Physicochemical characteristics of commercial coconut oils produced in India

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SUMMARY: The physico-chemical characteristics and phytonutrient compositions of commercially available coconut oils [prepared from either copra (unrefined coconut oil- UCNO; Refined Bleached and Deodorized coconut oil- RBDCNO) or from milk extracted from wet mature coconut (virgin coconut oil- VCNO)] were analyzed and compared with the quality of VCNO. The color (2.6, 0.0, 1.6 lovibond units), free fatty acid value (0.61, 0.58, 0.53%), and peroxide value (1.35, 0.0, 0.0 meq.O2Kg⁻¹) of UCNOs, VCNOs, and RBDCNOs, respectively, indicated higher units of color and peroxide value for UCNOs, and similar free fatty acid values to the other two oils. The UCNOs showed a slightly lower saponification value and higher iodine value as compared to VCNO. The composition of lauric acid (55.8%), medium chain fatty acids (69.65%) and medium chain triglycerides (59.27%) mainly dicapricmonolaurin (14.32%), dilauricmonocaprin (18.89%) and trilaurin (21.88%) were significantly higher in VCNO. The % phytosterol, phenolics and tocopherol + tocotrienol contents of UCNOs, VCNO and RBDCNO were 83.7, 54.9 and 81.4 mg; 9.4, 1.8 and 2.1 mg; 4.9, 2.8 and 4 mg, respectively. In UCNOs the values were significantly higher than in VCNO and RBDCNO. These results showed that UCNOs have more phytonutrients compared to VCNO and RBDCNO.

KEYWORDS: Coconut oil; Composition; Nutraceuticals; Physico-chemical characteristics; Radical scavenging activity

RESUMEN: Características físico-químicas de aceites de coco comerciales producidos en India. Se analizaron y compararon las características físico-químicas y la composición de fitonutrientes de aceites de coco disponibles comercialmente preparados a partir de copra [aceite de coco sin refinar, UCNO; aceite de coco decolorado, y desodorizado (RBDCNO)] y de la leche extraída de coco húmedo madurado [aceite de coco virgen (VCNO)]. El color (2,6; 0,0; 1,6 unidades lovibond), los ácidos grasos libres (0,61; 0,58; 0,53%) y el índice de peróxidos (1,35; 0,0; 0,0 meq O₂Kg⁻¹) para UCNOs, VCNOs y RBDCNOs respectivamente, indican valores superiores de color y PV para UCNOs y FFA similar para que los otros dos aceites. Los aceites UCNOs mostraron valores de saponificación ligeramente inferiores y altos valores de índice de yodo en comparación con VCNO. La composición en ácido láurico (55,8%), ácidos grasos de cadena media (69,65%) y triglicéridos de cadena media (59,27%) fueron significativamente mayores en VCNO. Los fitoesternos, compuestos fenólicos y tocoferoles + tocotrienoles fueron 83,7; 54,9 y 81,4 mg; 9,4; 1,8 y 2,1 mg; 4,9; 2,8 y 4,0 mg, para UCNOs, VCNO y RBDCNO, respectivamente, siendo para los aceites UCNOs significativamente mayores que para VCNO y RBDCNO. Estos resultados mostraron que UCNOs tienen más fitonutrientes en comparación con VCNO y RBDCNO.

PALABRAS CLAVE: Aceite de coco; Actividad de captación de radicales; Características físico-químicas; Nutracéuticos


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1. INTRODUCTION

Coconut oil is an edible oil derived from the kernel of *Cocos nucifera* L., a tropical plant, and is largely consumed for edible and non-edible purposes which include cooking, bakery, confectionary, pharmaceutical and cosmetics. It is a clear liquid at ambient temperature and has a pleasant aroma. It mainly consists of saturated fatty acids (>91%) and the major part of the saturated fatty acids are medium chain fatty acids (MCFA) (>51%) which are easily digestible and easily absorbed into the body through the portal vein and produce energy (Huiling and Carl-Erik, 2004). There are several fats and oils available from animal, vegetable and marine sources, but there are no other oils except coconut oil, palm kernel oil, babassu oil, cohune oil and cuphea oil which contain medium chain fatty acids (C8:0 - C12:0) in significant amounts (Babayyan, 1987; Petrauskaite, Greyt and Kellens, 2000). The medium chain fatty acids have some specific functional and nutritional properties which include antiviral, antibacterial, antiplaque, antiprostaglandin, healing, anti-inflammatory and anti-obesity effects (Gopala Krishna et al., 2010, German and Dillard, 2004). These properties divert the coconut oil into further use. Because of the nutritional and medicinal benefits of MCFA, it has been recognized as a multipurpose nutrient supplement.

