International Journal of Nutrition and Food Sciences
2026, Vol. 15, No. 6, pp. 332–338
https://doi.org/10.11648/j.ijnfs.20261506.13

SciencePG
Science Publishing Group

Research Article

Comparative Evaluation of Oxidative Quality and Thermal Oxidative Stability of Commercial Olive Oil Brands Using Lipid Oxidation Indices

Simcha Chinyere Okeyahweh[1, *], Lazarus Afamefuna Okoye[2], Patrick Okechukwu Ugwudike[3]

[1]Department of Biochemistry, Caritas University, Enugu, Nigeria

[2]Department of Medical Laboratory Science, Caritas University, Enugu, Nigeria

[3]Department of Biochemistry, Enugu State University of Science and Technology, Enugu, Nigeria

Abstract

Olive oil is valued for its nutritional composition and bioactive constituents, but lipid oxidation during storage and heating can reduce quality and produce primary and secondary oxidation products. This study evaluated the oxidative quality and thermal oxidative stability of eleven commercially available extra virgin olive oil brands marketed in Enugu State, Nigeria. Fresh samples (S1–S11) were analysed for peroxide value (PV), p-anisidine value (P-AV), and total oxidation (TOTOX) value. Separate aliquots were heated at 180 ℃ for 10, 15, and 20 min, and all determinations were performed in triplicate. PV was determined by the AOCS iodometric method, P-AV by the AOCS p-anisidine method, and TOTOX was calculated as 2PV + P-AV. Fresh PV, P-AV, and TOTOX values ranged from 4.50 ± 0.95 to 25.85 ± 0.05 meq O2/kg, 0.43 ± 0.05 to 17.50 ± 0.89, and 13.26 ± 1.59 to 53.92 ± 0.55, respectively. After 20 min of heating, PV, P-AV, and TOTOX ranged from 2.25 ± 0.45 to 16.05 ± 0.05 meq O2/kg, 1.64 ± 0.29 to 48.66 ± 6.22, and 16.24 ± 0.13 to 61.36 ± 7.21, respectively. Heating altered the oxidation indices ($p < 0.05$), but the magnitude and direction of change varied among brands. Some samples showed declining PV during prolonged heating while P-AV or TOTOX remained elevated, demonstrating the dynamic formation and decomposition of oxidation products. The findings show substantial variation in the initial oxidative status and thermal response of commercial olive oils and indicate that PV, P-AV, and TOTOX should be interpreted together when assessing oxidative quality and thermal stability.

Keywords

Olive Oil, Oxidative Stability, Thermal Oxidation, Peroxide Value, P-anisidine Value, TOTOX, Lipid Oxidation

1. Introduction

Olive oil is highly valued for its nutritional composition, sensory characteristics and bioactive constituents. Its relatively high monounsaturated fatty-acid content, together with phenolic compounds, tocopherols, carotenoids, phytosterols and squalene, contributes to its nutritional value and oxidative behaviour [3, 16].

*Correspondence: Simcha Chinyere Okeyahweh (simcha.chinyere@gmail.com)

Received: 14 September 2026; **Accepted:** 22 September 2026; **Published:** 19 November 2026

Copyright: © The Author(s), 2026. Published by Science Publishing Group. This is an **Open Access** article, distributed under the terms of the Creative Commons Attribution 4.0 License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

Despite these properties, olive oil is susceptible to oxidation during processing, storage, transportation and heating. Lipid oxidation proceeds through the formation of primary products such as hydroperoxides and their subsequent decomposition into secondary products including aldehydes and ketones. These reactions can adversely affect flavour, aroma, nutritional quality and shelf life [12, 16].

Thermal treatment accelerates oxidation by increasing reaction rates, promoting hydroperoxide decomposition and reducing the effectiveness of endogenous antioxidants. The extent of deterioration depends on fatty-acid composition, phenolic content, processing history, packaging, oxygen exposure, light and storage conditions [4, 6, 12, 14, 16].

Peroxide value (PV) measures primary oxidation products, whereas p-anisidine value (P-AV) provides information about secondary aldehydic products. Total oxidation (TOTOX), calculated as 2PV + P-AV, integrates both indices and therefore provides a broader description of oxidative status [12, 18]. Because these indices can change in different directions during heating, their combined interpretation is important when assessing thermally treated oils.

