

Evaluation of Chemical and Sensory Quality Indicators of Olive Oil from Selected Varieties in Qasr Al-Akhiar and Tarhuna — Libya

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ABSTRACT

Five olive oil samples extracted from Arbosana, Gargashi, and Rossly cultivars grown in the Gmatha and Tarhuna regions of northwestern Libya were evaluated against International Olive Council (IOC, 2019) and European Commission (EC 2568/91) standards. Free fatty acid (FFA) content ranged from 0.468% to 4.630%, and peroxide values (PV) from 6.0 to 26.0 meq O₂/kg, with only one sample — Arbosana from Tarhuna — meeting the Extra Virgin threshold on both parameters simultaneously. Carotenoid concentrations ranged from 18.27 to 30.87 mg/kg, while chlorophyll content varied sharply between 26.54 and 280.80 mg/kg, a spread that largely reflects differences in harvest maturity and cultivar pigmentation. Sensory evaluation corroborated the chemical data: the two Tarhuna-origin samples exhibited moderate fruitiness and pungency, consistent with higher phenolic content, whereas samples from Gmatha scored lower on both attributes. Two samples were classified as Lampante grade, unsuitable for direct consumption without refining. The results indicate that post-harvest handling — specifically the interval between picking and milling, mechanical damage during transport, and storage conditions — is at least as consequential as cultivar identity in determining final oil quality. Practical implications for Libyan olive oil producers and regulatory bodies are discussed.

KEYWORDS: olive oil quality; free fatty acid; peroxide value; carotenoids; chlorophyll; Libya; IOC standards; post-harvest handling; Arbosana; Tarhuna

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1. INTRODUCTION

Olive cultivation is an important part of Libya's agricultural heritage and continues to play a significant role in the country's rural economy. Although Libya has a long history of olive growing, the sector remains less documented than in several Mediterranean olive-producing countries. Recent evidence indicates that olive oil production in Libya has fluctuated considerably over recent decades, reflecting the influence of climatic conditions, production capacity, and agricultural management practices. Therefore, further scientific attention is needed to better understand the characteristics, quality, and development potential of Libyan olive oil (Al-Baqi & Muhammad, 2026). Olive cultivation is mainly concentrated in areas with relatively suitable rainfall and moderate climatic conditions, particularly along the coastal belt and in traditional producing areas such as Tarhuna and other western and eastern agricultural regions of Libya.

Despite this scale, only a small fraction of Libyan oil consistently reaches the Extra Virgin grade on international markets, a gap that is routinely attributed to poor post-harvest practices rather than any inherent deficiency in cultivar quality.

Free fatty acid content and peroxide value are the two primary chemical markers used in global olive oil grading systems. Elevated FFA is usually a sign of enzymatic lipolysis, which accelerates when damaged or bruised fruit is allowed to sit for extended periods before milling (Servili et al., 2004). High peroxide value, by contrast, signals oxidative stress, which can result from prolonged exposure to heat, light, or oxygen during storage. Together, these two indices provide a useful diagnostic picture of where quality was lost — whether in the field, during transport, at the mill, or after extraction.

Pigment composition — specifically carotenoids and chlorophylls — adds another dimension to quality characterization. Both pigment classes contribute to color and carry antioxidant capacity, though their relative concentrations depend heavily on harvest timing and cultivar genetics (Minguez-Mosquera et al., 1990). A high chlorophyll concentration generally indicates earlier-stage green fruit; as olives ripen and turn from green to black, chlorophyll degrades and carotenoids increasingly dominate. Chlorophyll in oil is a double-edged feature: it signals freshness and phenolic richness when measured at extraction, but the same compounds accelerate photooxidation during storage, making opaque packaging essential.

Sensory evaluation under the IOC panel test protocol provides a complementary perspective that instrumental analysis alone cannot capture. The presence or absence of off-flavors such as fusty, musty, or rancid notes reflects the cumulative history of the fruit — from grove to glass — in a way that no single chemical index fully encodes.

This study examines five olive oil samples drawn from Arbosana, Gargashi, and Rossly cultivars cultivated in Gmatha and Tarhuna, two production zones with distinct microclimates and management practices. Our primary objectives were: (i) to characterize chemical and sensory quality against IOC (2019) standards; (ii) to assess whether region or cultivar is the stronger predictor of quality variation; and (iii) to identify the most likely failure points in the post-harvest chain that account for the observed range in quality outcomes.

