10% of the MAL set by FDA Philippines, method reagent blanks were used instead to compute the LOD of 0.009 AU. The value is lower than 0.010 AU (10% of 0.100 AU), implying analytical confidence at the regulation's assigned minimum detection value. LOQ, on the other hand, was computed at 0.021 AU, suggesting the minimum absorbance level with acceptable performance.

Table 2 summarizes the calculated %RSDs at three different levels by two different analysts. For both analysts, %RSDs were observed to decrease with increasing absorbance values–a trend similar to the precision tables established by AOAC. The results also indicate that the difference in variation per level is minimal (i.e. 0.60%-3.04%), implying satisfactory repeatability within each analyst, and good precision between analysts across the absorbance range 0.040-0.305 AU.

Table 2: Repeatability of Absorbance Measurements Across Three Levels for Each Analyst

Analyst	Level	Absorbance (AU)	%RSD
Analyst A	Low	0.040 ± 0.005	13.0
	Mid	0.110 ± 0.004	3.85
	High	0.305 ± 0.014	4.50
Analyst B	Low	0.040 ± 0.005	12.4
	Mid	0.104 ± 0.007	6.89
	High	0.282 ± 0.010	3.38

To further verify the method's precision, pooled averages and standard deviations of the absorbance values per level were calculated (Table 3). As with single analyst measurements, data spread was observed to decrease with increasing absorbance levels i.e. 12.7% for 0.040 AU, 5.52% for 0.107 AU, and 3.94% for 0.294. Combining with the average absorbance (0.009 AU) and %RSD (49.4%) of the method reagent blanks used for LOD and LOQ, the acceptable criteria for repeatability of measurements for TACs from LDPE to high-fat low-moisture foods was established (Table 4).

Table 3: Intermediate Precision Across Three Levels for Two Analysts

Level	Absorbance (AU)		Pooled Average (AU)	Pooled %RSD
	Analyst A	Analyst B		
Low	0.040 ± 0.005	0.040 ± 0.005	0.040	12.7
Mid	0.110 ± 0.004	0.104 ± 0.007	0.107	5.52
High	0.305 ± 0.014	0.282 ± 0.010	0.294	3.94

Sample Profiling and Statistical Analysis

The results of testing all 46 LDPE samples using the validated method are summarized in Table 5. The absorbance values ranged from 0.044 AU to 0.229 AU, highlighting a broad distribution of contaminant migration levels among the samples. Meanwhile, the %RSDs ranged from 1.44-11.5% for samples with absorbance values within 0.040 ≤ AU < 0.107, and 0.676-5.09% for samples with absorbance values within 0.107 ≤ AU < 0.294, aligning with the established acceptable criteria for repeatability of measurements.

Table 4: Acceptance Criteria for Repeatability of TACs Migrating from 50 cm^2 LDPE Films to n-Heptane as Fatty and Oily Food Simulant by Single Extraction (25 ± 3 °C for 30 minutes) and Qualitative Spectral Scanning (λ = 220-360 nm, 5 cm path length)

AU / TACs Migrated from 50 cm^2 LDPE	%RSD
0.009 ≤ AU < 0.040	49.4
0.040 ≤ AU < 0.107	12.7
0.107 ≤ AU < 0.294	5.52
0.294 ≤ AU	3.94

Table 5: Average Absorbance Values and %RSDs of TACs from 46 LDPE Samples to n-Heptane

Location	Code		Average Absorbance (AU), n = 3	%RSD
	Polymer Classification	Brand		
Muntinlupa	LDPE	0001	0.063	7.541
Taguig	LDPE	0001	0.111	1.378
Pasig	LDPE	0002	0.050	2.020
Valenzuela	LDPE	0003	0.150	5.086
Manila	LDPE	0004	0.226	0.676
Makati	LDPE	0005	0.136	1.945
Taguig	LDPE	0005	0.146	3.139
Valenzuela	LDPE	0005	0.221	2.569
Las Pinas	LDPE	0006	0.075	4.807
Navotas	LDPE	0006	0.105	6.321
Pasay	LDPE	0006	0.074	4.325
Pateros	LDPE	0006	0.096	2.161
Quezon City	LDPE	0006	0.106	8.688
San Juan	LDPE	0006	0.101	7.356
Valenzuela	LDPE	0006	0.104	4.016
Malabon	LDPE	0007	0.106	1.437
Manila	LDPE	0007	0.133	2.634
Mandaluyong	LDPE	0008	0.145	1.439
Manila	LDPE	0008	0.102	3.162
Marikina	LDPE	0008	0.113	3.695
Paranaque	LDPE	0008	0.114	3.535
Taguig	LDPE	0008	0.128	3.405
Valenzuela	LDPE	0008	0.152	1.003
Valenzuela	LDPE	0009	0.049	9.579
Caloocan	LDPE	0010	0.084	3.623
Las Pinas	LDPE	0010	0.121	2.338
Malabon	LDPE	0010	0.093	5.987
Manila	LDPE	0010	0.044	11.127
Marikina	LDPE	0010	0.098	6.771
Navotas	LDPE	0010	0.097	8.439
Pateros	LDPE	0010	0.124	0.806
Quezon City	LDPE	0010	0.046	11.503