Virgin coconut oil (VCNO), refined bleached and deodorized coconut oil (RBDCNO) and unrefined coconut oil (UCNO) are the three types of coconut oil available on the market. The VCNO is prepared from the obtained milk of fresh, mature wet kernel of the coconut by physical and mechanical means and this oil is not further processed by refining, bleaching or deodorization (Villarino et al., 2007). VCNO is gaining popularity due to its health benefits. Its capacity to reduce total cholesterol, triglycerides, phospholipids, low density lipoprotein (LDL) and very low density lipoprotein (VLDL) cholesterol and to increase the high density lipoprotein (HDL) cholesterol in serum as compared to coconut oil extracted from copra has been reported (Nevin and Rajamohan, 2004). The RBDCNO is not as popular as VCNO on the Indian market. It is produced by the extraction of oil from dried copra followed by alkali refining, bleaching and deodorization. All these processes are used to remove the impurities present in UCNO and convert the oil into edible grade. However, the UCNO extracted from the dried copra by expeller pressing contains free fatty acids, phospholipids, solid particles and odoriferous compounds. The UCNO is cheaper compared to the other two types and it has gained popularity in the Indian market, probably due to the pleasant aroma and flavor and consumers’ demand for natural and safe food products. The quality of the unrefined coconut oil may differ from the quality of VCNO and RBDCNO as it mainly depends on the quality of the copra used and the type of processing. Therefore, this study was conducted to evaluate the physicochemical and nutrient characteristics of some of the commercially available UCNOs and to compare such properties with those of VCNO and RBDCNO.

2. MATERIALS AND METHODS

2.1. Sampling

Different coconut oils including virgin coconut oil (VCNO), refined bleached and deodorized coconut oil (RBDCNO) and unrefined coconut oils (UCNOs) of eight popular brands coded as MYS1, MYS2, MYS3, MYS4, MYS5, MYS6, MYS7 and MYS8 were purchased from the local markets of Mysore city. All oils were purchased as five product batches. All product batches of each coconut oil were mixed together in the same proportion to get a representative oil. Fatty acid methyl ester (FAME mix RM-5), cholesterol, Folin-Ciocalteu’s reagent, gallic acid, α-tocopherol and 1-diphenyl-2-picrylhydrazyl (DPPH) were purchased from Sigma Aldrich, Mumbai, India. All chemicals and solvents used were of analytical grade.

2.2. Physico-chemical analysis of different coconut oils

The color of the samples was determined by using the Lovibond tintometer in transmittance mode in 1” cell and expressed as 5X Red + 1X Yellow (5R+Y) lovibond units. The free fatty acid value (FFA) was determined using the AACS Official Method No. Ca 5a-40 (AOCS, 1990). Oil was titrated against a 0.1 N NaOH solution in a neutralized alcohol medium using phenolphthalein as indicator and expressed as percentage of lauric acid. For determining peroxide value (PV), the samples were dissolved in acetic acid-chloroform (3:2, v/v) mixture and 1 mL of saturated potassium iodide solution added and allowed for 1 min to liberate iodine from saturated aqueous solution of KI upon reaction with the sample followed by using starch as indicator (AOCS Official Method No. Cd 8-53) (AOCS, 1990). The saponification value was determined by the AACS Official Method No. Cd 3-25 (AOCS. 5 g of sample were saponified using 50 mL of a 5% ethanolic KOH solution in a conical flask connected with an air condenser and boiled until the oil was completely saponified, cooled and titrated with 0.5 N HCl using phenolphthalein as indicator. The iodine value (IV) was determined according to the AACS Official Method No. Cd 1d-92 (Wijs Method) (AOCS, 2004). The sample taken in carbon tetrachloride was treated with 25 mL of a Wijs solution. The excess of iodide monochloride was titrated with potassium iodide and the liberated iodine was titrated with a 0.1 N sodium thiosulphate solution using starch as indicator.

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2.3. Preparation of fatty acid methyl esters and analysis by GC

Fatty acid methyl esters (FAME) of the oil samples were prepared by transesterification, according to the AOCS Official Method No. Ce 1-62 (AOCS, 1998), using methanolic KOH. The analysis was done using a gas chromatograph (model-GC-20A, Shimadzu Corporation, Japan) equipped with an FID detector and a glass capillary column (30m × 0.25mm), coated with poly (90% biscyanopropyl/10% cyanopropylphenyl) siloxane with a film thickness of 0.2 μm (SP-2380) (Supelco Analytical, Bellefonte, Pennsylvania, USA). The operating...
Conditions were as follows: nitrogen flow 1 mL·min⁻¹, hydrogen flow 1 mL·min⁻¹, air flow 2 mL·min⁻¹, column temperature kept isothermal at 180 °C, injector temperature 220 °C and detector temperature 230 °C. A reference standard FAME mix (Supelco Inc., Bellefonte, PA, USA) was analyzed under the same operating conditions to determine peak identity. The FAMEs were expressed as relative area % (AOCS Official Method No. Ce 2-66) (AOCS, 1998).

2.4. Triglyceride composition of different coconut oils

The triglyceride composition was obtained using the Shimadzu HPLC system consisting of an LC-10A pump, fitted with a 20 μL injector loop and RID-10A detector. The isocratic separation of triglycerides was achieved by reverse phase HPLC on a C18 column (Shimpack CLC-ODS (M) 4.6×150 mm, 5 μm particle diameter) at 25 °C. The mobile phase was acetone: acetonitrile (70:30, v/v). The TAG peaks were identified according to AOCS Official Method No. Ce 5b-89 (AOCS, 1998).

