

Oxidative Stability and Antioxidant Capacity of Refined Vegetable Oils Under Thermal Stress: A Market Survey of Major Brands in Rivers State, Nigeria

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Abstract

Original Research Article

The thermal stability of edible oils is a critical food safety concern, particularly for frequently reused cooking oils in developing nations. This study evaluated the oxidative stability and antioxidant capacity of eight commercially refined vegetable oil brands, comprising palm olein, soybean, sunflower, and groundnut oils, purchased from major markets in Port Harcourt, Rivers State, Nigeria, following repeated thermal stress (frying at $180 \pm 5^\circ\text{C}$ for 0, 2, 4, 6, and 8 hours). Physicochemical quality indices including peroxide value (PV), free fatty acid content (FFA), p-anisidine value (p-AV), total oxidation value (TOTOX), acid value (AV), saponification value (SV), and iodine value (IV) were determined using standard AOCS and AOAC methods. Antioxidant capacity was assessed via the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay and ferric reducing antioxidant power (FRAP) assay. Tocopherol (vitamin E) content was quantified by HPLC-fluorescence detection. Results revealed that progressive thermal treatment significantly elevated PV, FFA, p-AV, and TOTOX values across all oil types, with groundnut oil exhibiting the highest initial antioxidant capacity (DPPH $\text{IC}_{50} = 12.4 \text{ mg/mL}$) and palm olein demonstrating the greatest oxidative stability owing to its higher saturated fatty acid content and residual carotenoid contribution. Soybean and sunflower oils showed the most rapid deterioration, with TOTOX values exceeding regulatory thresholds (CODEX Alimentarius) after six hours of thermal stress. Tocopherol content declined by 58–82% across all samples following eight hours of heating. Several brands did not conform to CODEX and SON (Standards Organisation of Nigeria) quality benchmarks even in their unheated state. These findings underscore the urgent need for consumer education, regulatory enforcement, and improved quality standards for refined vegetable oils in Nigeria.

Keywords: oxidative stability, antioxidant capacity, vegetable oil, thermal stress, DPPH, tocopherol, Port Harcourt, Rivers State, Nigeria

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1. INTRODUCTION

Refined vegetable oils are among the most widely consumed food commodities globally, constituting a primary source of dietary fat and energy in both developed and developing nations (Boateng et al., 2016). In Nigeria, refined

vegetable oils including palm olein, soybean, sunflower, and groundnut oil are extensively used in household cooking, food manufacturing, and street vending activities. Port Harcourt, the oil-rich capital of Rivers State, serves as a major distribution hub for refined edible oils, with



diverse brand types from both domestic and international manufacturers freely available in open markets, supermarkets, and roadside retail outlets (Ohiokpehai, 2018).

Thermal processing, particularly deep frying, is the predominant cooking method in Nigerian culinary practice. Oils are frequently reused multiple times, often at elevated temperatures between 160 and 200°C, without adequate quality monitoring or replacement protocols (Chukwu & Chinma, 2019). Under such conditions, refined vegetable oils undergo complex and progressive chemical deterioration reactions including hydrolysis, oxidation, polymerisation, and isomerisation, collectively resulting in the generation of harmful secondary oxidation products such as aldehydes, ketones, hydroperoxides, acrolein, and trans fatty acids (Choe & Min, 2007; Matthäus, 2010).

Oxidative stability refers to the resistance of an oil or fat to oxidative degradation under pro-oxidant conditions such as heat, light, or oxygen exposure. It is governed by the degree of unsaturation of the constituent fatty acids, the presence of natural or added antioxidants, the concentration of prooxidant trace metals, and the processing conditions applied during refining (Frankel, 2005). Oils rich in polyunsaturated fatty acids (PUFAs) such as linoleic acid (C18:2) and linolenic acid (C18:3), as found abundantly in soybean and sunflower oils, are particularly susceptible to oxidative deterioration during thermal processing (Shahidi & Zhong, 2010).

Antioxidants, including tocopherols (vitamin E homologues), carotenoids, and phenolic compounds, play a vital protective role in retarding lipid oxidation in vegetable oils. However, the industrial refining process—comprising degumming, neutralisation (alkali refining), bleaching, and deodorisation—substantially diminishes the natural antioxidant complement of crude oils, rendering the final refined product more vulnerable to oxidative degradation (Morales et al., 2010; Kamal-Eldin & Appelqvist, 1996). The residual antioxidant activity of commercially available refined oils therefore varies considerably among brands depending on the refining intensity, additive formulations, and storage conditions applied prior to retail.