Commercial olive oils may differ substantially in oxidative status because products can originate from different cultivars, production systems, storage histories and distribution chains. Comparative testing of products available in Nigerian markets can therefore provide useful evidence for quality monitoring [7, 11, 16, 17]. The present study evaluated eleven commercially available extra virgin olive oil brands using PV, P-AV and TOTOX before and after heating at 180 ℃ for 10, 15 and 20 min.

2. Materials and Methods

2.1. Materials and Sample Collection

Eleven commercially available extra virgin olive oil brands were purchased from retail outlets in Enugu State, Nigeria. Samples were obtained in their original sealed containers, transported to the laboratory under ambient conditions and stored at approximately 25 ℃ in a cool, dry environment protected from direct sunlight. Eleven brands were selected to provide a comparative set of distinct commercial products accessible at the time of sampling.

Table 1. *Commercial olive oil samples and codes.*

Sample Code	Commercial Olive Oil Brand
S1	Bertolli Extra Virgin Olive Oil
S2	Filippo Berio Extra Virgin Olive Oil
S3	Borges Extra Virgin Olive Oil
S4	Goya Extra Virgin Olive Oil
S5	Gallo Extra Virgin Olive Oil
S6	La Espa ñola Extra Virgin Olive Oil
S7	Laser Extra Virgin Olive Oil
S8	Sabroso Extra Virgin Olive Oil
S9	SPAR Extra Virgin Olive Oil
S10	Marc Joseph Extra Virgin Olive Oil
S11	Betis Extra Virgin Olive Oil

2.2. Study Design and Thermal Treatment

A completely randomized design (CRD) was used. Fresh samples S1–S11 were analysed for PV, P-AV and TOTOX. Separate aliquots of each sample were heated in clean glass beakers on a thermostatically controlled hot plate at 180 ℃ for 10, 15 and 20 min and cooled to ambient temperature before analysis. All determinations were performed in triplicate (n = 3).

2.3. Chemicals and Analytical Methods

Analytical-grade reagents were used throughout. Glacial acetic acid, chloroform, potassium iodide, sodium thiosulfate, starch indicator, p-anisidine reagent, iso-octane and distilled water were used for the oxidation analyses.

Peroxide value was determined using the American Oil Chemists' Society (AOCS) iodometric procedure (Cd 8b-90) [1, 2, 10]. Briefly, 1 g of oil was diluted with the acetic acid–

chloroform solvent, treated with potassium iodide, diluted with distilled water and titrated against sodium thiosulfate using starch as indicator. The peroxide value was calculated according to the analytical equation used in the study.

P-anisidine value was determined according to the AOCS procedure [1]. Oil samples were dissolved in iso-octane and absorbance was measured at 350 nm before and after reaction with p-anisidine reagent. The method estimates secondary aldehydic oxidation products.

TOTOX was calculated as: TOTOX = (2 × PV) + P-AV. This index integrates information from primary and secondary oxidation products.

2.4. Oxidation Calculations

Percentage change in PV, P-AV and TOTOX after 20 min of heating was calculated as [(final value − initial value) / initial value] × 100. The calculation was used to compare the magnitude of change among S1–S11.

2.5. Statistical Analysis

Data were expressed as mean ± standard deviation (SD) and analysed using SPSS version 16. One-way analysis of variance (ANOVA) was used to test differences among samples. Values of $p < 0.05$ were considered statistically significant.

3. Results

3.1. Oxidative State of Fresh Olive Oil Samples

Table 2 presents the oxidative indices of fresh samples S1–S11. PV ranged from 4.50 ± 0.95 meq O_2/kg (S8) to 25.85 ± 0.05 meq O_2/kg (S6). P-AV ranged from 0.43 ± 0.05 (S9) to 17.50 ± 0.89 (S7), while TOTOX ranged from 13.26 ± 1.59 (S1) to 53.92 ± 0.55 (S6). These results indicate substantial differences in initial oxidative status among the commercial brands.