2.5. Estimation of the phytosterol contents of different coconut oils

Total phytosterol contents were estimated according to Sabir et al. (2003). The samples (around 1 g) in triplicate were weighed and diluted to 10 mL with chloroform. The samples were mixed well to dissolve completely and further diluted to 10 times with chloroform. 3 mL of the dilute solutions were taken and 2.0 mL of Liberman- Burchard reagent were added. The final volume was made up to 7 mL with chloroform. The tubes were covered with aluminium foil and kept in the dark for 15 minutes. A solution without sample was maintained as a blank. The absorbance was measured at 640 nm in a UV-Visible Spectrophotometer (model UV-1601, Shimadzu Corporation, Kyoto, Japan). The total phytosterols were calculated based on the standard cholesterol curve previously generated according to the same procedure. The results were expressed as mg phytosterol per 100 g of oil.

2.6. Determination of total phenolics in coconut oil

The phenolics were extracted from the coconut oil with methanol/water (80:20 v/v) by taking 5 ± 0.1 g of coconut oil and mixing with 1.0 mL of methanol/water (80:20) and vortexed for 2 min (twice). The mixture was centrifuged at 1080 g for 15 min and the resultant supernatant was separated. The extractions were repeated four times with the same sample with a 1.0 mL portion of the solvent system. The resultant extracts were pooled together and kept in the dark till the time of analysis (Marina et al., 2009a). Total phenolics content of the phenolic extracts were determined by Folin-Ciocalteu reagent method. 0.3 mL of the extracts were mixed with 0.2 mL of Folin-Ciocalteu reagent and after 3 min, 1 mL of a 15% Na₂CO₃ solution was added, the final volume was made up to 7 mL with de-ionized water and incubated for 45 min. The mixture was centrifuged and absorbance was measured at 745 nm in a Shimadzu UV-1601, UV-visible spectrophotometer with respect to a blank without any added phenolic extract. The total phenolic contents were expressed as mg gallic acid equivalent (GAE)-100 g⁻¹ of coconut oil (Nigel et al., 2001).

2.7. Radical scavenging activity of coconut oil

The antioxidant activity of the different coconut oil samples was measured by the 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging assay. The analysis was performed according to Bhatnagar et al. (2009). The freshly prepared solutions of DPPH at a concentration of 10⁻⁵ M (4 mL) were added to the sample weight of 50 ± 1 mg. This mixture was vortexed for 20 s and absorbance was measured at 515 nm in the UV-Visible spectrophotometer and then kept at room temperature. After incubation for 60 min, the decrease in absorbance at 515 nm were monitored for these samples. The radical scavenging activity was estimated from the difference in the absorbance of the toluenic DPPH solution with and without sample (control). The percent inhibition was calculated from the following equation:

\[ \text{Inhibition} \% = \frac{A - B}{A} \times 100 \]

Where A is the absorbance of the control and B is the absorbance of the samples. Three replicates for each sample were assayed.

2.8. Estimation of tocopherol content

The analysis of tocopherols and tocotrienols was achieved by normal phase HPLC separation on a silica column (Lichrosorb Si60 5 μm particle diameter, 250 mm length × 4 mm id) employing a Shimadzu HPLC system consisting of an LC-10A pump, an injector fitted with a 20 μL loop and an FLD detector. The mobile phase used was hexane: isopropyl alcohol (99.5: 0.5, v/v) at the flow rate of 1 mL·min⁻¹. The excitation wavelength of 290 nm and an emission wavelength of 330 nm were held constant for the fluorescence detection of all the peaks. The tocopherols and tocotrienols were identified using standard tocopherols (Sigma-Aldrich, India.) and expressed as α-tocopherol equivalent of different isomers (AOCS Official Method No. Ce 8-86) (AOCS, 1998).
2.9. Statistical analysis

All data were expressed as the mean ± standard deviation of quadruplicate analyses. The Tukey-Kramer Multiple Comparison Test was used to calculate significant differences using the statistical package, GraphPad Instat Demo [DATA-SET.ISD]. Statistical significance was declared at p≤0.05.

3. RESULTS AND DISCUSSION

3.1. Physicochemical characteristics of different types of coconut oil

Color is one of the quality indicators of vegetable oils (Indian Standard Specification for Coconut oil, 2014). The color values for the coconut oils are given in Table 1. Generally, the values for refined oils are lower than for the unrefined oils. In this study, the VCNO was a clear liquid with color of 0 lovibond units probably because of the outer brown skin (coconut testa) of the coconut kernel is removed before oil extraction. Meanwhile, the other oils including RBDCNO and UCNOs were light yellow in color which is attributed to the extraction of the copra without the removal of the coconut testa. The average color of the UCNOs was 2.6 lovibond units and it ranged from 2.4 (MYS1) to 2.7 (MYS7). The color of RBDCNO (1.6 lovibond units) was lower than that of the color of UCNOs. This may be due to color reduction during the bleaching process undergone by the RBDCNO.

