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# 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.$O_2Kg^{-1}$) 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·$O_2Kg^{-1}$) para UCNOs, VCNOs y RBDCNOs respectivamente, indican valores superiores de color y PV para UCNOs y FFA similar que para 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 fitoesteroles, compuestos fenólicos y tocoferoles + tocoferoles 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; Composición; 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 (Babayan, 1987; Petrauskaite, Greyt and Kellens, 2000). The medium chain fatty acids have some specific functional and nutritional properties which include antiviral, antibacterial, antiplaque, antiprotozoal, 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 AOCS 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 saturate 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 AOCS 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 AOCS 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 treated with potassium iodide and the liberated iodine was titrated with a 0.1 N sodium thiosulphate solution using starch as indicator.

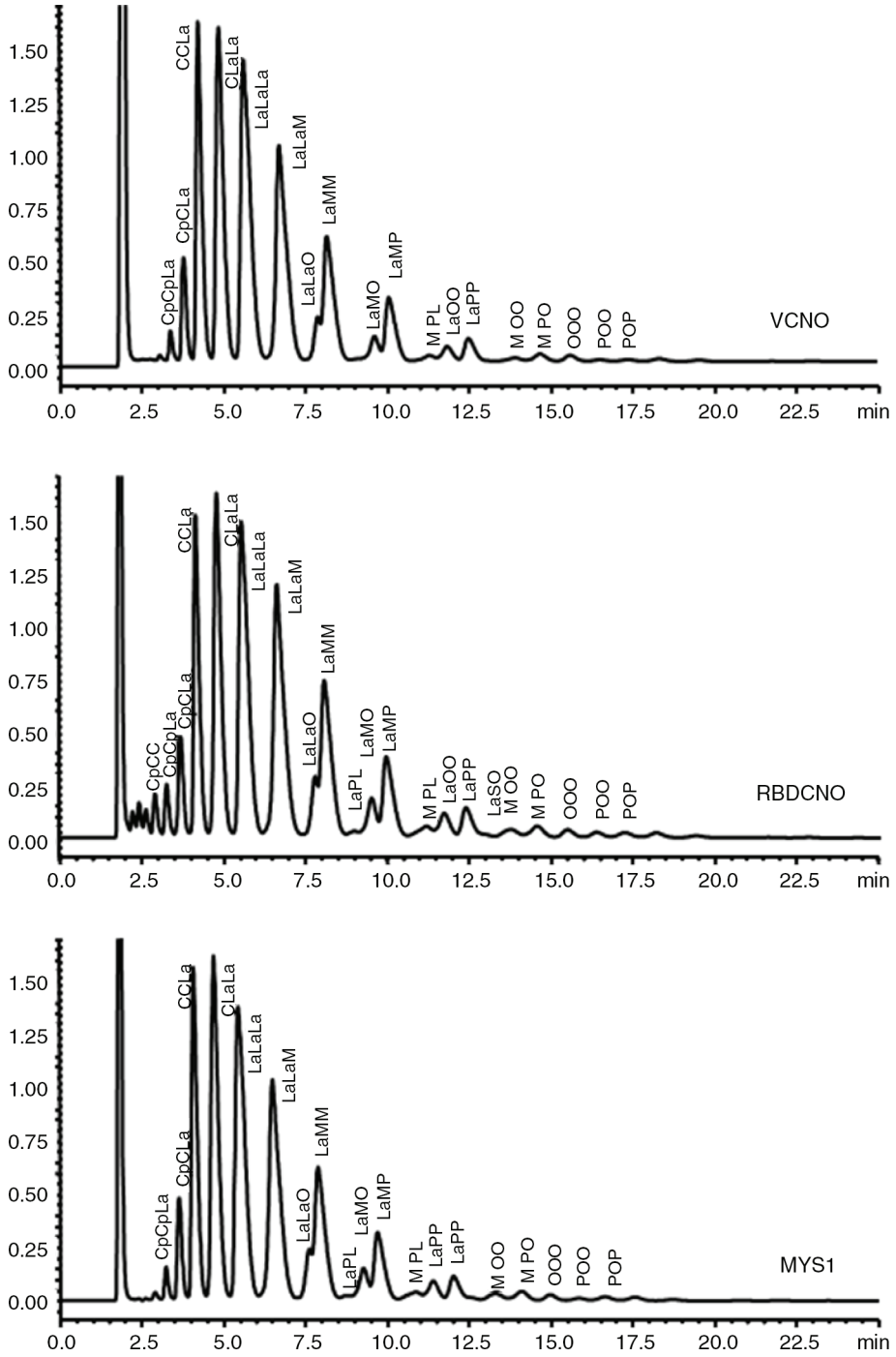


FIGURE 1. Triacylglycerol profile of virgin coconut oil (VCNO), refined bleached and deodorized coconut oil (RBDCNO) and unrefined coconut oil-MYS1.

### 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, 1mL of a 15% $Na_2CO_3$ 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 $10^{-4}$ 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 decreases 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 1mL·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 $p \leq 0.05$.