2. MATERIALS AND METHODS

2.1 Sample Collection

Five olive oil samples were obtained directly from local producers in November 2025. Samples 4 and 5 originated from Tarhuna (Rossly and Arbosana cultivars, respectively), harvested on 2 November 2025 and cold-extracted within 24 hours. Samples 1, 2, and 3 were sourced from Gmatha (Arbosana and Gargashi cultivars), with variable intervals between harvest and milling. All samples were collected in dark glass bottles, stored at 15–18°C, and analyzed within one week of collection.

2.2 Free Fatty Acid Determination

FFA was determined by titration according to IOC/T.20/Doc. No 34 (2018). Approximately 5 g of oil were dissolved in 50 mL of neutralized ethanol–diethyl ether solution (1:1, v/v) and titrated with 0.1 N KOH in the presence of phenolphthalein indicator. Results are expressed as percentage of oleic acid. All measurements were performed in triplicate and averaged.

2.3 Peroxide Value Determination

Peroxide value was measured by the iodometric method per IOC/T.20/Doc. No 35 (2017). Samples of 1–2 g were dissolved in acetic acid–chloroform (3:2, v/v), saturated KI solution was added, and the liberated iodine was titrated with 0.01 N sodium thiosulfate using starch as indicator. Results are expressed in milliequivalents of active oxygen per kilogram of oil (meq O₂/kg).

2.4 Pigment Analysis

Carotenoid and chlorophyll concentrations were measured spectrophotometrically using the method of Minguez-Mosquera et al. (1990). Oils were dissolved in n-hexane and absorbance was read at 470 nm for carotenoids and at 670 nm for chlorophylls. Concentrations were calculated using published molar absorption coefficients: $\epsilon^{470} = 2000$ for carotenoids and $\epsilon = 613$ (based on the conversion factor 4597.5) for chlorophylls, expressed as mg/kg.

2.5 Sensory Evaluation

Sensory assessment followed the IOC panel test method (IOC/T.20/Doc. No 15/Rev. 10, 2018). A trained panel of eight assessors evaluated each sample for the presence of positive attributes (fruitiness, bitterness, pungency) and negative defects (fusty, musty, rancid, winery, metallic) using a 10-cm unstructured scale. Samples were presented in dark coded glasses at 28°C. The panel coordinator calculated medians and assigned a quality category based on the absence of defects and the median fruitiness score.

2.6 Quality Standards Applied

IOC (2019) trade standard for olive oil and EC Regulation 2568/91 were used as grading references. Key thresholds: Extra Virgin — FFA ≤0.8%, PV ≤20 meq O₂/kg, no sensory defects; Virgin — FFA ≤2.0%, PV ≤20; Ordinary Virgin — FFA ≤3.3%; Lampante — FFA >3.3% or sensory defects present.

3. RESULTS

3.1 Free Fatty Acid Content

Table 1 presents FFA values for all five samples, arranged by ascending acidity. The range — 0.468% to 4.630% — is wide enough to span three IOC quality categories within a single study, which alone suggests that something other than cultivar genetics is driving the variance.

Sample 5 (Arbosana, Tarhuna) posted the lowest FFA at 0.468%, comfortably within the Extra Virgin ceiling of 0.8%. Samples 2 and 4 (Gargashi and Rossly, Tarhuna and Gmatha) fell in the Virgin range at 1.070% and 1.410%, respectively. Samples 1 and 3, both from Gmatha, exceeded the 3.3% threshold for ordinary-grade oil and were classified as Lampante.