The health implications of consuming thermally oxidised vegetable oils are well-documented. Repeated ingestion of oxidised lipid products has been associated with increased risk of cardiovascular disease, cancer, hepatotoxicity, and gastrointestinal inflammation (Srivastava et al., 2017; Ng et al., 2014). In the Nigerian context, where health literacy regarding oil quality is generally limited and regulatory oversight of cooking oil standards remains inconsistent, the extent of oxidative deterioration in market-sold refined oils under habitual thermal stress conditions constitutes a significant public health concern.

Despite the nutritional and toxicological significance of thermally stressed vegetable oils, data specifically evaluating the oxidative stability and antioxidant capacity of refined oil brands commercially available in Rivers State markets remain scarce. Most existing Nigerian studies have focused on crude or minimally processed oils (Dike & Ogan, 2016; Oyelaran et al., 2020) or have examined single oil types without comparative multi-brand assessments across extended thermal exposure durations. There is therefore a compelling need for systematic, brand-specific evaluation of refined oil quality under simulated frying conditions reflective of actual consumer practices in Port Harcourt.

This study was therefore designed to: (i) assess the physicochemical quality indices of major refined vegetable oil brands available in Port Harcourt markets before and after repeated thermal stress; (ii) quantify the antioxidant capacity of these oils using DPPH and FRAP assays at each thermal interval; (iii) determine tocopherol content as a key natural antioxidant indicator; and (iv) compare findings against CODEX Alimentarius and Standards Organisation of Nigeria (SON) benchmarks for refined edible oil quality.

2. MATERIALS AND METHODS

2.1 Sample Collection

Eight brands of commercially refined vegetable oils, encompassing four oil types (palm olein, soybean, sunflower, and groundnut oil), were purchased from major retail markets in Port

Harcourt, Rivers State, Nigeria, including Mile 1 Market, Mile 3 Market, Oil Mill Market, and Rumuola Market. Two brands per oil type were selected based on market prevalence, consumer patronage, and brand diversity. All samples were collected between October and December 2024 in their original factory-sealed packaging, with manufacture dates and expiry dates recorded. Samples were immediately transported to the analytical laboratory, stored at ambient temperature ($26 \pm 2^\circ\text{C}$) in the dark, and analyzed within two weeks of purchase.

2.2 Thermal Stress Treatment

Each oil sample (500 mL per replicate) was subjected to controlled thermal stress in a stainless steel frying vessel maintained at $180 \pm 5^\circ\text{C}$ using a calibrated electric hotplate fitted with a thermocouple. Thermal exposure was conducted in five intervals: 0 h (control/unheated), 2 h, 4 h, 6 h, and 8 h of cumulative heating. No food substrate was added during heating to ensure uniform oxidative challenge. At each interval, a 50 mL aliquot was withdrawn, cooled to room temperature, and stored in amber glass vials under nitrogen headspace at -20°C pending analysis. All experiments were performed in triplicate.

2.3 Physicochemical Analysis

Peroxide value (PV), free fatty acid content (FFA), acid value (AV), saponification value (SV), and iodine value (IV) were determined following AOAC (2019) and AOCS (2017) official methods. The p-anisidine value (p-AV) was measured spectrophotometrically at 350 nm per AOCS Cd 18-90. Total oxidation value (TOTOX) was calculated as $\text{TOTOX} = 2\text{PV} + \text{p-AV}$. All measurements were expressed as appropriate units per the respective standard methods.

2.4 DPPH Radical Scavenging Assay

Antioxidant capacity was assessed using the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging method adapted from Brand-

Williams et al. (1995). Oil solutions (1 mg/mL in hexane) were prepared and serial dilutions made. Absorbance was measured at 517 nm using a UV-Vis spectrophotometer (Shimadzu UV-1800). The IC_{50} value (concentration required to inhibit 50% of DPPH radicals) was calculated from dose-response curves. Ascorbic acid was used as a positive reference standard.

2.5 Ferric Reducing Antioxidant Power (FRAP) Assay

The FRAP assay was performed according to the method of Benzie and Strain (1996) with modifications for oil matrices. Oil samples (0.1 mL) were mixed with freshly prepared FRAP reagent (2.5 mL; containing 300 mM acetate buffer pH 3.6, 10 mM TPTZ in 40 mM HCl, and 20 mM FeCl_3) and incubated at 37°C for 30 minutes. Absorbance was measured at 593 nm and results expressed as mmol Fe^{2+} equivalent per kilogram of oil.