Table 2. *Oxidative indices of fresh olive oil samples.*

Samples	Peroxide value (meq)	P-anisidine value	Total oxidation value
S1	5.85 ±0.87a	1.56 ±0.76bc	13.26 ±1.59a
S2	6.55 ±0.93a	12.93 ±0.72f	26.03 ±1.18b
S3	10.45 ±1.45a	14.63 ±0.49g	35.53 ±2.41c
S4	21.33 ±2.57d	9.29 ±0.23a	51.96 ±5.33de
S5	6.55 ±0.87a	3.95 ±0.71d	17.05 ±1.71a
S6	25.85 ±0.05e	2.22 ±0.65c	53.92 ±0.55e
S7	16.92 ±1.49c	17.50 ±0.89i	51.33 ±3.30de
S8	4.50 ±0.95a	13.47 ±0.60f	22.46 ±2.39b
S9	23.45 ±2.05d	0.43 ±0.05a	47.33 ±4.14d
S10	16.07 ±0.40c	1.11 ±0.09ab	33.24 ±0.72c
S11	10.07 ±1.13b	16.37 ±0.76h	36.51 ±1.59a

Results are expressed as mean ± SD (n = 3). Different superscript letters indicate significant differences at $p < 0.05$.

3.2. Effect of Heat on Peroxide Value

Table 3 shows the effect of heating at 180 ℃ on PV for S1–S11. After 10 min, PV ranged from 1.85 ± 0.05 meq O_2/kg (S1) to 20.15 ± 1.03 meq O_2/kg (S11); after 15 min, from 2.65 ± 0.15 (S2) to 15.17 ± 0.58 (S11); and after 20 min, from 2.25 ± 0.45 (S2) to 16.05 ± 0.05 (S6). Percentage change after 20 min ranged from 5% (S11) to 71% (S10).

Table 3. *Effect of heat on peroxide value of olive oil samples.*

Samples	PV (meq/kg) at 10 min	PV (meq/kg) at 15 min	PV (meq/kg) at 20 min	% change in PV (meq/kg) at 20 min
S1	1.85 ±0.05a	6.30 ±0.80c	7.65 ±0.87cd	24%

Samples	PV (meq/kg) at 10 min	PV (meq/kg) at 15 min	PV (meq/kg) at 20 min	% change in PV (meq/kg) at 20 min
S2	6.20 ±0.90b	2.65 ±0.15a	2.25 ±0.45a	66%
S3	6.20 ±1.20de	12.10 ±0.20f	12.67 ±1.42fg	21%
S4	11.95 ±0.55de	13.32 ±11.40ef	8.87 ±1.63d	58%
S5	15.94 ± 0.55a	4.10 ±0.20b	3.63 ±0.65a	45%
S6	16.89 ±1.14e	13.53 ±1.33g	16.05 ±0.05h	39%
S7	8.50 ±0.40c	11.15 ±0.55ef	11.15 ±0.55de	34%
S8	15.27 ±0.59d	8.23 ±0.31d	13.38 ±1.18g	66%
S9	7.92 ±0.53c	10.52 ±1.11e	7.05 ±0.05c	70%
S10	7.75 ±0.650c	11.08 ±1.51ef	4.65 ±0.35b	71%
S11	20.15 ±1.03f	15.17 ±0.58h	10.65 ±0.30e	5%

Results are expressed as mean ± SD (n = 3). Different superscript letters indicate significant differences at $p < 0.05$.

3.3. Effect of Heat on P-anisidine Value

Table 4 shows the effect of heating on P-AV for S1–S11. After 10 min, values ranged from 0.43 ± 0.05 (S8) to 22.63 ± 1.56 (S10); after 15 min, from 1.11 ± 0.09 (S8) to 20.95 ± 0.69 (S1); and after 20 min, from 1.64 ± 0.29 (S11) to 48.66 ± 6.22 (S5). Percentage change after 20 min ranged from 6% (S4) to 98% (S9).