Table 1. Free fatty acid content of olive oil samples and IOC classification

Sample	Cultivar & Region	Volume (mL)	FFA (%)	IOC Classification
5	Arbosana (Tarhuna)	0.83	0.468	Extra Virgin
2	Gargashi (Gmatha)	1.90	1.070	Virgin
4	Rossly (Tarhuna)	2.50	1.410	Virgin
1	Arbosana (Gmatha)	7.60	4.284	Lampante
3	Gargashi (Gmatha)	8.21	4.630	Lampante

IOC (2019) thresholds: Extra Virgin $\leq 0.8\%$; Virgin $\leq 2.0\%$; Ordinary $\leq 3.3\%$; Lampante $> 3.3\%$

3.2 Peroxide Value

Peroxide values (Table 2) mirrored the FFA pattern in part, though with one notable divergence. Sample 5 was again the clear standout at 6.0 meq O₂/kg, a figure more typical of freshly extracted oil than anything that has spent meaningful time at ambient temperature. Sample 2 registered 17.0 meq O₂/kg, below the 20-unit ceiling. The remaining three samples exceeded the limit, with Sample 3 reaching 26.0 meq O₂/kg.

The case of Sample 4 (Rossly, Tarhuna) is worth noting separately. Its PV of 21.0 meq O₂/kg sits just above the threshold despite a relatively moderate FFA of 1.410%. This decoupling — low lipolysis but elevated oxidation — suggests the quality problem here is storage-related rather than harvest-related.

Table 2. Peroxide values of olive oil samples relative to the IOC limit (20 meq O₂/kg)

Sample	Cultivar & Region	Volume (mL)	PV (meq O ₂ /kg)	Status (limit ≤ 20)
5	Arbosana (Tarhuna)	3.0	6.0	Compliant ✓
2	Gargashi (Gmatha)	8.5	17.0	Compliant ✓
4	Rossly (Tarhuna)	10.5	21.0	Exceeds limit
1	Arbosana (Gmatha)	10.8	21.6	Exceeds limit
3	Gargashi (Gmatha)	13.0	26.0	Exceeds limit

3.3 Carotenoid Content

Carotenoid concentrations (Table 3) ranged from 18.27 to 30.87 mg/kg, with a mean of 21.47 mg/kg. Sample 4 (Rossly, Tarhuna) recorded the highest value at 30.87 mg/kg, suggesting either a cultivar predisposition toward carotenoid accumulation, a greener harvest stage, or both. Samples 3 and 5 shared the lowest reading of 18.27 mg/kg.

Table 3. Carotenoid content of olive oil samples determined at 470 nm

Sample	Cultivar & Region	Absorbance at 470 nm	Carotenoids (mg/kg)
1	Arbosana (Gmatha)	0.287	19.13
2	Gargashi (Gmatha)	0.327	21.80
3	Gargashi (Gmatha)	0.274	18.27
4	Rossly (Tarhuna)	0.463	30.87
5	Arbosana (Tarhuna)	0.274	18.27

Formula applied: Carotenoids (mg/kg) = $(A_{470} \times 10^6) / (\epsilon \times c \times l)$; $\epsilon = 2000$, $c = 7.5$ g/100 mL, $l = 1$ cm

3.4 Chlorophyll Content

Chlorophyll values (Table 4) showed the sharpest contrast of any parameter measured in this study, spanning nearly an order of magnitude from 26.54 to 280.80 mg/kg. The Arbosana samples anchored the low end (Tarhuna: 26.54 mg/kg; Gmatha: 38.72 mg/kg), while the two Gargashi samples from Gmatha and the Rossly sample from Tarhuna occupied the high range (201.85, 221.21, and 280.80 mg/kg, respectively).

Table 4. Chlorophyll content of olive oil samples determined at 670 nm

Sample	Cultivar & Region	Absorbance at 670 nm	Chlorophyll (mg/kg)
5	Arbosana (Tarhuna)	0.122	26.54
1	Arbosana (Gmatha)	0.178	38.72
2	Gargashi (Gmatha)	0.928	201.85
3	Gargashi (Gmatha)	1.017	221.21
4	Rossly (Tarhuna)	1.291	280.80

Formula applied: Chlorophylls (mg/kg) = $(A^{670} \times 10^6) / 4597.5$

3.5 Sensory Evaluation

No defects were detected in any of the five samples (Table 5). Samples 4 and 5, both from Tarhuna, exhibited moderate fruitiness combined with moderate pungency, the combination that characterizes fresher, phenolic-rich oils. The three Gmatha samples either lacked pungency entirely or registered it only at the slight level, and fruitiness in Sample 2 was slight rather than moderate.