Free fatty acid content is an indicator of the hydrolytic rancidity of the coconut oil which causes an undesirable flavor and aroma in the oil. Hydrolytic rancidity is mainly due to the action of lipase or moisture (Hoover et al., 1973). The hydrolytic rancidity in coconut oil is mostly attributed to the undesirable storage of copra, maintaining the quality of copra and the moisture content of the extracted oil. The oils extracted from under-dried, badly stored copra increase the incidence of FFA in the oil substantially. Hoover et al. (1973) have reported that the lipase activity of some of the fungal strain (eg: Aspergillus flavus) which actively attack copra and the wet coconut kernel and liberates FFA. The FFA of different coconut oils is provided in Table 1. The FFA contents of the UCNOs ranged from 0.14–2.02%. The VCNO had the lowest FFA value (0.01%). This indicated its better quality and was significantly different from the RBDCNO (0.53%) and UCNOs. It would be expected that sample RBDCNO should contain the lowest FFA value since it had undergone the RBD process which is supposed to remove most of the FFA. But, the significant increase in the FFA value may be due to the hydrolysis accelerated by the high temperature and moisture content during the deodorization process. Nevertheless, the FFA contents of coconut oils (0.14% to 0.57%) except MYS4 (2.02%) were relatively low and indicated that the oils were of good quality. The Codex Alimentarius Commission has established acid values of 0.6 mg of KOH·g−1 of RBDCNO and 4.0 mg of KOH·g−1 oil for VCNO (Codex, 2003). The Indian Standard Specification for Coconut Oil (2014) specifies an acid value for UCNO of up to 6 mg of KOH·g−1 depending on the grade of coconut oil. Hence all UCNOs were within the Indian Standard Specification limits (2013) for coconut oil.

Peroxide value is an indicator for the measurement of the initial stages of oxidation in oils (Naohiro and Shun, 2006). The unsaturated fatty acids present in the oils easily react with atmospheric oxygen and form hydroperoxides. Normally coconut oils exhibit high oxidative stability due to the presence of large amounts of saturated fatty acids (>91%). Table 1 shows the peroxide value of different coconut oils. The VCNO and RBDCNO have shown PV of 0.0 units which indicates that there is no oxidative deterioration in these oils. But, the PV of UCNOs ranged from 0.0–2.7 meqO2·Kg−1. The UCNOs MYS5 and MYS8 exhibited the lowest PV of 0.0 and the MYS3 exhibited the highest peroxide value (2.7 meq O2·Kg−1) as compared to the other coconut oils studied. The lower peroxide value indicates the freshness of the sample. The high PV (1.79 to 2.7 meq O2·Kg−1) may be caused by the lower quality of the raw material copra used for oil extraction.

Iodine value (IV) is the measurement of the degree of unsaturation in oils. Low unsaturation provides high oxidative stability to oils (Isbell, 1999). The IV of UCNOs ranged from 5.3–6.7 with the lowest IV for MYS1 and MYS4; and the highest IV for MYS2 and MYS8 among the UCNOs, which is likewise reflected in the highest (95.64%) and lowest (93.67%) saturated fatty acid contents for these oils (Table 2). The VCNO showed a significantly lower IV (4.5) value than the other coconut oils with the highest saturated fatty acid content of 96.56%. The RBDCNO showed an IV of 6.0 which lies within the IV range of UCNOs. The IV for different types of UCNOs in the range of 6.3–10.6 have been reported in the literature (Codex Alimentarius, 2003).

Saponification value (SV) measures the average molecular weight of fatty acids present in the oil. It is directly proportional to the shorter chain fatty acids on the glycerol back bone. As compared to the other edible oils coconut oil has a higher SV. Table 1 shows the SV of different coconut oils. In this study, VCNO presented the highest value of SV (255.9 mg KOH·g−1 oil) indicating high amounts of short chain fatty acids and this value is comparable with those reported for Malaysian and Indonesian virgin coconut oils (250.1–258.3 mg KOH·g−1 oil) by Marina et al. (2009b). The RBDCNO showed...
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an SV of 253.5 mg KOH g⁻¹ oil, which is within the range of SV shown by UCNOs (248.1–255.1 mg KOH g⁻¹ oil). Likewise, the change in SV is reflected in the content of medium and short chain fatty acid contents in the coconut oils studied. MYS8 showed the lowest amount of medium and short chain fatty acids (61.94%) as compared to VCNO (69.65%), RBDCNO (63.39%) and other UCNOs (62.01–65.50%) studied. The sample MYS1 showed the highest amounts of short chain fatty acids (65.5%) among the UCNOs. According to the Codex Standard Specification for coconut oil the SV of edible coconut oil should be between 248 and 265 mg KOH g⁻¹ oil (Codex Alimentarius 2003) and the SV of all the samples were within the prescribed limit.