Table 4. *Effect of heat on p-anisidine value of olive oil samples.*

Samples	PAV at 10 min	PAV at 15 min	PAV at 20 min	% change in PAV at 20 min
S1	12.77 ±3.045de	20.95 ± 0.69fg	16.33 ±1.56bcd	90%
S2	14.63 ±0.49de	9.29 ±0.23def	11.73 ±1.03b	9%
S3	6.65 ±0.49e	9.29 ±0.23def	17.99 ±0.86cd	19%
S4	17.38 ±1.44e	15.13 ±0.89def	14.65 ±0.50cd	6%
S5	4.35 ±0.69b	4.46 ±0.33ab	48.66 ±6.22g	92%
S6	1.11 ±3.43d	19.90 ±10.19g	29.24 ±7.23f	92%
S7	1.10 ±0.62a	10.14 ±0.69bcd	21.59 ±3.4de	19%
S8	0.43 ±0.05c	1.11 ±0.09a	16.37 ±0.76a	18%
S9	13.31 ±1.23de	20.73 ±0.89fg	23.55 ±0.34cde	98%
S10	22.63 ±1.56e	12.51 ± 2.31cde	25.25 ±4.13ef	96%
S11	11.92 ±0.09de	8.49 ±0.34bc	1.64 ±.29a	90%

Results are expressed as mean ± SD (n = 3). Different superscript letters indicate significant differences at $p < 0.05$.

3.4. Effect of Heat on TOTOX Value

Table 5 shows the effect of heating on TOTOX for S1–S11. After 10 min, values ranged from 9.29 ± 0.52 (S5) to 52.22 ± 2.06 (S11); after 15 min, from 12.66 ± 0.63 (S5) to 53.82 ± 5.31 (S6); and after 20 min, from 16.24 ± 0.13 (S2) to 61.36 ± 7.21 (S6). Percentage change after 20 min ranged from 4% (S10) to 70% (S5).

Table 5. Effect of heat on TOTOX value of olive oil samples.

Samples	Totox at 10 min	Totox at 15min	Totox at 20 min	% change in at 20 min
S1	16.45 ±2.94b	33.55 ±0.91c	31.63 ±2.40c	58%
S2	27.17 ±1.15b	21.34 ±0.19b	16.24 ±0.13a	38%
S3	49.05 ±3.74f	41.23 ±0.31e	43.32 ±2.05d	18%
S4	49.27 ±1.55f	35.69 ±7.62c	32.38 ±2.76c	38%
S5	9.29 ±0.52a	12.66 ±0.63a	55.92 ±6.36e	70%
S6	44.88 ±1.61d	53.82 ±5.31g	61.36 ±7.21e	12%
S7	18.10 ±0.18b	32.44 ±1.79c	43.9 ±4.33d	14%
S8	37.64 ±1.04d	18.12 ±0.93a	29.45 ±2.83c	24%
S9	29.14 ±2.12c	44.58 ±1.91f	34.83 ±0.96c	26%
S10	37.83 ±2.85d	34.81 ±5.23cd	34.55 ±3.44c	4%
S11	52.22 ±2.06f	38.83 ±1.36cd	22.94 ±0.51b	38%

Results are expressed as mean ± SD (n = 3). Different superscript letters indicate significant differences at $p < 0.05$.

4. Discussion

4.1. Oxidative Quality of Fresh Olive Oil Samples

The fresh samples showed marked differences in PV, P-AV and TOTOX. PV, an indicator of primary lipid oxidation, was lowest in S8 and highest in S6. S4, S6 and S9 exceeded the 20 meq O_2/kg maximum specified for extra virgin olive oil by the International Olive Council and Codex standards [8, 9]. This observation indicates that some products had a relatively high primary oxidation burden at the time of analysis. However, the study did not independently determine storage duration, cultivar, antioxidant concentration or supply-chain conditions for individual brands; therefore, these factors should be considered possible explanations rather than demonstrated causes.

P-AV also varied widely. S7 had the highest fresh P-AV, whereas S9 had the lowest. The combination of relatively high PV and low P-AV in S9 contrasts with the relatively moderate PV and high P-AV observed in S7. Such differences are consistent with the dynamic nature of lipid oxidation: hydroperoxides can accumulate initially and later decompose into aldehydic products. Consequently, PV alone may not adequately represent the overall oxidative condition of an oil [15, 18].

TOTOX integrated the two oxidation indices and showed a broad range among S1–S11. The variation indicates that the brands entered the experiment with different oxidative histories. Packaging, light exposure, oxygen availability, storage temperature, processing history and antioxidant composition are recognised factors affecting olive-oil stability [7, 11, 16]. These variables were not directly measured in the present study and therefore cannot be assigned as specific causes for individual samples.

