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# Comparative Nutritional and Phytochemical Evaluation of Cold-Pressed Versus Refined Coconut Oil: A Laboratory Study

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**ABSTRACT:** Background: Coconut oil is a dietary and cultural staple across the South Indian coconut belt spanning Kerala, Tamil Nadu, and Karnataka. Cold-pressed (virgin) and industrially refined coconut oils are both widely marketed, yet consumers in South India have limited comparative information on how processing influences the retention of bioactive micronutrients, antioxidant capacity, and oxidative stability while preserving basic food-grade quality. Objective: To compare the physicochemical quality, nutritional and phytochemical composition, fatty-acid profile, and antioxidant properties of cold-pressed and refined coconut oil using standard laboratory methods. Methods: In this laboratory-based comparative study, six analytical batches each of cold-pressed and refined coconut oil (n = 12 total) were evaluated for moisture, free fatty acid (FFA), peroxide value, iodine value, and saponification value; for vitamin E, total carotenoids, total phenolics (Folin-Ciocalteu), DPPH radical-scavenging activity, and oxidative stability (Rancimat); and for fatty-acid composition by gas chromatography. Data are expressed as mean ± standard deviation and compared using independent-samples t-tests (df = 10) with Cohen's d effect sizes; $p < 0.05$ was significant. Results: Cold-pressed oil retained

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markedly higher vitamin E (48.31 ± 2.81 vs 20.06 ± 3.35 mg/kg), total carotenoids (2.757 ± 0.480 vs 0.768 ± 0.176 mg/kg), and total phenolics (75.42 ± 8.10 vs 26.99 ± 5.03 mg GAE/kg; mean difference 48.43), with correspondingly greater DPPH inhibition (58.93 ± 3.37 vs 22.73 ± 1.90 %) and oxidative stability (18.83 ± 0.63 vs 12.02 ± 0.81 h); all $p < 0.001$ with very large effect sizes. Refined oil showed lower moisture, FFA, and peroxide value, consistent with purification. Fatty-acid composition was essentially equivalent between oils (both lauric-dominant, ~90-92 % saturated). Conclusion: Cold-pressed coconut oil is nutritionally and antioxidant-superior, whereas refined oil is more purified; fatty-acid composition is equivalent. These low-cost quality indicators are relevant to consumers and the coconut industry across South India.

## 1. INTRODUCTION

Coconut oil occupies a distinctive place in the food culture, cuisine, and traditional medicine of South India. The southern states of Kerala, Tamil Nadu, and Karnataka constitute the country's coconut belt, where the crop underpins rural livelihoods and where coconut oil is used routinely for cooking, seasoning, infant and elder care, and personal grooming. Given this deep culinary and economic reliance, the quality and nutritional attributes of the oils reaching South Indian households are of direct public interest. In recent years the market has diversified sharply, with cold-pressed or "virgin" coconut oils positioned as premium, minimally processed products alongside conventionally refined coconut oils that dominate the mass market.

The two product classes differ fundamentally in how they are manufactured. Cold-pressed (virgin) coconut oil is extracted from fresh coconut kernel or coconut milk, typically by mechanical expression or low-temperature separation, without the application of high heat or chemical solvents [1-3]. This gentle processing is intended to preserve the natural minor constituents of the oil-tocopherols, carotenoids, and polyphenolic compounds-that contribute aroma, colour, and biological activity. Refined coconut oil, in contrast, is generally produced from dried copra and subsequently refined, bleached, and deodorised (RBD). Refining removes moisture, free fatty acids, colour pigments, and volatile impurities, yielding a bland, colourless, thermally stable oil, but the same purification steps can also strip out heat-labile micronutrients and antioxidant phytochemicals [4,5].