Taguig	LDPE	0010	0.100	9.641
Valenzuela	LDPE	0010	0.120	2.205
Muntinlupa	LDPE	0011	0.103	8.510
Pasig	LDPE	0012	0.110	3.188
Caloocan	LDPE	0013	0.117	3.095
Mandaluyong	LDPE	0013	0.091	10.406
Navotas	LDPE	0013	0.115	3.135
Paranaque	LDPE	0013	0.081	4.354
Pasay	LDPE	0013	0.139	5.087
Taguig	LDPE	0013	0.093	3.763
Navotas	LDPE	0014	0.064	4.134
San Juan	LDPE	0014	0.063	3.974
Valenzuela	LDPE	0014	0.078	3.414
Makati	LDPE	0015	0.229	2.062

Discussion

Comparison with Regulatory Limit

Out of the 46 samples analyzed, 58.7% exceeded the 0.100 AU MAL set by FDA Philippines, indicating possible occurrence of chemical migration and non-compliance of the majority of the purchased LDPE with local regulation. The figure suggests the need for inter-agency collaboration to probe further into the evaluation and monitoring of plastic *labo* circulating within Metro Manila and used by local eateries and street stalls as food packaging.

Variation Across Brands within a Single Location

To determine the spread of data within a single location, areas with more than three samples namely Valenzuela (7 brands). Taguig (5 brands), Navotas (4 brands) and Manila (4 brands) were evaluated. Majority of the brands purchased from Valenzuela (5 out of 7) and Taguig (4 out of 5) exceeded the MAL, implying potentially high risk of accessing plastic packaging that likely demonstrates chemical migration when in contact with high-fat low-moisture food products. In contrast, 100% of the brands purchased from Manila were below the 0.100 AU limit, suggesting potentially low risk of fatty and oily food contamination via migration. Many factors contribute to the variation of values in a single location. First, the manufacturers from which the supplies have originated differ hence, the large variability.[30-32] For follow through studies, it may be necessary to acquire samples directly from the producers to properly trace commodities demonstrating chemical migration. Second, while plastic packaging may yield low absorbance values post-production, distribution and storage conditions and practices may affect the products' physico-chemical properties, resulting in modifications. The effects of temperature and time on the release of TACs to fatty and oily food simulants requires further investigation. In addition, follow through studies may need to probe further into actual consumption of brands to better gauge the population's exposure to TACs.

Table 6: Average Absorbance Values and % RSDs of TACs per LDPE Brand to n-Heptane

Brand	Average Absorbance (AU)	%RSD
0001	0.087, n = 2	39.0
0002	0.050, n = 1	-
0003	0.150, n = 1	-
0004	0.226, n = 1	-
0005	0.168, n = 3	27.7
0006	0.094, n = 7	14.8
0007	0.120, n = 2	16.0
0008	0.126, n = 6	15.6
0009	0.049, n = 1	-
0010	0.093, n = 10	30.6
0011	0.103, n = 1	-
0012	0.110, n = 1	-
0013	0.106, n = 6	20.3
0014	0.068, n = 3	12.3
0015	0.229, n = 1	-

Variation Across Brands from Multiple Locations

Disregarding the limitations on the number of samples, n, per brand, the average absorbance values were determined and presented in Table 6. Of the 15 brands, 60% were found to be above the 0.100 AU limit set by FDA Philippines. This implies that manufacturers of said brands may need to look into its raw materials, processes, and other factors contributing to chemical migrations. In addition, regulatory agencies may start monitoring said brands for product improvement and consumer safety.

Four (4) of the 15 brands (LDPE-0006, LDPE-0008, LDPE-0010, and LDPE-0013) were included for further investigation (Table 7). Among these, the average absorbance values of LDPE-0008 (0.126 AU) and LDPE-0013 (0.106 AU) exceeded the FDA regulatory limit, raising concerns regarding their suitability for food contact applications. In contrast, LDPE-0006 (0.094 AU) and LDPE-0010 (0.093 AU) remained within regulatory compliance. Nevertheless, all exhibited %RSDs greater than the established criteria (Table 4), indicating varied migration of UV-absorbing contaminants across different sampling locations.