2.6 Tocopherol Quantification

Total tocopherol content (α -, β -, γ -, and δ -tocopherols) was determined by HPLC with fluorescence detection (excitation 290 nm, emission 330 nm) according to AOCS Ce 8-89. An Agilent 1260 Infinity HPLC system equipped with a normal-phase silica column (250×4.6 mm, $5 \mu\text{m}$) was used. Mobile phase: n-hexane/2-propanol (99:1 v/v) at a flow rate of 1.0 mL/min. α -Tocopherol standard (Sigma-Aldrich) was used for calibration.

2.7 Statistical Analysis

Data were subjected to one-way analysis of variance (ANOVA) using IBM SPSS Statistics v26.0. Tukey's honest significant difference (HSD) post hoc test was used to identify significant differences among means at $p < 0.05$. Pearson's correlation analysis was performed to assess relationships between oxidative indices and antioxidant parameters. Results are expressed as mean \pm standard deviation (SD) of triplicate determinations.

3. RESULTS

Table 1. Physicochemical Quality Indices of Eight Refined Vegetable Oil Brands at 0 h (Unheated Control), Port Harcourt Markets, Rivers State, Nigeria.

Brand/Oil Type	PV (meq/kg)	FFA (%)	AV (mg KOH/g)	IV (g I ₂ /100g)	SV (mg KOH/g)	p-AV	TOTOX
Brand A (Palm olein)	1.82±0.12	0.21±0.02	0.42±0.04	54.2±1.3	196.4±3.2	3.11±0.21	6.75
Brand B (Palm olein)	2.04±0.18	0.25±0.03	0.50±0.06	52.8±1.1	194.8±2.9	3.68±0.19	7.76
Brand C (Soybean)	2.46±0.22	0.32±0.04	0.64±0.07	124.7±2.8	189.3±4.1	4.52±0.31	9.44
Brand D (Soybean)	2.78±0.24	0.36±0.04	0.72±0.08	126.3±3.1	187.6±3.8	5.10±0.28	10.66
Brand E (Sunflower)	2.92±0.26	0.38±0.05	0.76±0.09	131.5±3.4	185.2±4.3	5.44±0.34	11.28
Brand F (Sunflower)	3.14±0.28	0.41±0.05	0.82±0.09	129.4±2.9	183.7±3.6	5.88±0.32	12.16
Brand G (Groundnut)	1.64±0.14	0.19±0.02	0.38±0.04	94.6±2.1	191.2±3.4	2.94±0.18	6.22
Brand H (Groundnut)	1.88±0.16	0.23±0.03	0.46±0.05	92.3±1.8	190.5±3.1	3.22±0.22	6.98
CODEX limit	≤10	≤0.60	≤1.20	Varies	—	—	≤10

Table 2. Effect of Thermal Stress on Peroxide Value (PV, meq O₂/kg) of Eight Refined Vegetable Oil Brands across Heating Intervals.

Brand/Oil Type	0 h	2 h	4 h	6 h	8 h
Brand A (Palm olein)	1.82±0.12	4.16±0.31	7.88±0.54	11.42±0.72	16.34±0.98
Brand B (Palm olein)	2.04±0.18	4.58±0.34	8.34±0.61	12.76±0.84	17.88±1.12
Brand C (Soybean)	2.46±0.22	6.72±0.48	14.36±0.88	22.14±1.34	31.46±2.04
Brand D (Soybean)	2.78±0.24	7.14±0.52	15.62±0.94	24.38±1.52	34.82±2.16
Brand E (Sunflower)	2.92±0.26	7.68±0.56	16.44±1.04	26.22±1.64	36.74±2.38
Brand F (Sunflower)	3.14±0.28	8.12±0.62	17.86±1.14	28.44±1.78	39.28±2.54
Brand G (Groundnut)	1.64±0.14	3.88±0.28	7.14±0.48	10.56±0.68	14.92±0.92
Brand H (Groundnut)	1.88±0.16	4.22±0.32	7.76±0.54	11.68±0.74	16.14±0.96

Table 3. DPPH Radical Scavenging Activity (IC₅₀, mg/mL) and FRAP Values (mmol Fe²⁺eq/kg) of Refined Vegetable Oils at Each Thermal Interval.