Table 5. Sensory evaluation results for all samples under IOC panel test conditions

Sample	Cultivar & Region	Defects	Fruitiness	Pungency	Bitterness	Grade
1	Arbosana (Gmatha)	None	Moderate	Slight	Slight	Virgin
2	Gargashi (Gmatha)	None	Slight	Slight	Slight	Virgin
3	Gargashi (Gmatha)	None	Moderate	Slight	Slight	Virgin
4	Rossly (Tarhuna)	None	Moderate	Moderate	Slight	Extra Virgin
5	Arbosana (Tarhuna)	None	Moderate	Moderate	Slight	Extra Virgin

4. DISCUSSION

4.1 Free Fatty Acid Variation and Its Likely Causes

The 0.468% FFA recorded for Sample 5 is consistent with what Cuevas et al. (2024) reported for Arbosana oils produced under controlled, mechanized harvesting conditions: the cultivar is not inherently prone to high acidity when conditions allow for prompt processing. The contrast with Sample 1 (Arbosana from Gmatha, 4.284%) is therefore striking. The same cultivar, presumably carrying the same genetic predisposition toward low acidity, produced an oil that barely qualifies as Lampante grade. A difference of this magnitude between two sites does not have a genetic explanation.

The most parsimonious explanation involves the cumulative effect of practices that accelerate lipase activity: delayed milling, mechanical bruising during hand or mechanical harvest, and warm-temperature holding of fruit before processing. Servili et al. (2004) established that reducing the harvest-to-mill interval below 24 hours substantially suppresses FFA accumulation, regardless of cultivar. Arvaniti et al. (2020) documented comparable acidity spikes in oils derived from fruit infested with *Bactrocera oleae*, whose larval tunneling creates anaerobic microenvironments where lipolytic enzymes run unchecked. Without direct evidence of infestation in these samples, pest pressure remains a plausible contributing factor for the Gmatha oils rather than a confirmed cause. The geography also matters in less obvious ways. Gmatha lies at lower elevation than Tarhuna and experiences higher ambient temperatures during October and November, the typical harvest window in northwestern Libya. Higher ambient heat during the holding period before milling would accelerate both enzymatic and microbial lipase activity, compounding the quality loss.

4.2 Peroxide Values and the Distinction Between Lipolytic and Oxidative Damage

Sample 5's PV of 6.0 meq O₂/kg places it squarely in the range seen in fresh, well-protected oils. The value for Sample 2 (17.0 meq O₂/kg) is elevated but still within IOC limits, suggesting recent extraction with some subsequent oxygen exposure. What is analytically useful here is Sample 4's profile: 21.0 meq O₂/kg against an FFA of only 1.410%. In oxidative degradation, peroxides form before secondary oxidation products and before FFA necessarily rises, because the mechanism is distinct — it involves unsaturated fatty acid autoxidation rather than ester hydrolysis (Morales et al., 2013). Sample 4 therefore presents as a relatively clean oil at the point of extraction that was subsequently exposed to suboptimal storage conditions, most likely insufficient exclusion of oxygen and possibly light.

This matters practically. Sample 4 is not beyond rescue in the sense that its lipolysis was controlled; the oxidation damage, if caught at an earlier stage and with proper nitrogen-blanketed stainless-steel storage, might have been largely prevented. The same cannot be said for Samples 1 and 3, where both mechanisms appear to have operated.

4.3 Pigment Profiles as Indicators of Harvest Stage and Cultivar Character

The eight-fold difference in chlorophyll between the lowest (Sample 5, 26.54 mg/kg) and highest (Sample 4, 280.80 mg/kg) values recorded here is not unusual when comparing oils harvested at different maturity indices. Minguez-Mosquera et al. (1990) documented progressive chlorophyll degradation as the olive ripening index increases from 0 (fully green) toward 7 (fully black), with most of the loss occurring in the 2–5 range during veraison. The low chlorophyll in Arbosana samples, combined with their lower carotenoid readings, is consistent with more mature fruit at harvest, while Gargashi and Rossly oils — with substantially higher chlorophylls — were likely extracted from greener fruit.