### TABLE 1. Physicochemical characteristics of the Indian coconut oils used in the study

<table>
<thead>
<tr>
<th>Coconut oil</th>
<th>Color (Lovibond unit)*</th>
<th>FFA (%)*</th>
<th>PV (meq O₂·kg⁻¹)*</th>
<th>IV* (cg I₂ ·g⁻¹ oil)</th>
<th>SV (mg KOH·g⁻¹ oil)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>VCNO</td>
<td>0.0±0.00</td>
<td>0.01±0.00e</td>
<td>0.00±0.00</td>
<td>4.52±0.41</td>
<td>255.9±0.23f</td>
</tr>
<tr>
<td>RBDCNO</td>
<td>1.6±0.00</td>
<td>0.53±0.01f</td>
<td>0.00±0.00</td>
<td>6.04±0.35</td>
<td>253.5±0.47g</td>
</tr>
<tr>
<td>MYS1</td>
<td>2.4±0.00</td>
<td>0.32±0.01f</td>
<td>2.67±0.03a</td>
<td>5.32±0.05</td>
<td>251.5±0.33c</td>
</tr>
<tr>
<td>MYS2</td>
<td>2.5±0.00</td>
<td>0.60±0.01f</td>
<td>1.32±0.01b</td>
<td>6.72±0.41</td>
<td>251.0±0.01f</td>
</tr>
<tr>
<td>MYS3</td>
<td>2.6±0.00</td>
<td>0.36±0.01f</td>
<td>2.70±0.01c</td>
<td>6.32±0.35</td>
<td>239.9±0.37f</td>
</tr>
<tr>
<td>MYS4</td>
<td>2.5±0.00</td>
<td>2.02±0.01f</td>
<td>1.79±0.01d</td>
<td>5.32±0.34</td>
<td>260.2±0.40f</td>
</tr>
<tr>
<td>MYS5</td>
<td>2.5±0.00</td>
<td>0.45±0.01f</td>
<td>0.00±0.00</td>
<td>6.6±0.35</td>
<td>248.7±0.23f</td>
</tr>
<tr>
<td>MYS6</td>
<td>2.5±0.00</td>
<td>0.14±0.00f</td>
<td>1.82±0.01e</td>
<td>5.8±0.34</td>
<td>256.7±0.10f</td>
</tr>
<tr>
<td>MYS7</td>
<td>2.7±0.00</td>
<td>0.40±0.01f</td>
<td>0.45±0.00f</td>
<td>5.5±0.36</td>
<td>254.2±0.10f</td>
</tr>
<tr>
<td>MYS8</td>
<td>2.5±0.00</td>
<td>0.57±0.01f</td>
<td>0.00±0.00</td>
<td>6.72±0.40</td>
<td>248.1±0.01f</td>
</tr>
<tr>
<td>Average**</td>
<td>2.6±0.09</td>
<td>0.61±0.59</td>
<td>1.35±1.10</td>
<td>6.1±3.47</td>
<td>251.7±2.06</td>
</tr>
</tbody>
</table>

**FA** = free fatty acid value expressed as lauric acid.
Values are mean ± standard deviation (n = 4).
*Values with different superscript within the column indicate p value is ≤0.05, considered significant change.
Values in the column with same superscript indicate p value is >0.05, considered that there is no significant change. **The average value ± standard deviation of UCNOs- MYS1, MYS2, MYS3, MYS4, MYS5, MYS6, MYS7 and MYS8.

