

Preliminary Assessment of Total UV-Absorbing Contaminants Migrating from Philippine-based Microwavable Containers to Fatty / Oily Food Simulant using Modified 21 CFR Part 177 Method

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Abstract – Single-use microwavable containers are commonly employed to package food products because they are perceived as convenient, durable, and safe. In this study, a modification of 21 CFR Part 177 validated by Alejandro et al. to profile low-density polyethylene (LDPE) bags was used to assess rigid microwavable polypropylene (PP) food packaging. A Welch two-sample t-test between LDPE and PP samples (n=15) yielded $t_{stat} = 0$, and $p(1.00) > 0.05$, confirming method robustness. Spectral scanning of 21 brands of Philippine-based microwavable PP containers resulted in a range of 0.008-0.199 AU, indicating large variability. Of the samples analyzed, 23.8% were above the 0.1 AU maximum allowable limit set by the FDA Philippines, implying possible chemical migration upon contact with high-fat, low-moisture food products typically sold in local eateries and quick-service restaurants. Further investigations include migration studies at non-ambient conditions and to other food simulants, and targeted and quantitative analyses.

I. INTRODUCTION

The use of microwavable plastic containers has become pervasive in the food service industry [1], particularly in developing countries [2] such as the Philippines, where urbanization, changing lifestyles, and the rise of food delivery services have increased reliance on ready-to-eat and takeaway meals [3]. According to the ASEAN-Norwegian (ASEANO) Cooperation Project report, approximately 27% of food service establishments studied in the Philippines utilize microwavable plastic containers for packaging food products [4]. These containers, primarily made from polypropylene [1], are favored for their low production cost, durability, and moisture and thermal resistance [5]. However, their popularity surged significantly during the COVID-19 pandemic, when health

concerns prompted a shift towards single-use plastics to safeguard consumers [6]. The escalation in production and use of such materials led to a parallel rise in environmental waste and potential food safety issues [7], particularly concerning the leaching of hazardous substances into food [8].

Chemical migration—the transfer of substances from packaging or any other contact material and article into food [9]—is a multifactorial process governed by the physicochemical properties of the container and the food it holds [10]. Factors such as food composition (e.g., fat or acid content), temperature, duration of contact, and the nature of the contact material can significantly affect migration rates [9,10,11]. For example, lipophilic contaminants such as phthalates and bisphenol A tend to migrate into fatty foods [12], particularly when subjected to elevated temperatures such as cooking and microwaving [13]. Moreover, studies have revealed that microwaving plastic containers can trigger physical and chemical degradation, releasing microplastics [14] and exogenous toxic substances [1]. Despite growing scientific evidence, chemical migration studies remain limited in Southeast Asia [15,16,17], and few have explored the specific materials and usage patterns prevalent in the Philippine market [18].

The systematic evaluation of microwavable containers for chemical migration is essential to ensure environmental sustainability [19] and public health [20]. Such assessments can offer critical insights to contact article manufacturers in formulating safer materials, inform consumers about proper usage, and guide policymakers in drafting evidence-based regulations. Regulatory frameworks such as those outlined by the European Food Safety Authority (EFSA) and the U.S. Food and Drug Administration (FDA) are well established because of the collective efforts of the stakeholders,

scientific community, and legislators in several developed countries. The vision is that the same level of appreciation and support for contact material and article safety is experienced in the Global South. As such, this study is a preliminary assessment of chemical contaminants in commercially available microwavable containers from the Philippines. By evaluating potential migrants under specified conditions, the research intends to establish a scientific platform to advocate for improved packaging safety among manufacturers, greater consumer awareness, and enhanced regulatory oversight in the local context.

II. MATERIALS AND METHODS

A. Sample Collection

Different brands of rigid microwavable plastic containers were purchased from various markets across Metro Manila and nearby provinces. Samples were ensured to be marked with Resin Identification Code “5”, indicating composition as predominantly polypropylene (PP). The global positioning system (GPS) coordinates and retailer address were recorded for each sample acquired. A representative unit for each brand was used to measure material thickness using a Mitutoyo 2046-08 thickness gauge.