The nutritional identity of coconut oil is defined chiefly by its fatty-acid composition. Coconut oil is unusual among culinary fats in being predominantly saturated (roughly 90 %) and rich in medium-chain fatty acids, with lauric acid (C12:0) alone accounting for close to half of the total fatty acids [6,7]. This composition is the basis of the long-running scientific and public debate over coconut oil and cardiovascular health. Systematic reviews and controlled trials have reported that coconut oil raises LDL cholesterol relative to unsaturated plant oils, prompting caution from some authorities [8], while other reviews emphasise the distinct metabolic handling of medium-chain fatty acids and the absence of consistent hard clinical endpoints [9]. Randomised comparisons against olive oil and butter have shown nuanced lipid effects , meta-analyses of body-weight outcomes have been largely null [10], and narrative and mechanistic reviews continue to explore lauric acid's antimicrobial, anti-inflammatory, and other bioactivities Importantly, this controversy concerns the saturated-fat backbone, which is shared by cold-pressed and refined oils alike; it does not address the minor bioactive fraction that processing can differentially preserve or destroy.

The minor constituents are nonetheless nutritionally meaningful. Tocopherols (vitamin E), carotenoids, and phenolic compounds contribute antioxidant capacity, protect the oil against oxidative rancidity, and have been linked to the anti-inflammatory and skin-protective properties attributed to virgin coconut oil [11,12]. From a food-quality standpoint, the same antioxidants prolong shelf life, whereas indices such as moisture, FFA, and peroxide value reflect purity and the extent of hydrolytic and oxidative deterioration. A direct, side-by-side laboratory comparison of these attributes therefore offers practical value to South Indian consumers weighing the premium price of cold-pressed oil against its purported benefits, and to producers seeking objective quality benchmarks.

Despite the abundance of coconut oil in South Indian markets, accessible comparative data generated using simple, low-cost analytical methods remain limited [13]. The present laboratory study was undertaken to address this gap. Its objective was to compare cold-pressed and refined coconut oil across a panel of physicochemical quality indices, nutritional and phytochemical

constituents, antioxidant activity, oxidative stability, and gas-chromatographic fatty-acid composition, and thereby to characterise how processing shapes the overall quality profile of the two most common coconut-oil types available in South India.

## 2. MATERIALS AND METHODS

### 2.1 Study design and setting

This was a laboratory-based comparative analytical study conducted at the Department of Food Science and Technology/Biochemistry South India, during [v.no. 2536]. The study compared two categories of coconut oil-cold-pressed (virgin) and industrially refined-obtained as commercially representative products from the South Indian market. Six independent analytical batches of each oil type were evaluated, giving twelve samples in total (n = 6 per group).

### 2.2 Oil samples

Cold-pressed coconut oil was represented by oil obtained by mechanical cold expression of fresh coconut kernel without external heating or solvent extraction. Refined coconut oil was represented by conventionally refined, bleached, and deodorised (RBD) oil produced from copra. All samples were stored in clean, amber glass containers away from light and heat until analysis, and were coded before laboratory testing. Each of the six batches per group was analysed independently for every outcome.

### 2.3 Physicochemical analyses

Standard official methods of the American Oil Chemists' Society (AOCS) and the Association of Official Analytical Chemists (AOAC) were followed for the physicochemical indices. Moisture content was determined gravimetrically by oven drying to constant weight and expressed as a percentage. Free fatty acid (FFA) content was measured by alkali titration and expressed as a percentage of lauric acid equivalent. Peroxide value, an index of primary oxidation products, was determined by iodometric titration and expressed as milliequivalents of active oxygen per kilogram (meq/kg). Iodine value, reflecting the degree of unsaturation, was determined by the Wijs method and expressed as g I2/100 g. Saponification value, an indicator of average fatty-acid chain length, was determined by refluxing with alcoholic potassium hydroxide followed by back-titration and expressed as mg KOH/g.