However, despite the spread of values and differences in the locations of purchase, LDPE-0008 is of great interest as all its representative samples were consistently above the MAL, narrowing down potential sources of contamination primarily to raw materials and manufacturing.[33-35] Separate investigation of ingredients and analysis of output per production process may be necessary to pinpoint actual cause of chemical migration. Research assistance may be provided to help the manufacturer improve the quality and safety of its plastic packaging, and comply with local regulation.

Table 7: Descriptive Statistics of Selected LDPE Brands

Brand	Mean (AU)	Median (AU)	Standard Deviation (AU)	Variance (AU²)	Min (AU)	Max (AU)	Range (AU)	Coefficient of Variation
0006	0.09443	0.101	0.01401	0.000196	0.074	0.106	0.032	14.83682
0008	0.12567	0.121	0.01964	0.000386	0.102	0.152	0.05	15.63142
0010	0.09270	0.098	0.02839	0.000806	0.044	0.124	0.08	30.62604
0013	0.10600	0.104	0.02149	0.000462	0.081	0.139	0.058	20.27753

To evaluate the distribution and significance of absorbance variations across different LDPE brands, a Shapiro-Wilk test for normality was conducted (Table 8). The results indicate that LDPE-0008, LDPE-0010 and LDPE-0013 exhibited normal distributions ($p > 0.05$), while LDPE-0006 did not ($p < 0.05$), necessitating the use of a different statistical approach for further analysis.

Table 8: Result of Shapiro-Wilk Test for Normality (n ≥ 6)

Brand	w	p-value	Remarks
0006	0.77232	0.02158	not normal
0008	0.93035	0.52828	normal
0010	0.8644	0.08597	normal
0013	0.93734	0.63790	normal

For a non-normally distributed sample (LDPE-0006), a Kruskal-Wallis rank sum test was performed to determine whether absorbance values varied significantly across different locations (Table 9). The results for LDPE-0006 ($\chi^2 = 6$, df = 6, $p = 0.4232$) indicate no significant difference, suggesting that absorbance levels remained relatively consistent across sampling sites for this brand.

Table 9: Result of Kruskal-Wallis Rank Sum Test for Samples Not Normally Distributed

Brand	Chi-squared	df	p-value
0006	6	6	0.4232

For normally distributed samples (LDPE-0008, LDPE-0010 and LDPE-0013), a one-sample t-test was applied to assess whether their absorbance values significantly deviated from the FDA regulatory limit (0.100 AU) (Table 10. LDPE-0008 exhibited a significant difference (t = 3.2006, df = 5, p = 0.02398), indicating that its absorbance values were consistently above the FDA threshold, confirming non-compliance and previously mentioned possible contamination source. Conversely, LDPE-0010 (t = -0.81312, df = 9, p = 0.0710) and LDPE-0013 (t = 0.68376, df = 5, p = 0.52450) did not show a significant difference, suggesting that its absorbance values were not consistently above from the regulatory limit.

Table 10: Result of One Sample T-test for Normally Distributed Samples

Brand	t	df	p
0008	3.20060	5	0.02398
0010	-0.81312	9	0.43710
0013	0.68376	5	0.52450

In general, LDPE-008 demonstrated consistent absorbance values across multiple locations, indicating strong quality control and material consistency, while others such as LDPE-006, LDPE-0010 and LDPE-0013 showed wide fluctuations in TACs levels, raising concerns about inconsistent manufacturing, distribution and storage practices.

The variability in TAC levels in LDPE samples with the same brand but across different locations can be attributed to several factors, which align with findings from previous studies. One major factor is the inconsistency in raw material sourcing. The study of Hertz *et al*.[36] reported that dual sourcing of plastic feedstock may introduce significant batch-to-batch variation, while Eriksen *et al*.[37] noted that recycled plastics often contain impurities and residual metals that affect final product quality. The incorporation of recycled content into LDPE films could also be implicated. Franz and Welle[38] showed that PET bottles reused in food packaging contain higher levels of non-intentionally added substances (NIAS), many of which are persistent and difficult to eliminate through standard processing. Núñez *et al*.[39] further identified polycyclic aromatic hydrocarbons (PAHs) and heavy metals in recycled polyethylene, stressing the importance of monitoring contaminants not only in virgin but also in recycled inputs. Other relevant studies from Koynov and Muzzio[40] emphasized the need for raw material characterization in ensuring product consistency, and Doganaksoy and Hahn[41] demonstrated how blending polymers from varying sources, without standardization, leads to heterogeneous material properties. These findings collectively underscore the critical role of material selection in influencing TACs migration.