One implication that operators should not overlook: high-chlorophyll oils are photosensitive. Pheophytin, a chlorophyll degradation product that forms even under mild acidic conditions, acts as a photosensitizer and accelerates singlet-oxygen oxidation pathways under light exposure (Aparicio & Roda, 1994). Samples 3 and 4, with their 221 and 280 mg/kg chlorophyll readings, require dark glass or opaque packaging and cool storage as a basic quality-preservation measure, independent of everything else.

4.4 Sensory Data in Context

The absence of any detectable defects across all five samples — including the two Lampante-classified oils — is initially surprising. Lampante classification is typically associated with a combination of chemical and sensory failures, yet here the chemical thresholds were exceeded while the sensory profile remained acceptably clean. This is not unprecedented: Vichi et al. (2003) noted that some Lampante-grade oils, particularly those whose high FFA arises from relatively recent enzymatic activity rather than prolonged microbial fermentation, may still lack the fusty or rancid notes associated with prolonged storage of degraded fruit. The panel in the present study was trained but the sample set was small, and the panel's sensitivity at the lower end of the scale may not have been sufficient to detect incipient off-notes that a more extensive tasting would have revealed. (Estuty et al., 2024).

What is clear from the sensory data is that the Tarhuna samples genuinely show a qualitative difference in positive attributes. Moderate pungency and moderate fruitiness in Samples 4 and 5 are consistent with a higher content of oleocanthal and oleacein — the compounds responsible for the throat-scratch and bitter-green flavor characteristics of fresh Extra Virgin oils (Beauchamp et al., 2005). While no direct phenolic quantification was performed here, the sensory pattern is consistent with the hypothesis that Tarhuna-origin oils have higher total phenol content, a hypothesis that future chromatographic work should test explicitly.

4.5 Region Versus Cultivar as Quality Predictors

The most direct test this dataset offers for the region-versus-cultivar question is the comparison within Arbosana: Sample 1 (Gmatha) produced Lampante-grade oil with 4.284% FFA and 21.6 meq O₂/kg PV, while Sample 5 (Tarhuna) produced the best oil in the study on every single metric. The cultivar is identical. The region, and by extension the production chain associated with that region, accounts for all the difference. This finding is broadly consistent with what Ranalli et al. (2003) observed in Italian olive-growing regions: inter-cultivar variation in quality is real but frequently swamped by the variance introduced by post-harvest logistics.

None of this means cultivar is irrelevant to Libya's olive oil development strategy. The Rossly sample's exceptional pigment profile, combined with its reasonable FFA and its high sensory scores, suggests genuine cultivar-specific potential that could be exploited if storage conditions were addressed. But the data argue clearly that investing in harvest timing protocols, short-haul logistics, and mill hygiene would yield larger and more immediate quality gains than any cultivar selection program.

5. CONCLUSIONS

Of the five oils studied, only Sample 5 — Arbosana extracted in Tarhuna with a short harvest-to-mill interval — simultaneously met the Extra Virgin standard on both primary chemical criteria and the sensory panel test. Two samples from Gmatha failed both the FFA and PV thresholds sufficiently to be classified as Lampante, meaning they require industrial refining before they can be sold for human consumption. The gap between these outcomes within a geographically compact study region, and within a single cultivar in the case of Arbosana, points to post-harvest practice as the dominant quality determinant.

Chlorophyll content varied by nearly an order of magnitude, partly reflecting different harvest maturities across the samples. This has direct consequences for storage: high-chlorophyll oils are photosensitive and must be kept in opaque containers regardless of their chemical grade at extraction.

Priorities for quality improvement in Libyan olive oil production, based on these findings, are: reducing the harvest-to-mill interval to below 24 hours; minimizing mechanical damage to fruit during collection and transport; implementing nitrogen-blanketed stainless-steel storage; monitoring for *Bactrocera oleae* infestation; and adopting cold-extraction protocols that keep paste temperature below 27°C. Regulatory adoption of IOC (2019) as the national grading standard, combined with routine market surveillance, would provide the institutional framework within which these changes can be enforced and incentivized.

Future work should address the phenolic composition of these cultivars directly, using validated HPLC methods, and should apply principal component analysis to a larger set of samples drawn from multiple harvest years and more production regions. A shelf-life study tracking the oxidative trajectory of these oils under different storage regimes would also substantially strengthen the evidence base for post-harvest recommendations.

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