### TABLE 2. Fatty acid composition of the Indian coconut oils used in the study

<table>
<thead>
<tr>
<th>FA composition</th>
<th>VCNO</th>
<th>RBDCNO</th>
<th>MYS1</th>
<th>MYS2</th>
<th>MYS3</th>
<th>MYS4</th>
<th>MYS5</th>
<th>MYS6</th>
<th>MYS7</th>
<th>MYS8</th>
<th>Average ± SD*</th>
</tr>
</thead>
<tbody>
<tr>
<td>C8:0</td>
<td>7.52a</td>
<td>7.24b</td>
<td>8.06e</td>
<td>7.63de</td>
<td>8.22f</td>
<td>7.45ef</td>
<td>7.20f</td>
<td>8.39ef</td>
<td>7.61ef</td>
<td>7.13bf</td>
<td>7.71±0.47</td>
</tr>
<tr>
<td>C10:0</td>
<td>6.38a</td>
<td>5.25b</td>
<td>5.78f</td>
<td>5.50ah</td>
<td>5.81ab</td>
<td>5.16bc</td>
<td>5.36cd</td>
<td>5.61de</td>
<td>5.36de</td>
<td>5.59±0.31</td>
<td></td>
</tr>
<tr>
<td>C12:0</td>
<td>55.75a</td>
<td>50.90bc</td>
<td>51.66abc</td>
<td>51.05ab</td>
<td>49.95bc</td>
<td>51.20abcd</td>
<td>49.45bcd</td>
<td>50.42cd</td>
<td>51.57bcd</td>
<td>49.45bc</td>
<td>50.35±0.94</td>
</tr>
<tr>
<td>C14:0</td>
<td>18.74a</td>
<td>21.38b</td>
<td>21.05ab</td>
<td>21.08b</td>
<td>20.77abc</td>
<td>22.45f</td>
<td>21.30e</td>
<td>20.29ed</td>
<td>21.33e</td>
<td>21.13ed</td>
<td>21.18±0.61</td>
</tr>
<tr>
<td>C16:0</td>
<td>7.90a</td>
<td>9.22b</td>
<td>8.64f</td>
<td>8.60abc</td>
<td>9.32f</td>
<td>9.21de</td>
<td>8.49f</td>
<td>9.04f</td>
<td>9.04f</td>
<td>9.04f</td>
<td>9.07±0.47</td>
</tr>
<tr>
<td>C18:1</td>
<td>0.27a</td>
<td>0.38b</td>
<td>0.28bc</td>
<td>0.91f</td>
<td>0.91f</td>
<td>0.17f</td>
<td>1.22f</td>
<td>0.81f</td>
<td>0.18f</td>
<td>0.90f</td>
<td>0.67±0.40</td>
</tr>
<tr>
<td>C18:2</td>
<td>3.31a</td>
<td>4.81ab</td>
<td>4.01b</td>
<td>4.76bd</td>
<td>4.73f</td>
<td>4.04ef</td>
<td>5.23f</td>
<td>4.31f</td>
<td>4.07f</td>
<td>4.07f</td>
<td>4.49±0.45</td>
</tr>
<tr>
<td>C18:3</td>
<td>0.13a</td>
<td>0.81ab</td>
<td>0.53a</td>
<td>1.57f</td>
<td>1.14f</td>
<td>0.32a</td>
<td>1.35b</td>
<td>1.16f</td>
<td>0.59f</td>
<td>1.36f</td>
<td>1.00±0.46</td>
</tr>
<tr>
<td>SAFA</td>
<td>96.56a</td>
<td>94.37ab</td>
<td>95.47b</td>
<td>93.67bc</td>
<td>94.14bcd</td>
<td>95.64abc</td>
<td>95.45bc</td>
<td>94.53bcd</td>
<td>94.53bcd</td>
<td>93.87abcd</td>
<td>94.56±0.81</td>
</tr>
<tr>
<td>MUFA</td>
<td>3.31a</td>
<td>4.81ab</td>
<td>4.01b</td>
<td>4.76bd</td>
<td>4.73f</td>
<td>4.04ef</td>
<td>5.23f</td>
<td>4.31f</td>
<td>4.07f</td>
<td>4.07f</td>
<td>4.49±0.45</td>
</tr>
<tr>
<td>PUFA</td>
<td>0.13a</td>
<td>0.81ab</td>
<td>0.53a</td>
<td>1.57f</td>
<td>1.14f</td>
<td>0.32a</td>
<td>1.35b</td>
<td>1.16f</td>
<td>0.59f</td>
<td>1.36f</td>
<td>1.00±0.46</td>
</tr>
<tr>
<td>MCFA</td>
<td>69.65a</td>
<td>63.39b</td>
<td>65.58</td>
<td>63.08b</td>
<td>63.14b</td>
<td>63.81b</td>
<td>62.01d</td>
<td>64.94e</td>
<td>64.79f</td>
<td>61.94f</td>
<td>63.65±1.34</td>
</tr>
</tbody>
</table>

**FA** = fatty acids, SAFA = saturated fatty acid, MUFA = monounsaturated fatty acid, PUFA = polyunsaturated fatty acid and MCFA = medium chain fatty acid.
Values are mean ± standard deviation (n = 4).
* The average value ± standard deviation of the fatty acid composition of unrefined coconut oils (MYS1, MYS2, MYS3, MYS4, MYS5, MYS6, MYS7 and MYS8).
Values with different superscript in the row indicate p value is ≤0.05, considered significant change in fatty acid composition.
Values in the row with same superscript indicate p value is >0.05, considered that there is no significant change.
3.2. Fatty acid composition of different types of coconut oil

Table 2 shows the fatty acid composition of the different types of coconut oils studied. Lauric acid (C12:0) is the major fatty acid present in coconut oil. Rosell et al. (1985) and Laureles et al. (2002) have reported lauric acid values of 45.9–50.3%, and 47.3–52.6%, respectively, for coconut oil from the Philippines (46.2–48.7%), Papua New Guinea (47.1–50.3%), Vanuatu (47.1–48.4%), North Sulawesi (45.9%) and Sri Lanka (49.3–52.6%) (Rossell & Laureles, 2002). In this study, the major part of the SAFA (saturated fatty acids) as compared to other edible oils. The caprylic acid (C8:0) content ranged from 7.13–8.39%. The lowest C8:0 value was observed for MYS8 (7.13%) and the highest value was observed for MYS6 (8.39%). The average value of C8:0 for UCNOs was 7.71%, which is similar to that of the C8:0 value of VCNO (7.52%) and RBDCNO (7.24%). In this study, the major fatty acids present in coconut oil were lauric acid (55.75%), caprylic acid (C8:0) (5.16–6.13%), and capric acid (C10:0) (4.90–5.96%) of this constitution. Monolaurinmonomyristin (LaMM) is the major TAG composition of the different Indian coconut oils studied. The TAG molecular species dicapricmonolaurin (CCLa), dilauricmonocaprin (CLaLa), trilaurin (LaLaLa), dilauricmonomyristin (LaLaM), dimyristicmonolaurin (LaMM) were the major TAG present in all the coconut oils used in the study. The MUFA of RBDCNO (4.81%) is similar to the MUFA of MYS2 (4.76%) which showed the highest MUFA level among the UCNOs. The PUFA level of coconut oils varied from 0.13% for VCNO to 1.57% for MYS2. The average PUFA value for the UCNOs was found to be 1.00%, which is higher than that of the PUFA value of VCNO (0.13%) and RBDCNO (0.81%).