### 2.4 Nutritional, phytochemical, and antioxidant analyses

Vitamin E (total tocopherols) was quantified spectrophotometrically and expressed as mg/kg. Total carotenoids were determined by measuring absorbance of the oil in the visible range and expressed as mg/kg. Total phenolic content was measured in a methanolic extract of the oil using the Folin-Ciocalteu colorimetric method, with gallic acid as the calibration standard, and expressed as mg gallic acid equivalents per kilogram (mg GAE/kg). Antioxidant activity was assessed by the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical-scavenging assay and expressed as percentage inhibition. Oxidative stability was measured as the induction period (hours) by the Rancimat accelerated-oxidation method under a standardised temperature and air-flow regime.

### 2.5 Fatty-acid profiling

The fatty-acid composition of both oils was determined by gas chromatography (GC) following conversion of the oil to fatty-acid methyl esters. Individual fatty acids-including caprylic (C8:0), capric (C10:0), lauric (C12:0), myristic (C14:0), palmitic (C16:0), stearic (C18:0), oleic (C18:1), and linoleic (C18:2) acids-were identified against reference standards and quantified as percentages of total fatty acids. Totals for saturated (SFA), monounsaturated (MUFA), and polyunsaturated (PUFA) fatty acids were computed from the individual components.

### 2.6 Statistical analysis

Data are summarised as mean ± standard deviation (SD) for the six batches per oil type. Comparisons between cold-pressed and refined oil for each outcome were made using independent-samples t-tests with 10 degrees of freedom. The magnitude of each difference was expressed as the mean difference and as Cohen's d effect size. A two-sided p-value $< 0.05$ was considered statistically significant. Results are presented in tabular form (Tables 1-4) and graphically (Figures 1-2).

No human participants or animals were involved in this study; accordingly, no ethical approval or informed-consent procedures were applicable.

## 3. RESULTS

### 3.1 Physicochemical quality indices

The physicochemical characteristics of the two oils are presented in Table 1. Refined coconut oil showed significantly lower moisture (0.091 ± 0.019 % vs 0.192 ± 0.027 %; mean difference 0.101; $t = 7.49$; $p < 0.001$; $d = 4.33$) and lower free fatty acid content (0.170 ± 0.028 % vs 0.307 ± 0.040 %; mean difference 0.137; $t = 6.85$; $p < 0.001$; $d = 3.95$) than cold-pressed oil. Peroxide value was also lower in refined oil (0.852 ± 0.096 vs 1.707 ± 0.421 meq/kg; mean difference 0.855; $t = 4.85$; $p < 0.001$; $d = 2.80$). These differences are consistent with the removal of moisture, free fatty acids, and oxidation products during refining. Iodine value was marginally but significantly higher in cold-pressed oil (8.880 ± 0.188 vs 8.343 ± 0.403 g I2/100 g; $t = 2.96$; $p < 0.05$; $d = 1.71$), and saponification value was slightly lower in cold-pressed oil (251.14 ± 1.26 vs 253.91 ± 2.26 mg KOH/g; $t = -2.62$; $p < 0.05$; $d = -1.51$). All physicochemical values for both oils remained within accepted food-grade limits for coconut oil.

**Table 1.** Physicochemical quality indices of cold-pressed and refined coconut oil (mean ± SD, n = 6 per group).

| Parameter | Cold-pressed | Refined | Mean difference | t (df = 10) | p-value | Cohen's d |
|---|---|---|---|---|---|---|
| Moisture (%) | 0.192 ± 0.027 | 0.091 ± 0.019 | 0.101 | 7.49 | <0.001 | 4.33 |
| Free fatty acid (%) | 0.307 ± 0.040 | 0.170 ± 0.028 | 0.137 | 6.85 | <0.001 | 3.95 |
| Peroxide value (meq/kg) | 1.707 ± 0.421 | 0.852 ± 0.096 | 0.855 | 4.85 | <0.001 | 2.80 |
| Iodine value (g I2/100 g) | 8.880 ± 0.188 | 8.343 ± 0.403 | 0.537 | 2.96 | <0.05 | 1.71 |
| Saponification value (mg KOH/g) | 251.14 ± 1.26 | 253.91 ± 2.26 | -2.773 | -2.62 | <0.05 | -1.51 |