Brand	0 h IC ₅₀	2 h IC ₅₀	4 h IC ₅₀	6 h IC ₅₀	8 h IC ₅₀	FRAP (0h, mmol/kg)
Brand A (Palm olein)	18.4±1.2	22.6±1.6	29.4±2.1	38.8±2.8	51.2±3.4	6.42±0.38
Brand B (Palm olein)	20.2±1.4	24.8±1.8	32.6±2.4	42.4±3.1	56.8±4.1	5.88±0.34
Brand C (Soybean)	24.6±1.8	32.4±2.4	44.2±3.2	62.6±4.4	84.4±5.8	4.22±0.28
Brand D (Soybean)	26.8±2.0	34.6±2.6	48.4±3.6	68.2±4.8	92.6±6.4	3.96±0.26
Brand E (Sunflower)	28.4±2.2	38.2±2.8	54.6±4.0	76.4±5.4	108.2±7.2	3.74±0.24
Brand F (Sunflower)	30.6±2.4	41.4±3.2	58.8±4.4	82.6±5.8	116.4±8.1	3.48±0.22
Brand G (Groundnut)	12.4±0.9	16.2±1.2	21.8±1.6	28.4±2.0	38.6±2.8	7.86±0.42
Brand H (Groundnut)	14.8±1.1	18.6±1.4	24.4±1.8	32.8±2.4	44.2±3.2	7.14±0.38

Table 4. Tocopherol Content (mg/kg) of Refined Vegetable Oils Before and After Thermal Treatment.

Brand/Oil Type	0 h (mg/kg)	2 h (mg/kg)	4 h (mg/kg)	6 h (mg/kg)	8 h (mg/kg)
Brand A (Palm olein)	142.4±8.2	118.6±6.8	92.4±5.4	68.2±4.1	42.6±2.8
Brand B (Palm olein)	136.8±7.6	112.4±6.4	86.8±5.1	62.4±3.8	38.4±2.4
Brand C (Soybean)	218.6±12.4	176.4±9.8	128.2±7.4	84.6±5.2	46.2±3.1
Brand D (Soybean)	224.4±13.1	182.6±10.2	132.8±8.1	88.4±5.6	48.6±3.4
Brand E (Sunflower)	264.8±14.6	208.4±11.8	148.6±8.8	96.4±6.1	52.4±3.6
Brand F (Sunflower)	258.2±14.2	202.6±11.4	142.4±8.4	92.2±5.8	48.8±3.3
Brand G (Groundnut)	186.4±10.6	158.2±9.1	124.6±7.2	88.8±5.4	56.4±3.8
Brand H (Groundnut)	178.8±9.8	152.4±8.6	118.2±6.8	82.6±5.1	52.8±3.5

Table 5. Total Oxidation Value (TOTOX = 2PV + p-AV) of Refined Vegetable Oils Across Thermal Intervals Compared to CODEX Regulatory Threshold.

Brand/Oil Type	0 h	2 h	4 h	6 h	8 h
Brand A (Palm olein)	6.75	11.43	19.87	31.26	45.12
Brand B (Palm olein)	7.76	12.84	22.16	34.88	50.24
Brand C (Soybean)	9.44	18.66	37.24	58.72	83.46
Brand D (Soybean)	10.66	20.38	40.34	64.86	90.74
Brand E (Sunflower)	11.28	21.80	44.32	70.88	100.96
Brand F (Sunflower)	12.16	24.12	49.58	78.32	112.44
Brand G (Groundnut)	6.22	10.70	18.22	27.66	38.78
Brand H (Groundnut)	6.98	11.66	20.06	30.54	44.42
CODEX Limit (≤ 10)	—	—	—	—	—

Table 6. Pearson Correlation Coefficients Between Oxidative Indices and Antioxidant Parameters Across All Oil Samples (n = 40).

Parameter	PV	TOTOX	FFA	DPPH IC ₅₀	Tocopherol
PV	1.000				
TOTOX	0.968**	1.000			
FFA	0.912**	0.924**	1.000		
DPPH IC ₅₀	0.884**	0.896**	0.842**	1.000	
Tocopherol	-0.876**	-0.891**	-0.831**	-0.924**	1.000

Note: ** $p < 0.01$; PV = Peroxide Value; FFA = Free Fatty Acid; DPPH IC₅₀ = concentration for 50% radical inhibition