## 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 or 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 $KOH \cdot g^{-1}$ of RBDCNO and 4.0 mg of $KOH \cdot g^{-1}$ 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 $KOH \cdot g^{-1}$ 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 $meqO_2.kg^{-1}$. The UCNOs MYS5 and MYS8 exhibited the lowest PV of 0.0 and the MYS3 exhibited the highest peroxide value (2.7 meq $O_2.Kg^{-1}$) 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 $O_2.Kg^{-1}$) 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 $KOHg^{-1}$ 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

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

| Coconut oil | Physicochemical characteristics | | | | |
|---|---|---|---|---|---|
| | Color (Lovibond unit)* | FFA (%)* | PV (meq $O_2 \cdot kg^{-1}$)* | IV* (cg $I_2 \cdot g^{-1}$ oil) | SV (mg KOH·$g^{-1}$ oil)* |
| VCNO | 0.0±0.00 | 0.01±0.00$^{a}$ | 0.00±0.00 | 4.5±0.41$^{ad}$ | 255.9±0.23$^{f}$ |
| RBDCNO | 1.6±0.00 | 0.53±0.01$^{b}$ | 0.00±0.00 | 6.0±0.35$^{abce}$ | 253.5±0.47$^{b}$ |
| MYS1 | 2.4±0.00 | 0.32±0.01$^{c}$ | 2.67±0.03$^{a}$ | 5.3±0.05$^{bc}$ | 255.1±0.33$^{e}$ |
| MYS2 | 2.5±0.00 | 0.60±0.01$^{d}$ | 1.32±0.01$^{b}$ | 6.7±0.41$^{bd}$ | 251.0±0.01$^{d}$ |
| MYS3 | 2.6±0.00 | 0.36±0.01$^{e}$ | 2.70±0.01$^{c}$ | 6.3±0.35$^{bd}$ | 239.9±0.37$^{d}$ |
| MYS4 | 2.5±0.00 | 2.02±0.01$^{f}$ | 1.79±0.01$^{d}$ | 5.3±0.34$^{ac}$ | 260.2±0.40$^{e}$ |
| MYS5 | 2.5±0.00 | 0.45±0.01$^{g}$ | 0.00±0.00 | 6.6±0.35$^{dbde}$ | 248.7±0.23$^{f}$ |
| MYS6 | 2.5±0.00 | 0.14±0.00$^{h}$ | 1.82±0.01$^{e}$ | 5.8±0.34$^{cdef}$ | 256.7±0.10$^{e}$ |
| MYS7 | 2.7±0.00 | 0.40±0.01$^{i}$ | 0.45±0.00$^{f}$ | 5.5±0.36$^{cdgh}$ | 254.2±0.10$^{e}$ |
| MYS8 | 2.5±0.00 | 0.57±0.01$^{j}$ | 0.00±0.00 | 6.7±0.40$^{de}$ | 248.1±0.01$^{g}$ |
| Average** | 2.6±0.09 | 0.61±0.59 | 1.35±1.10 | 6.1±3.47 | 251.7±2.06 |