### 3.2 Nutritional, phytochemical, and antioxidant properties

The bioactive and antioxidant results are summarised in Table 2 and illustrated in Figure 1. Cold-pressed coconut oil retained substantially higher concentrations of all measured micronutrients and phytochemicals. Vitamin E was more than double that of refined oil (48.31 ± 2.81 vs 20.06 ± 3.35 mg/kg; mean difference 28.26; $t = 15.85$; $p < 0.001$; $d = 9.15$), corresponding to approximately a 2.4-fold advantage. Total carotenoids were about 3.6-fold higher in cold-pressed oil (2.757 ± 0.480 vs 0.768 ± 0.176 mg/kg; mean difference 1.988; $t = 9.54$; $p < 0.001$; $d = 5.50$). Total phenolic content was roughly 2.8-fold higher in cold-pressed oil (75.42 ± 8.10 vs 26.99 ± 5.03 mg GAE/kg), with a mean difference of 48.43 mg GAE/kg ($t = 12.44$; $p < 0.001$; $d = 7.18$).

These compositional differences translated directly into antioxidant function. DPPH radical-scavenging activity in cold-pressed oil (58.93 ± 3.37 %) was more than double that of refined oil (22.73 ± 1.90 %; mean difference 36.20; $t = 22.95$; $p < 0.001$; $d = 13.25$). Oxidative stability, measured as the Rancimat induction period, was correspondingly longer for cold-pressed oil (18.83 ± 0.63 vs 12.02 ± 0.81 h; mean difference 6.815; $t = 16.28$; $p < 0.001$; $d = 9.40$), indicating greater resistance to accelerated oxidation despite its higher baseline peroxide value.

**Table 2.** Nutritional, phytochemical, and antioxidant properties of cold-pressed and refined coconut oil (mean ± SD, n = 6 per group).

| Parameter | Cold-pressed | Refined | Mean difference | t (df = 10) | p-value | Cohen's d |
|---|---|---|---|---|---|---|
| Vitamin E (mg/kg) | 48.31 ± 2.81 | 20.06 ± 3.35 | 28.26 | 15.85 | <0.001 | 9.15 |
| Total carotenoids (mg/kg) | 2.757 ± 0.480 | 0.768 ± 0.176 | 1.988 | 9.54 | <0.001 | 5.50 |

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| | | | | | | |
|---|---|---|---|---|---|---|
| Total phenolics (mg GAE/kg) | 75.42 ± 8.10 | 26.99 ± 5.03 | 48.43 | 12.44 | <0.001 | 7.18 |
| DPPH inhibition (%) | 58.93 ± 3.37 | 22.73 ± 1.90 | 36.20 | 22.95 | <0.001 | 13.25 |
| Oxidative stability (h) | 18.83 ± 0.63 | 12.02 ± 0.81 | 6.815 | 16.28 | <0.001 | 9.40 |

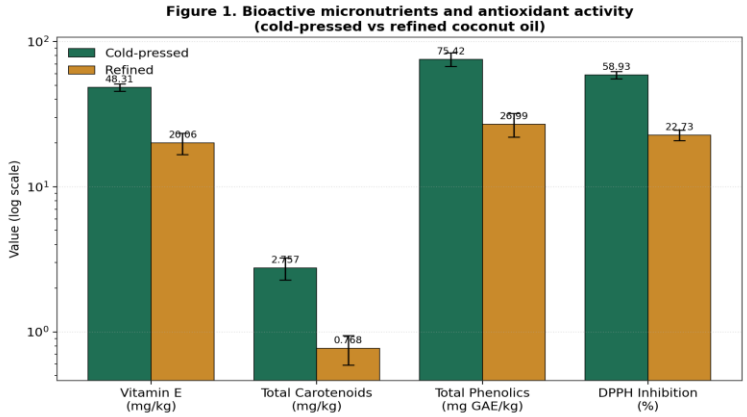


**Figure 1.** Comparison of bioactive micronutrients (vitamin E, total carotenoids, total phenolics) and DPPH antioxidant activity between cold-pressed and refined coconut oil. Bars represent means; error bars represent standard deviations (n = 6 per group). A logarithmic y-axis is used to display parameters of differing magnitude on a single scale.