4.2. Effect of Heat on Peroxide Value

Heating produced different PV trajectories among S1–S11. Some samples showed increases, whereas others declined after prolonged heating. This behaviour is expected because heating can simultaneously accelerate hydroperoxide formation and hydroperoxide decomposition. A declining PV during heating therefore does not necessarily mean that oxidation has decreased; it may indicate that primary oxidation products are being converted into secondary products [4, 5, 13-15, 18].

The largest percentage change after 20 min occurred in S10, while S11 showed the smallest percentage change. S1 increased from 1.85 meq O_2/kg at 10 min to 7.65 meq O_2/kg at 20 min, whereas S2 declined from 6.20 to 2.25 meq O_2/kg. These contrasting patterns show why PV should be interpreted together with P-AV and TOTOX when assessing heated oils. The present data demonstrate different responses to the same temperature and heating duration, but the mechanisms responsible for each brand cannot be confirmed without measurements of fatty-acid composition and antioxidants.

4.3. Effect of Heat on P-anisidine Value

Heating markedly changed P-AV in several samples, particularly S5, S6, S9 and S10. At 20 min, S5 recorded the highest P-AV, followed by S6 and S10, indicating substantial accumulation of secondary aldehydic oxidation products. S9 showed the largest percentage change. In contrast, S4 changed relatively

little over the same period. The different responses indicate that the initial composition and oxidative history of each product influenced its behaviour during thermal treatment.

The decline observed in S11 from 11.92 at 10 min to 1.64 at 20 min should not be interpreted as evidence of improved oil quality. Secondary oxidation products can themselves undergo further reactions, volatilisation or degradation during prolonged heating [5, 15]. Thus, a lower P-AV after heating can coexist with continued oxidative deterioration. The combined results reinforce the need to evaluate secondary oxidation alongside PV.

4.4. Effect of Heat on TOTOX Value

TOTOX integrates PV and P-AV and therefore captures changes occurring across primary and secondary oxidation. At 20 min, S6 had the highest TOTOX value, followed by S5 and S7, whereas S2 had the lowest. S5 showed the largest percentage increase, while S10 showed the smallest percentage change. The divergent trajectories reflect the fact that oxidation products are continuously formed, transformed and degraded during heating [12, 15, 18].

The results also demonstrate why no single oxidation index should be interpreted in isolation. Samples with declining PV may still show increasing P-AV or TOTOX, indicating progression from primary to secondary oxidation. Conversely, reductions in TOTOX can occur when measurable oxidation products undergo further degradation. The present study therefore supports the use of PV, P-AV and TOTOX together when comparing thermal oxidative behaviour of commercial olive oils.

5. Conclusion

Eleven commercial extra virgin olive oil brands showed substantial differences in oxidative status before heating and in their responses to heating at 180 ℃. PV, P-AV and TOTOX changed differently among S1–S11, demonstrating that thermal oxidation is dynamic and that a single oxidation index cannot fully describe oil deterioration. The combined assessment of primary and secondary oxidation indices provides a broader basis for evaluating the oxidative quality and thermal behaviour of commercial olive oils.

6. Recommendations

Routine quality assessment of commercial olive oils should include PV, P-AV and TOTOX rather than relying on a single index. Storage and distribution should minimise exposure to heat, light and oxygen. Regulatory and quality-control laboratories may use comparative oxidation testing to monitor products marketed as extra virgin olive oil. Further studies should measure fatty-acid composition, total phenolic compounds, tocopherols and other antioxidants, and should investigate repeated heating cycles and storage conditions to explain differences among brands.

Abbreviations

AOCS	American Oil Chemists' Society
ANOVA	Analysis of Variance
CRD	Completely Randomized Design
P-AV	p-anisidine Value
PV	Peroxide Value
SD	Standard Deviation
TOTOX	Total Oxidation

Author Contributions

Simcha Chinyere Okeyahweh: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Writing – original draft

Lazarus Afamefuna Okoye: Conceptualization, Formal Analysis, Supervision, Validation, Writing – review & editing

Patrick Okechukwu Ugwudike: Supervision, Validation, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] American Oil Chemists' Society. (1998). Official method Cd 8b-90: Peroxide value, acetic acid–isooctane method. In Official methods and recommended practices of the American Oil Chemists' Society. AOCS Press.