Beyond sourcing, production and storage practices are pivotal. Poor control over extrusion temperatures or prolonged processing times may degrade the polymer backbone, forming low molecular weight compounds that leach into food, as shown in study by Andersson *et al*.[42] while Narhi *et al*.[43] observed that physical stress during packaging transport and storage could also facilitate the formation of leachables. Moreover, Garcia *et al*.[44] demonstrated that even well-recycled polypropylene can retain volatile residues if not adequately cleaned. The current study observed high intra-brand variability in TACs, consistent with these findings, especially for LDPE-0010, where variability exceeded 30% across locations.

The use of additives also emerged as a possible contributor to elevated TACs. Additives like UV stabilizers, plasticizers, and colorants, while enhancing performance, have been found to migrate under thermal or fatty food exposure. Ye *et al*.[45] highlighted how environmental matrices influence additive release, and Thornley[46] emphasized that pigments may be chemically unstable under UV exposure. This is particularly relevant to the Philippine setting, where packaging may be stored in open-air markets exposed to sunlight and high humidity, conditions known to accelerate degradation. Studies by Vulic *et al*.[47] and Akoueson *et al*.[48] affirmed that stabilizer migration is enhanced under such conditions.

Environmental conditions during storage significantly affect contaminant migration. High temperature, salinity, and UV exposure have been reported to exacerbate the leaching of phthalates and degradation by-products from LDPE, as shown by Dhavamani *et al*.[49] and Abboudi *et al*.[50] In the study of Danwittayakul *et al*.[51] confirmed that even low-density polyethylene bags used in solar disinfection showed degradation signs after prolonged UV exposure. These findings support the elevated TACs seen in samples exposed to harsher retail environments.

Conclusion

The findings from this study revealed that 58.7% of the 46 LDPE samples tested for TACs exceeded the FDA limit of 0.100 AU, implying the occurrence of chemical migration and highlighting a significant level of non-compliance among the samples analyzed. This result underscores critical issues in the quality and safety of LDPE materials intended for food packaging, particularly high-fat low-moisture products. The observed variability in TACs levels, both within and across brands, indicates possible inconsistencies in raw material sourcing, production and storage practices, and possibly the use of additives or recycled content, which may have contributed to elevated contaminant levels in many samples. The findings suggest the need for improved quality control across the supply chain, and the establishment and stricter enforcement of specific guidelines for LDPE food packaging. Moreover, the validated UV-Vis spectrophotometric method used in this study proves to be a cost-effective and accessible tool that can support continued monitoring and regulatory interventions aligned with both international and local safety benchmarks.

Recommendation

To address the observed non-compliance of LDPE samples with FDA limits for TACs, the need for follow-up investigations should be conducted in collaboration with retailers to trace the supply chain and pinpoint high-risk sources of non-compliant products. This will help identify key points where contamination may be introduced and guide future interventions. Additionally, further research is needed to investigate the influence of additives, recycled content, and production processes on TAC levels. Understanding the specific contributions of these factors will provide data-driven insights that can inform improvements in production practices and support the development of stricter regulatory frameworks. To complement these efforts, specific migration testing should be implemented to identify and quantify the chemical composition of migrating contaminants. This detailed analysis will help determine the actual risks posed by non-compliant materials and provide critical information for refining manufacturing practices, enhancing regulatory oversight, and improving public health protection. Incorporating these measures into routine monitoring and regulatory programs will collectively strengthen the safety and quality of LDPE materials intended for food packaging, ensuring they meet the required safety standards and minimizing potential risks to consumers. Lastly, it should be noted that the extraction was conducted at room temperature for a short period of time. Hence, migrations from LDPE food contact articles to fatty and oily foods at lower and elevated temperatures, and extended time frames had not been accounted for and thus, require further investigation.

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Conflict of Interest

The authors do not have any conflict of interest.

Data Availability Statement

This statement does not apply to this article.

Ethics Statement

The research did not involve human participants, animal subjects, or any material that requires ethical approval.

Informed Consent Statement

This study did not involve human participants, and therefore, informed consent was not required.

Clinical Trial Registration

This research does not involve any clinical trials.

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Author Contributions

- **Winnie Pagaduan Alejandro:** Methodology, writing, analysis, data collection – Original draft, review and editing
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