4. DISCUSSION

4.1 Baseline Physicochemical Quality of Unheated Oils

The baseline physicochemical quality assessment of unheated refined vegetable oil brands (Table 1) revealed that all samples met CODEX Alimentarius and SON (2004) specified

limits for PV (≤ 10 meq O₂/kg), FFA ($\leq 0.60\%$), and TOTOX (≤ 10) prior to thermal treatment. However, notable inter-brand variability was observed even at baseline. Sunflower oil brands (E and F) recorded the highest unheated PV values (2.92 and 3.14 meq/kg, respectively), reflecting their greater vulnerability to oxidative initiation during transport and storage,

attributable to their elevated PUFA content (Frankel, 2005). Groundnut oil brands (G and H) exhibited the lowest baseline PV values (1.64 and 1.88 meq/kg), consistent with their intermediate fatty acid saturation profile compared to the more unsaturated soybean and sunflower oil types.

Iodine values were highest for sunflower oils (129.4–131.5 g I₂/100g) and soybean oils (124.7–126.3 g I₂/100g), confirming their high degree of unsaturation (Matthäus, 2010). Palm olein brands recorded the lowest iodine values (52.8–54.2 g I₂/100g), consistent with their predominantly saturated and monounsaturated fatty acid composition. These baseline iodine values are consistent with reference values reported by CODEX STAN 210-1999 and corroborate findings by Oyelaran et al. (2020) for similar oil types purchased from Nigerian markets.

4.2 Effect of Thermal Stress on Oxidative Deterioration

Thermal treatment at 180 ± 5°C progressively elevated all oxidative deterioration indices across all brands in a time-dependent manner (Tables 2 and 5). Peroxide values increased markedly from baseline through 8 hours of heating, with the most dramatic escalation observed in sunflower oil brands E and F, reaching 36.74 and 39.28 meq O₂/kg respectively at 8 h, approximately 12-fold above their respective baselines. These values far exceed the CODEX Alimentarius maximum permissible limit of 10 meq O₂/kg for refined vegetable oils intended for human consumption.

Palm olein brands demonstrated the greatest relative oxidative stability, with Brand A recording 16.34 meq/kg and Brand B 17.88 meq/kg at 8 h of heating, substantially lower than the corresponding soybean and sunflower brands. This superior thermal stability of palm olein is attributable to its higher content of saturated fatty acids (primarily palmitic acid, C16:0, constituting approximately 44% of total fatty acids) and monounsaturated oleic acid (C18:1, approximately 39%), as well as its higher endogenous carotenoid content compared

to fully refined seed oils (Edem, 2002; Sundram et al., 2003).

The TOTOX values (Table 5) provide a composite measure of both primary (peroxides) and secondary (aldehydes via p-AV) oxidation products, and thus represent a more comprehensive indicator of overall oil oxidative quality. All brands exceeded the CODEX TOTOX threshold of 10 within 2 hours of thermal treatment, confirming that even two hours of continuous heating at 180°C renders refined vegetable oils potentially unsafe for repeated consumption. This finding is consistent with Srivastava et al. (2017) and Ng et al. (2014), who documented rapid TOTOX escalation in refined seed oils under simulated frying conditions.

4.3 Antioxidant Capacity and Tocopherol Depletion

Antioxidant capacity, assessed via DPPH IC₅₀ values (Table 3), followed an inverse relationship with duration of thermal exposure across all brands: lower IC₅₀ values indicate greater antioxidant potency. Groundnut oil brands (G and H) exhibited the lowest IC₅₀ values at baseline (12.4 and 14.8 mg/mL), reflecting the greatest antioxidant capacity among tested oils at the unheated state. This superior initial antioxidant activity may be attributed to the relatively higher residual concentrations of phenolic compounds and the mixed tocopherol profile characteristic of groundnut oil (Yoshida et al., 2005).

FRAP values (Table 3) similarly corroborated the DPPH findings, with groundnut oils recording the highest baseline FRAP values (7.14–7.86 mmol Fe²⁺/eq/kg), followed by palm olein (5.88–6.42 mmol/kg), soybean (3.96–4.22 mmol/kg), and sunflower (3.48–3.74 mmol/kg). These differences among oil types reflect both the inherent antioxidant composition of the raw oil and the differential impact of the industrial refining process on antioxidant retention (Kamal-Eldin & Appelqvist, 1996).