B. Method Robustness

The method developed and validated by Alejandro et al. [18] for total UV-absorbing contaminants (TACs) migrating from low-density polyethylene (LDPE) to fatty/oily food simulant was tested to check applicability to PP. Using the method, randomly selected units of PP samples were screened to estimate absorbance units (AU). Fifteen (15) units of an LDPE sample with known AU were analyzed alongside 15 units of a PP sample with a relatively close, measurable, and repeatable AU value from the initial screening. Statistical tools were employed to determine the difference between matrices.

C. Spectral Scanning

Three new units from each collected PP sample were analyzed to establish the average absorbance per brand. As described by Alejandro et al., each replicate was cut into 5 cm x 10 cm, wiped with lint-free paper, and placed in separate beakers using tweezers. Approximately 100 mL of n-heptane was added, ensuring the replicate is entirely immersed. The beaker was covered with glass and allowed to stand for 30 minutes at 25 ± 3 °C. After the extraction period, the replicate was removed, and the solvent was analyzed using Shimadzu UV-1800 UV-Vis Spectrophotometer across the 220-360 nm range. Data were recorded, and statistical tools were used to assess variability within and across samples.

III. RESULTS AND DISCUSSION

A. Descriptive Statistics from Sample Collection

Twenty-one (21) unique brands were identified after sample collection. Each sample corresponds to a brand and was coded to ensure the confidentiality of results. From the

information gathered, only the sample codes, municipalities/cities of the retailers where the samples were purchased, and thickness measurements are summarized in Table 1.

Table 1. Details of Microwavable PP Samples Collected.

Sample Code	Purchase Location	Thickness, mm
PP-0001	Bacoor, Cavite	0.500
PP-0002	Makati	0.574
PP-0003	Mandaluyong	0.400
PP-0004	City of Manila	0.487
PP-0005	City of Manila	0.482
PP-0006	City of Manila	0.404
PP-0007	City of Manila	0.440
PP-0008	City of Manila	0.328
PP-0009	City of Manila	0.615
PP-0010	City of Manila	0.360
PP-0011	Muntinlupa	0.550
PP-0012	Parañaque	0.550
PP-0013	Parañaque	0.500
PP-0014	Pasig	0.450
PP-0015	Quezon City	0.440
PP-0016	Quezon City	0.530
PP-0017	Quezon City	0.400
PP-0018	Subic, Zambales	0.350
PP-0019	Subic, Zambales	0.310
PP-0020	Subic, Zambales	0.270
PP-0021	Subic, Zambales	0.370

The table shows that 76.2% of the purchased samples were available in Metro Manila, while the remaining 23.8% were found in nearby provinces. Of those secured from the capital, 43.8% were from the actual City of Manila, most likely because it has always been a center for trade [21], and its Divisoria public market is a common drop-off point for numerous general merchandise goods such as food contact articles imported from China [22].

The range of sample thickness is 0.270-0.615 mm with a mean of 0.443 mm. The closeness of the median (0.440 mm) to the mean indicates that the data distribution of sample thickness across brands is symmetrical and not heavily skewed.

B. Statistical Analysis for Method Robustness

Upon initial screening of selected PP samples, PP-0003, which demonstrated proximity, measurability, and repeatability, was compared against LDPE-0011 used by

Alejandro et al. Having two independent groups with unequal variances, a Welch's two-sample t-test was employed to determine the method's applicability to both matrices. The statistical data of the LDPE and PP representative samples for method robustness are summarized in Table 2.

Table 2. Statistical Data for Method Robustness.

Descriptive Statistics

	LDPE	PP
n	15	15
AU _{mean}	0.158	0.110
%Recovery _{mean}	100	100
Std Dev	0.009	0.004
%RSD	5.48	3.82
s ²	30.0	14.6

Welch two-sample t-test

	Value	Criterion
t-value	0	Equal to 0
df	25	
p-value	1.00	Greater than 0.05

The equal mean percent recoveries of LDPE and PP not only indicate accuracy but also suggest similarity, a conclusion further supported by the zero t-value. However, the p-value of 1.00, being higher than the significance level of 0.05, clearly establishes the lack of statistical significance between the recovery measurements of the two sample matrices. Therefore, the method initially intended for LDPE does not require a separate validation for PP and is directly suitable for sample profiling.