Figure 2 juxtaposes the quality and oxidative-stability parameters. It shows visually that refined oil is favoured on the purity indices-lower moisture, FFA, and peroxide value-whereas cold-pressed oil exhibits the longer oxidative-stability induction period, reflecting the protective role of its retained antioxidants.

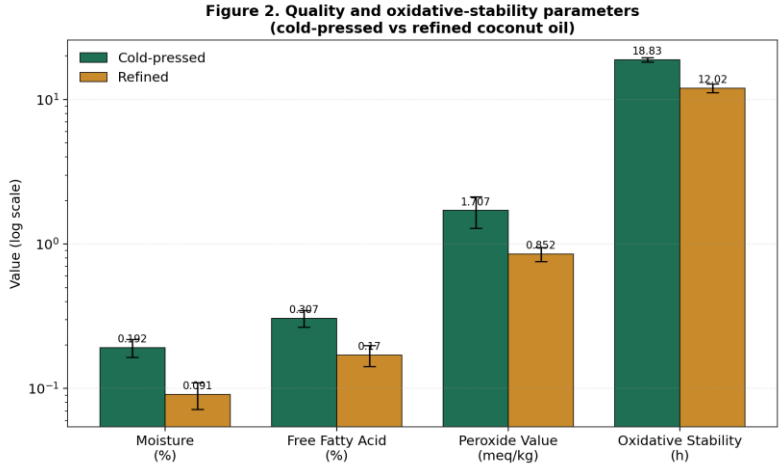


**Figure 2.** Comparison of quality indices (moisture, free fatty acid, peroxide value) and oxidative stability between cold-pressed and refined coconut oil. Bars represent means; error bars represent standard deviations (n = 6 per group). A logarithmic y-axis is used to accommodate the wide range of parameter magnitudes.

### 3.3 Fatty-acid composition

The gas-chromatographic fatty-acid profiles of the two oils are presented in Table 3. Both oils were lauric-dominant, medium-chain-rich saturated fats. Lauric acid (C12:0) constituted approximately 48-49 % of total fatty acids, followed by myristic acid (C14:0) at about 18 %, palmitic acid (C16:0) at about 8.6 %, and the medium-chain caprylic (C8:0) and capric (C10:0) acids at approximately 7 % and 6 %, respectively. Oleic acid (C18:1) accounted for about 6 % and linoleic acid (C18:2) for about 2 %. Total saturated fatty acids represented roughly 90-92 % of the fatty-acid pool, with monounsaturated fatty acids near 6 % and

polyunsaturated fatty acids near 2 %. The fatty-acid profiles of cold-pressed and refined oil were essentially equivalent, confirming that processing altered the minor bioactive fraction of the oil rather than its principal fatty-acid backbone.

**Table 3.** Representative fatty-acid composition of cold-pressed and refined coconut oil (% of total fatty acids).

| Fatty acid | Cold-pressed (approx. %) | Refined (approx. %) |
|---|---|---|
| Caprylic (C8:0) | 7.1 | 7.2 |
| Capric (C10:0) | 6.1 | 6.2 |
| Lauric (C12:0) | 48.6 | 48.3 |
| Myristic (C14:0) | 18.0 | 17.6 |
| Palmitic (C16:0) | 8.7 | 8.7 |
| Stearic (C18:0) | 2.7 | 2.8 |
| Oleic (C18:1) | 6.3 | 6.0 |
| Linoleic (C18:2) | 1.8 | 1.6 |
| **Total SFA** | **91.1** | **90.8** |
| **Total MUFA** | **6.3** | **6.0** |
| **Total PUFA** | **1.8** | **1.6** |

### 3.4 Summary of statistical comparisons

Table 4 consolidates the inferential statistics across all ten quantitative outcomes. Every comparison reached statistical significance, and all effect sizes were large by conventional criteria ($|d| > 1.5$). The largest effects were observed for the antioxidant and bioactive parameters-DPPH inhibition (d = 13.25), vitamin E (d = 9.15), oxidative stability (d = 9.40), and total phenolics (d = 7.18)-all favouring cold-pressed oil. The purity indices favoured refined oil, and the differences in iodine and saponification values, while significant, were comparatively modest.