[2] American Oil Chemists' Society. (2024). Official methods and recommended practices of the AOCS (7th ed.). AOCS Press.

[3] Boskou, D., Tsimidou, M. Z., & Blekas, G. (2021). Olive oil: Chemistry and technology (3rd ed.). AOCS Press.

[4] Choe, E., & Min, D. B. (2007). Chemistry of deep-fat frying oils. Journal of Food Science, 72(5), R77–R86. https://doi.org/10.1111/j.1750-3841.2007.00352.x

[5] Frankel, E. N. (2014). Lipid oxidation (2nd ed.). Woodhead Publishing.

[6] Gagour, J., El Gharby, S., Harhar, H., Kartah, B., & Charrouf, Z. (2024). Recent advances in assessing the oxidative stability and quality of virgin olive oil during storage and thermal processing. Foods, 13, 1125. https://doi.org/10.3390/foods13071125

[7] Gharby, S., Harhar, H., Kartah, B., El Monfalouti, H., & Charrouf, Z. (2023). Factors affecting the quality and oxidative stability of virgin olive oil: A review. Foods, 12(3), 512. https://doi.org/10.3390/foods12030512

[8] Gündüz, G. T., & Baştürk, A. (2023). Assessment of peroxide value, p-anisidine value and oxidative quality of commercially available edible oils marketed in Türkiye. Food Control, 152, 109865. https://doi.org/10.1016/j.foodcont.2023.109865

[9] International Olive Council. (2023). Trade standard applying to olive oils and olive-pomace oils (COI/T.15/NC No. 3/Rev. 19). International Olive Council.

[10] International Organization for Standardization. (2017). ISO 3960: 2017. Animal and vegetable fats and oils—Determination of peroxide value—Iodometric (visual) endpoint determination. International Organization for Standardization. https://doi.org/10.31030/2641749

[11] Lozano-Castellón, J., López-Yerena, A., Rinaldi de Alvarenga, J. F., Vallverdú-Queralt, A., & Lamuela-Raventós, R. M. (2023). Phenolic compounds in extra virgin olive oil: Composition, stability, and health effects. Antioxidants, 12(9), 1776. https://doi.org/10.3390/antiox12091776

[12] Ma, X., Wang, Y., Li, H., Zhang, Y., Liu, Z., & Chen, Q. (2023). Advances in lipid oxidation mechanisms and oxidative stability assessment of edible vegetable oils. Food Chemistry, 405, 134814. https://doi.org/10.1016/j.foodchem.2022.134814

[13] Matos, C., Sanches Silva, A., & Peres, A. M. (2022). Thermal degradation and oxidative stability of edible oils: Current analytical approaches and quality indicators. Foods, 11(23), 3816. https://doi.org/10.3390/foods11233816

[14] Mehany, T., El-Sayed, S. M., Hassan, A., & Abdel-Aziz, M. (2025). Effect of thermal processing on the oxidative stability and antioxidant properties of edible oils: A comprehensive review. Food Reviews International. Advance online publication.

[15] Shahidi, F., & Zhong, Y. (2020). Lipid oxidation and improving the oxidative stability. Chemical Society Reviews, 49(4), 1145–1190. https://doi.org/10.1039/C9CS00409A

[16] Stefanidis, S., Kalogeropoulos, N., & Andrikopoulos, N. K. (2023). Oxidative stability, phenolic composition, and quality characteristics of extra virgin olive oil during storage and thermal treatment. Antioxidants, 12(8), 1548. https://doi.org/10.3390/antiox12081548

[17] Tarapoulouzi, M., Kalogeropoulos, N., Chiou, A., & Andrikopoulos, N. K. (2022). Evaluation of peroxide value, p-anisidine value and TOTOX index for assessing the oxidative deterioration of edible oils during thermal processing. Foods, 11(19), 3024. https://doi.org/10.3390/foods11193024

[18] Codex Alimentarius Commission. (2023). Standard for Olive Oils and Olive Pomace Oils (CXS 33-1981). Food and Agriculture Organization of the United Nations (FAO)/World Health Organization (WHO).