C. Descriptive Statistics from Spectral Scanning

Table 3 summarizes the samples and their corresponding average absorbance. The average absorbance range is 0.008-0.199 AU with an overall mean of 0.076. The closeness of the median (0.078 AU) to the overall mean also indicates that, similar to sample thickness, the data distribution of average absorbance across brands is balanced with data points clustered around the center without any significant pull from either side. Meanwhile, the relative standard deviations for each sample are within the criteria established by Alejandro et al., implying good repeatability in all levels.

The direct relationship between absorbance value and the concentration of total UV-absorbing contaminants (TACs) migrating from plastic packaging is yet to be quantified and established in future studies. However, the mere increase in absorbance value (compared to that of a blank, i.e., n-heptane that is not exposed to any sample) often indicates that chemical migration has occurred.

D. Relationship between Location and Absorbance

Combining the data from Tables 1 and 3, the brand with the highest average absorbance (0.199 AU) is PP-0013 and was purchased from Parañaque. This is followed by PP-0003 from Mandaluyong (0.140 AU), PP-0009 from

Manila (0.124 AU), and PP-0014 from Pasig (0.110). The list of samples with absorbance greater than 0.1 AU, the maximum allowable limit (MAL) set by FDA Philippines for chemical migrations from plastic packaging made in contact with n-heptane, is completed by PP-0012, also from Parañaque.

The results indicate that 100% of samples from Parañaque failed to comply with the regulation, implying the need for Parañaque retailers to determine the root causes (e.g., raw materials and processes used by the supplying manufacturers, storage and transport conditions, etc. [12]) and seek options in mitigating chemical migration from packaging to fatty/oily food products. Further, 100% of the samples above the 0.1 AU absorbance limit are from Metro Manila, possibly due to economics [21,22] as discussed earlier.

Table 3. Details of Microwavable PP Samples Analyzed.

Sample Code	Ave. Absorbance, AU (n = 3)	Relative Std Dev, %
PP-0001	0.084	1.68
PP-0002	0.083	5.97
PP-0003	0.140	1.79
PP-0004	0.083	1.21
PP-0005	0.068	11.1
PP-0006	0.036	11.3
PP-0007	0.035	7.56
PP-0008	0.058	9.75
PP-0009	0.124	3.97
PP-0010	0.008	7.53
PP-0011	0.048	1.21
PP-0012	0.107	4.69
PP-0013	0.199	1.91
PP-0014	0.110	3.28
PP-0015	0.078	2.68
PP-0016	0.043	1.66
PP-0017	0.045	8.89
PP-0018	0.086	3.34
PP-0019	0.028	5.39
PP-0020	0.097	5.66
PP-0021	0.043	8.74

Meanwhile, the brand with the lowest average absorbance (0.008 AU) is PP-0010 and was also purchased from Metro Manila, specifically from the City of Manila. Hence, the relationship between the location of retailers

and sample absorbance cannot be established yet, if any. Additional units of each brand obtained from one or two other retailers not part of the original list may be acquired to yield $n = 3$ and analyzed to confirm the repeatability of values per brand across multiple locations. Moreover, conducting broader market surveys and engaging key stakeholders can help identify and profile other brands that may have been missed, providing a more comprehensive understanding of the microwavable PP market landscape in the Philippines.

E. Relationship between Thickness and Absorbance

By plotting sample thickness against absorbance, Figure 1 is generated, and a visual relationship between data sets is observed.