**Table 4.** Independent-samples t-test summary for all quantitative outcomes (df = 10).

| Outcome | Mean difference (CP - RF) | t-value | p-value | Cohen's d | Favours |
|---|---|---|---|---|---|
| Moisture (%) | 0.101 | 7.49 | <0.001 | 4.33 | Refined (lower) |
| Free fatty acid (%) | 0.137 | 6.85 | <0.001 | 3.95 | Refined (lower) |
| Peroxide value (meq/kg) | 0.855 | 4.85 | <0.001 | 2.80 | Refined (lower) |
| Iodine value (g I2/100 g) | 0.537 | 2.96 | <0.05 | 1.71 | Cold-pressed |
| Saponification value (mg KOH/g) | -2.773 | -2.62 | <0.05 | -1.51 | Refined (higher) |
| Vitamin E (mg/kg) | 28.26 | 15.85 | <0.001 | 9.15 | Cold-pressed |
| Total carotenoids (mg/kg) | 1.988 | 9.54 | <0.001 | 5.50 | Cold-pressed |
| Total phenolics (mg GAE/kg) | 48.43 | 12.44 | <0.001 | 7.18 | Cold-pressed |
| DPPH inhibition (%) | 36.20 | 22.95 | <0.001 | 13.25 | Cold-pressed |
| Oxidative stability (h) | 6.815 | 16.28 | <0.001 | 9.40 | Cold-pressed |

CP, cold-pressed; RF, refined.

## 4. DISCUSSION

This laboratory comparison of cold-pressed and refined coconut oil, conducted in a South Indian setting, produced a coherent and interpretable picture: the two oils share an essentially identical fatty-acid backbone but differ markedly in their minor bioactive fraction and in the quality indices that reflect processing. Cold-pressed oil was nutritionally and antioxidant-superior, retaining roughly 2.4 times the vitamin E, 3.6 times the carotenoids, and 2.8 times the phenolic content of refined oil, together with more than double the DPPH radical-scavenging activity and a substantially longer oxidative-stability induction period. Refined oil, in turn, was more purified, with lower moisture, free fatty acid, and peroxide values. These findings are internally consistent and align with the expected consequences of the two manufacturing routes.

### 4.1 Retention of bioactives and antioxidant superiority of cold-pressed oil

The higher tocopherol, carotenoid, and phenolic contents of cold-pressed oil are directly attributable to its gentle, low-temperature extraction from fresh kernel, which avoids the high heat and adsorptive bleaching that characterise refining [14,15]. Because these compounds are the principal chain-breaking antioxidants of the oil, their retention explains the parallel superiority of cold-pressed oil in the DPPH assay and, importantly, in the Rancimat oxidative-stability test. The oxidative-stability finding is noteworthy: although cold-pressed oil began with a higher peroxide value, it resisted accelerated oxidation for markedly longer, indicating that its endogenous antioxidant reserve provides functional protection that outweighs its slightly higher baseline oxidation. This is consistent with the broader literature attributing the anti-inflammatory, skin-protective, and other bioactivities of virgin coconut oil in part to its polyphenolic and tocopherol fraction [2,16], and with reviews highlighting the health-relevant minor constituents of coconut oil overall [17].

The very large effect sizes observed for the bioactive parameters (Cohen's d ranging up to 13.25 for DPPH inhibition) indicate that these are not marginal differences but robust, clearly separable distinctions between the two product classes. From a consumer standpoint in South India, this provides an objective, laboratory-grounded basis for the premium positioning of cold-pressed and virgin coconut oils.