The depletion of tocopherol content with progressive thermal treatment (Table 4) was statistically significant ($p < 0.001$) across all brands. Sunflower oils, while possessing the

highest initial tocopherol levels (258.2–264.8 mg/kg) consistent with published data for refined sunflower oil (Morales et al., 2010), exhibited the greatest absolute loss, retaining only 48.8–52.4 mg/kg (approximately 81% reduction) after 8 hours of heating. Groundnut oil brands retained comparatively higher residual tocopherol proportions following thermal treatment, consistent with a more thermostable antioxidant matrix.

The strong negative correlation between tocopherol content and DPPH IC₅₀ ($r = -0.924$, $p < 0.01$; Table 6) confirms that tocopherol depletion is a primary mechanistic driver of the progressive loss of antioxidant capacity observed during thermal processing. The equally strong positive correlations between PV, TOTOX, FFA, and DPPH IC₅₀ (all $r > 0.84$, $p < 0.01$) indicate that as oxidative deterioration intensifies, the antioxidant defence system of the oil is simultaneously overwhelmed and consumed, creating a compounding cycle of accelerated oxidative degradation (Shahidi & Zhong, 2010).

4.4 Public Health and Regulatory Implications

The findings of this study carry significant public health implications for consumers in Rivers State and Nigeria at large. The repeated use of thermally stressed vegetable oils—a culturally normalised practice in Nigerian domestic and commercial kitchens—results in escalating consumer exposure to toxic lipid oxidation products including malondialdehyde, 4-hydroxynonenal, acrolein, and various aldehyde species, which have been mechanistically linked to increased oxidative stress, endothelial dysfunction, and carcinogenesis (Choe & Min, 2007; Basu & Bhattacharya, 2012). The exceedance of CODEX and SON quality benchmarks within just two hours of heating at 180°C observed in all brands in this study underscores the inadequacy of current consumer guidance regarding safe oil reuse practices.

Moreover, several brands recorded TOTOX values approaching or marginally exceeding the regulatory ceiling even at baseline (unheated), suggesting inadequate quality control during

refining, inappropriate storage conditions in the supply chain, or misrepresentation of freshness through extended shelf-life labelling. Regulatory authorities including the National Agency for Food and Drug Administration and Control (NAFDAC) and the Standards Organisation of Nigeria (SON) should intensify market surveillance and enforcement of quality benchmarks for refined vegetable oils, with particular attention to PUFA-rich oil categories that demonstrate more rapid oxidative deterioration.

5. CONCLUSION

This study provides the first comprehensive, brand-specific assessment of oxidative stability and antioxidant capacity of commercially refined vegetable oils marketed in Port Harcourt, Rivers State, Nigeria, under empirical thermal stress conditions. All eight brands investigated showed progressive and statistically significant deterioration in oxidative quality indices (PV, FFA, p-AV, TOTOX) and antioxidant capacity (DPPH, FRAP, tocopherol) with increasing duration of heating at 180°C. TOTOX values exceeded CODEX Alimentarius limits within two hours of heating for all brands, with sunflower and soybean oils demonstrating the most rapid deterioration. Palm olein brands exhibited the greatest relative oxidative stability, while groundnut oils demonstrated the highest initial antioxidant capacity. Tocopherol content declined by 58–82% across all brands after 8 hours of thermal treatment. Several brands showed borderline quality parameters even in the unheated state, suggesting suboptimal pre-retail quality management. These findings highlight urgent gaps in regulatory enforcement, consumer awareness, and quality standards for refined vegetable oils in Nigeria.

6. RECOMMENDATIONS

Based on the findings of this study, the following recommendations are made:

1. NAFDAC and SON should implement mandatory pre-market and periodic post-market oxidative quality testing (including TOTOX determination) for all refined vegetable oil brands sold in Nigeria, with zero-tolerance

enforcement for products exceeding CODEX Alimentarius limits.

2. Consumers should be educated through public health campaigns on the dangers of repeated oil reuse, particularly for PUFA-rich oils such as sunflower and soybean oil, and should be advised to replace cooking oil after a maximum of two frying cycles.

3. Manufacturers of refined sunflower and soybean oils should consider incorporating approved natural antioxidants (e.g., mixed tocopherols, rosemary extract) to improve the thermal stability and shelf-life of their products.

4. Groundnut oil brands, which demonstrated the highest initial antioxidant capacity and intermediate oxidative stability, should be promoted as a relatively stable option for high-temperature frying applications in the Nigerian context.

5. Further research should characterize the specific aldehyde and polar compound profiles in thermally stressed vegetable oils from Nigerian markets to enable a more comprehensive risk assessment for consumer safety.

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