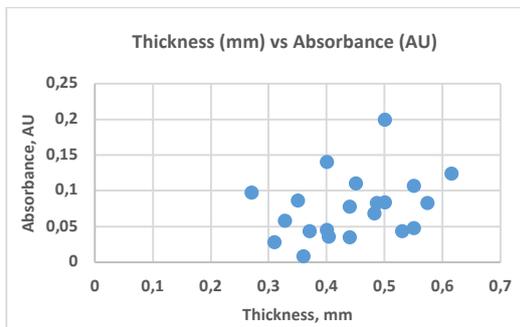


Figure 1. Scatter Plot of Microwavable PP Sample Thickness (mm) vs Absorbance (AU)

Computation of the correlation coefficient, r , yields a value of 0.322, suggesting a mild positive correlation. This implies that as thickness increases, absorbance tends to increase. This contradicts a previous study that explained an opposite relationship. Nerin et al. concluded that thicker packaging slows down migration [23]. However, a simulation by Pocas et al. explained that the presence of recycled additives and ingredients affected the chemical migration rates [24], resulting in modifications in the correlation and a less concrete conclusion. Relating the concept to this study, the increase in sample thickness likely exposed a slightly larger surface area for these materials to migrate. This led to relatively high absorbance values by thicker microwavable PP containers and, consequently, to a weak to moderate correlation as graphed and calculated.

F. Regulatory Compliance

Profiling of locally available microwavable PP containers revealed that 23.8% were above the 0.1 AU MAL set by FDA Philippines for plastic packaging in contact with n-heptane. Although the reference method, 21 CFR Part 177, used n-hexane as an extracting solvent to resemble high-fat, low-moisture food products, the regulatory body opted to use a more abusive simulant like n-heptane, possibly for precautionary measures.

Comparing the results with those of Alejandro et al., in which approximately 60% of the different brands of LDPE

bags exceeded the MAL, the current study suggests that using microwavable containers presents a lower risk of chemical migration. As such, street food stalls and local eateries that utilize LDPE bags [25] to package high-fat, low-moisture (usually deep-fried and sauce-based) food products [26] may shift to rigid microwavable PP containers as a form of regulatory support. Conversely, consumers may demand PP over LDPE for their safety.

G. Additional Recommendations

It is important to note that the results of the study are not all-encompassing and cannot be generalized for (a) low-fat, high-moisture, (b) acidic, (c) alcoholic, and (d) low-fat, low-moisture or dry food products. In addition, it does not cover extraction at non-ambient conditions. These variations in simulant, contact period, and temperature may qualify as an expansion of the research. An in-depth study of the combined effects of these factors can help explain the migration behaviors and patterns of TACs during a week of refrigeration or a three-minute microwaving set at medium-high, for example.

Further, the method acts only as a preliminary assessment for chemical migration. It cannot identify the specific elements or compounds from the packaging. As such, follow-through studies may employ targeted and quantitative analysis. Areas of interest may include phthalates, which have long been detected in microwavable PP containers through gas chromatography-mass spectrometry [27], microplastics, which are receiving increasing attention and are determined by quantity and size distribution via Raman microscopy [28], and even non-intentionally added substances (NIAS) formed in situ from the reaction between plastic migrants and natural food components [1].

IV. CONCLUSION

This study demonstrated the successful adaptation of a method originally developed for LDPE to analyze rigid microwavable PP food containers. Through rigorous statistical validation, the method was confirmed to be suitable for assessing the occurrence of chemical migration from PP to the simulant. A total of 21 distinct PP samples representing different commercial brands were subjected to extraction and spectrophotometric determination, focusing on parameters such as thickness and absorbance. Correlation of the two measurands exhibited a mild positive relationship, contrary to some literature, in which an increase in thickness slightly caused an increase in absorbance. Profiling revealed that while majority of the samples complied with the established regulatory threshold, five were found to exceed the highest permissible value set by FDA Philippines. These non-compliant samples warrant further investigation to deduce potential sources of contamination or inconsistencies in material formulation. Finally, the findings highlight the emerging concerns surrounding contact material and article safety in the local context. As the study of food

packaging safety in the Philippines remains in its infancy, it is crucial to foster stronger collaborations among various stakeholders. The commitment and participation of manufacturers to improve product quality through research, the awareness and discernment of consumers in the selection of packaging, and the vigilance of regulatory bodies in enforcing standards are all essential to safeguarding public health and advancing the field of food contact material and article safety in the country.

V. REFERENCES

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