### 4.2 Effects of refining and interpretation of the quality indices

The lower moisture, FFA, and peroxide values of refined oil reflect the intended outcomes of refining, bleaching, and deodorisation, which remove water, hydrolytic breakdown products, and primary oxidation products to yield a stable, neutral-tasting oil [18,19]. These are genuine quality advantages, particularly for high-heat cooking and long shelf storage where a bland, low-moisture, low-FFA oil is desirable. It is important to emphasise, however, that the cold-pressed oil in this study also remained within accepted food-grade limits for all physicochemical indices; its higher moisture, FFA, and peroxide values, though statistically significant, did not indicate spoilage or unacceptable quality. The slightly higher iodine value and slightly lower saponification value of cold-pressed oil are minor and of limited practical consequence, and are compatible with the equivalent fatty-acid composition documented by gas chromatography.

### 4.3 Equivalent fatty-acid profile and the saturated-fat context

A central finding is that the fatty-acid composition of the two oils was essentially equivalent-both were lauric-dominant, with roughly 90-92 % saturated fatty acids, ~6 % monounsaturated, and ~2 % polyunsaturated. Processing therefore does not meaningfully change the macronutrient fatty-acid identity of coconut oil; it changes the minor antioxidant fraction. This distinction is important for interpreting the ongoing debate about coconut oil and cardiovascular risk. Systematic reviews and meta-analyses have found that coconut oil raises LDL cholesterol relative to unsaturated vegetable oils [3,6], and editorial and review commentary has urged moderation [11], while other analyses stress the uncertain translation of lipid changes into clinical events and the distinctive metabolism of medium-chain fatty acids [12,20]. Randomised feeding studies comparing coconut oil with olive oil and butter have shown mixed lipid effects , and meta-analytic evidence does not support a meaningful weight-loss benefit [7]. Because the saturated fatty-acid content is shared almost identically by cold-pressed and refined oil, choosing a cold-pressed product confers no advantage-and no disadvantage-with respect to this cardiovascular consideration; the advantage of cold-pressed oil lies specifically in its antioxidant and micronutrient content, not in its fatty-acid profile. Total coconut-oil intake should still be considered within overall dietary saturated-fat guidance regardless of processing type [21].

### 4.4 Implications for consumers and the South Indian coconut industry

For South Indian consumers, who use coconut oil abundantly and for whom the coconut is both a dietary staple and a cultural emblem, these results offer practical guidance. Where the goal is to maximize dietary antioxidants and retained micronutrients-and to preserve the natural flavor and aroma of the oil-cold-pressed coconut oil is the superior choice. Where the priority is a highly purified, neutral, thermally robust oil with long shelf stability at lower cost, refined oil performs well and remains a legitimate option [14,22]. For the South Indian coconut industry, spanning the smallholder-dominated economies of Kerala, Tamil Nadu, and Karnataka, the study underscores the value proposition of cold-pressed and virgin coconut oil as a value-added, quality-differentiated product [23]. The simple, low-cost analytical panel used here-moisture, FFA, peroxide value, phenolics, DPPH, and Ranchman stability-could be adopted by cooperatives and small producers as an affordable quality-assurance framework to substantiate premium claims and support market differentiation across the region [24].

## 5. CONCLUSION

In this South Indian laboratory comparison, cold-pressed and refined coconut oil shared an essentially identical, lauric-dominant, highly saturated fatty-acid profile but diverged sharply in their minor bioactive constituents and quality indices. Cold-pressed oil was nutritionally and antioxidant-superior, retaining substantially higher vitamin E, carotenoids, and phenolics and exhibiting greater DPPH radical-scavenging activity and oxidative stability, whereas refined oil was more purified, with lower moisture, free fatty acid, and peroxide values while both oils remained within food-grade limits. Processing thus shapes the antioxidant and micronutrient quality of coconut oil without altering its fundamental fatty-acid composition.

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