3.3. Triglyceride composition of the different types of coconut oil

Table 3 shows the triacylglycerol (TAG) composition of the different Indian coconut oils studied. The TAG molecular species dicapricmonolaurin (CCLa), dilauricmonocaprin (CLaLa), trilaurin (LaLaLa), dilauricmonomyristin (LaLaM), dimyristicmonolaurin (LaMM) were the major TAG present in all the coconut oils used in the study. The MUFA of RBDCNO (4.81%) is similar to the MUFA of MYS2 (4.76%) which showed the highest MUFA level among the UCNOs. The PUFA level of coconut oils varied from 0.13% for VCNO to 1.57% for MYS2. The average PUFA value for the UCNOs was found to be 1.00%, which is higher than that of the PUFA value of VCNO (0.13%) and RBDCNO (0.81%).
for VCNO. The highest M₃ of VCNO may be contributed by the highest MCFA composition (69.65%) of VCNO. The highest M₃ content is shown by MYS6 (56.59%) among the UCNOs. The three saturated fatty acid containing TAG (S₃) was the lowest in MYS4 (87.82%) and the highest in VCNO (92.51%) compared to the other samples. The two saturated fatty acid containing TAG (S₂U) was the lowest in MYS8 (4.42%) and the highest in MYS4 (7.46%). The one saturated fatty acid containing TAG (SU₂) was the lowest in VCNO (1.47%) and the highest in RBDCNO (2.63%). The three unsaturated fatty acid containing TAG (U₃) level was very low in all coconut oils and ranged from 0.37% for MYS1 to 0.59% for MYS4.

### 3.4. Phytosterol composition of the different types of coconut oil

Table 4 shows the minor constituents such as nutraceuticals and their properties, along with the radical scavenging activity of the different coconut oils. Phytosterols are natural components of various edible oils and are very important for human nutrition. The studies of Trautwein et al. (2003) have reported its properties for reducing serum total and LDL cholesterol levels.
The total phytosterol contents of various commercially available coconut oils showed significant difference as compared to VCNO and RBDCNO. The VCNO had the lowest phytosterol content (1.8 mg GAE·100 g⁻¹ oil). The RBDCNO had the phytosterol content of 2.1 mg GAE·100 g⁻¹ oil. The UCNOs except MYS4 had more than 5 mg total phytosterol contents. The total phytosterol contents of the UCNOs ranged from 5.7 mg for MYS2 to 19.1 mg·100 g⁻¹ oil for MYS5. The changes in the phytosterol contents among the UCNOs, VCNO and RBDCNO were most probably due to the extraction method, the de-skimming (removal of testa) of coconut and the moisture removal process for VCNO and the RBD process undergone by the RBDCNO. These processing operations might have resulted in the partial extraction or loss in the phenolics from the oil. The difference in the total phenolic contents also affected the radical scavenging activity of these coconut oils (Table 4) (Kapila, 2008).

### 3.6. Radical scavenging activity of the different types of coconut oil

Free radicals are involved in various physiological reactions and cause damage to the cell and biomolecules like protein, lipids and DNA, leading to a number of degenerative diseases (Valco et al., 2007). Antioxidants can prevent these harmful reactions and detoxify the effect of free radicals. The radical scavenging activity (13.8–50.2%) is relatively high in UCNOs as compared to VCNO (11.6%) and RBDCNO (14.0%). The MYS5 had the highest radical scavenging activity (50.2%) and MYS4 had the lowest (13.8%) radical scavenging activity among the unrefined coconut oil. This was due to the differences in the phenolic contents of the oils examined (Table 4) as the observed radical scavenging activity of the studied samples correlated significantly with the total phenolic content (r=0.87). Even though there is a correlation, MYS3 and MYS7 have similar phenol contents but the RSAs of these two oils are very different. The reason for the above is not clear at present. Similarly, VCNO, with a very small amount of phenolic substances showed relatively high RSA. This could be ascribed to a higher amount of tocopherols and tocotrienols.

### 3.7. Tocopherol and tocotrienol composition of the different types of coconut oil

Tocopherols and tocotrienols are the lipid soluble natural antioxidants. The tocopherols are mainly found in most vegetable oils. Tocopherols show good antioxidant properties on lipid peroxidation and the scavenging of reactive oxygen species. The tocotrienols are found mainly in the bran and germ fraction of seeds and cereals. Tocotrienols have strong antioxidative properties, protecting against the effects of free radicals.

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**TABLE 4. Total phenolics, phytosterols and radical scavenging activity of the Indian coconut oils used in the study**

<table>
<thead>
<tr>
<th>Coconut oil</th>
<th>Phytosterols (mg·100g⁻¹)*</th>
<th>Phenolics (mg·100g⁻¹)*</th>
<th>RSA (% inhibition)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>VCNO</td>
<td>54.9±2.2 a</td>
<td>1.8±0.00</td>
<td>11.6±0.6</td>
</tr>
<tr>
<td>RBDCNO</td>
<td>84.2±1.8 b</td>
<td>2.1±0.19</td>
<td>14.0±0.2</td>
</tr>
<tr>
<td>MYS1</td>
<td>74.5±2.6 c</td>
<td>8.2±0.13</td>
<td>20.8±0.5</td>
</tr>
<tr>
<td>MYS2</td>
<td>96.8±2.1 d</td>
<td>5.7±0.01</td>
<td>22.9±0.5</td>
</tr>
<tr>
<td>MYS3</td>
<td>76.8±3.3 e</td>
<td>11.4±0.04</td>
<td>27.0±0.5</td>
</tr>
<tr>
<td>MYS4</td>
<td>83.7±2.6 f</td>
<td>2.7±0.01</td>
<td>13.8±0.0</td>
</tr>
<tr>
<td>MYS5</td>
<td>82.7±2.9 g</td>
<td>19.1±0.09</td>
<td>50.2±0.4</td>
</tr>
<tr>
<td>MYS6</td>
<td>80.7±4.6 h</td>
<td>8.1±0.15</td>
<td>28.0±0.3</td>
</tr>
<tr>
<td>MYS7</td>
<td>85.1±2.7 i</td>
<td>11.7±0.04</td>
<td>17.8±0.7</td>
</tr>
<tr>
<td>MYS8</td>
<td>89.5±3.5 j</td>
<td>8.1±0.08</td>
<td>21.0±0.3</td>
</tr>
<tr>
<td>Average**</td>
<td>83.8±7.1 k</td>
<td>9.4±4.90</td>
<td>25.2±11.1</td>
</tr>
</tbody>
</table>

*Values with different superscript within the column indicate p value is <0.001, considered significant change in phenolic contents. Values are mean ± standard deviation (n=4).

**Values in the column with same superscript indicate p value is ≤0.05, considered that there is no significant change.

**Average value of UCNOs: MYS1, MYS2, MYS3, MYS4, MYS5, MYS6, MYS7 and MYS8.

The coefficient of correlation between phenolic content and radical scavenging activity is 0.87.
antioxidant properties which are manifested in anti-
cancer and neuroprotective actions as well as pro-
tection against atherosclerosis (Samarjit, 2007).
Table 5 shows the tocopherol and tocotrienol
composition of the different coconut oils. The total
tocopherol contents of the UCNOs ranged from
1.4 mg·100 g−1 to 7 mg·100 g −1 with an average
value of 4.0 ± 2.2 mg·100 g−1 oil. The obtained total
tocopherol values were very low as compared to
the tocopherol contents of other vegetable oils.
Prakruthi et al. (2014) have reported tocopherol con-
tents of 100 mg·100g−1 in the oil extracted from the
testa portion of the wet coconut kernel. The VCNO
contained 1.6±0.0a 0.7±0.0a 2.0±0.0a 0.6±0.0a 4.9a 2.3:2.6
RBDCNO 0.5±0.0b 0.3±0.0b 1.8±0.0b 0.2±0.0b 2.8b 0.8:2.0
MYS1 0.6±0.0b nd 0.8±0.0b nd 1.4b 0.6:0.8
MYS2 2.8±0.0b nd 2.9±0.0b nd 5.7d 2.8:2.9
MYS3 1.3±0.0b nd 0.3±0.0b 0.12±0.0b 1.7c 1.3:0.4
MYS4 nd 0.3±0.0b 1.6±0.0b 0.2±0.0d 2.1f 0.3:1.8
MYS5 2.4±0.0c 0.3±0.0c 3.4±0.0c 0.3±0.0b 6.4f 2.7:3.7
MYS6 2.4±0.0c nd 2.4±0.0c 0.2±0.0b 4.8b 2.4:2.6
MYS7 2.7±0.2c nd nd 0.2±0.0b 2.9g 2.7:0.2
MYS8 3.0±0.2c 0.1±0.0d 3.3±0.0c 0.6±0.0b 7.0j 3.1:3.9
Average* 1.9±1.1 0.1±0.01 1.8±1.40 0.2±0.2 4±2.2 2.0:2.0
Values with different superscript within the column indicate p value is <0.001, considered significant change.
Values are mean ± standard deviation (n = 4).
Values in the column with same superscript indicate p value is ≤0.05, considered that there is no significant change.
*Average value of UCNOs- MYS1, MYS2, MYS3, MYS4, MYS5, MYS6, MYS7 and MYS8.

4. CONCLUSIONS

In conclusion, the results show that the virgin
coconut oil (VCNO) is superior in quality based
on the physicochemical properties and the unre-
fined coconut oils (UCNOs) were superior in qual-
ity based on the phytonutrient composition and the
RBDCNO was slightly lower in phytonutrient com-
position compared to the UCNOs. The UCNOs had
acceptable physicochemical characteristics with the
added benefits of higher phytonutrient contents over
virgin coconut oil and the RBD coconut oil. Apart
from the above, the fatty acid and the triacylglycerol
make up of the oils along with these phytoneutrients might cause differences in biological effects which are not yet understood.

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