FFA = 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

| FA composition | VCNO | RBDCNO | MYS1 | MYS2 | MYS3 | MYS4 | MYS5 | MYS6 | MYS7 | MYS8 | Average ±SD* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| C8:0 | 7.52$^{a}$ | 7.24$^{b}$ | 8.06$^{c}$ | 7.63$^{acd}$ | 8.22$^{cf}$ | 7.45$^{abdf}$ | 7.20$^{df}$ | 8.39$^{aceg}$ | 7.61$^{abcdfh}$ | 7.13$^{bfi}$ | 7.71±0.47 |
| C10:0 | 6.38$^{a}$ | 5.25$^{b}$ | 5.78$^{c}$ | 5.50$^{cd}$ | 5.81$^{cde}$ | 5.16$^{bdf}$ | 5.36$^{acdef}$ | 6.13$^{bcefg}$ | 5.61$^{cdeg}$ | 5.36$^{cdefh}$ | 5.59±0.31 |
| C12:0 | 55.75$^{a}$ | 50.90$^{bc}$ | 51.66$^{abc}$ | 49.95$^{abcd}$ | 49.11$^{cd}$ | 51.20$^{cd}$ | 49.45$^{cd}$ | 50.42$^{cd}$ | 51.57$^{cde}$ | 49.45$^{cde}$ | 50.35±0.94 |
| C14:0 | 18.74$^{a}$ | 21.38$^{b}$ | 21.05$^{abc}$ | 21.08$^{ac}$ | 20.77$^{abc}$ | 22.45$^{d}$ | 21.30$^{c}$ | 20.29$^{cd}$ | 21.33$^{c}$ | 21.13$^{cde}$ | 21.18±0.61 |
| C16:0 | 7.90$^{a}$ | 9.22$^{b}$ | 8.64$^{c}$ | 8.60$^{bc}$ | 9.32$^{bd}$ | 9.21$^{bde}$ | 9.32$^{fg}$ | 8.49$^{gh}$ | 9.04$^{e}$ | 9.90$^{i}$ | 9.07±0.47 |
| C18:0 | 0.27$^{a}$ | 0.38$^{b}$ | 0.28$^{abc}$ | 0.91$^{d}$ | 0.91$^{e}$ | 0.17$^{c}$ | 1.22$^{f}$ | 0.81$^{df}$ | 0.18$^{c}$ | 0.90$^{df}$ | 0.67±0.40 |
| C18:1 | 3.31$^{a}$ | 4.81$^{b}$ | 4.01$^{c}$ | 4.76$^{bd}$ | 4.73$^{d}$ | 4.04$^{ce}$ | 5.23$^{f}$ | 4.31$^{ce}$ | 4.07$^{ce}$ | 4.77$^{d}$ | 4.49±0.45 |
| C18:2 | 0.13$^{a}$ | 0.81$^{ab}$ | 0.53$^{ac}$ | 1.57$^{d}$ | 1.14$^{bde}$ | 0.32$^{c}$ | 1.35$^{de}$ | 1.16$^{de}$ | 0.59$^{c}$ | 1.36$^{def}$ | 1.00±0.46 |
| SAFA | 96.56$^{a}$ | 94.37$^{b}$ | 95.47$^{bc}$ | 93.67$^{bd}$ | 94.14$^{bcde}$ | 95.64$^{bacef}$ | 93.85$^{bcdfg}$ | 94.53$^{bacdefg}$ | 95.34$^{bcdefg}$ | 93.87$^{acdeghi}$ | 94.56±0.81 |
| MUFA | 3.31$^{a}$ | 4.81$^{ab}$ | 4.01$^{ac}$ | 4.76b$^{abc}$ | 4.73$^{abc}$ | 4.04$^{abc}$ | 5.23$^{bd}$ | 4.31$^{abc}$ | 4.07$^{abc}$ | 4.77$^{abcd}$ | 4.49±0.45 |
| PUFA | 0.13$^{a}$ | 0.81$^{b}$ | 0.53$^{c}$ | 1.57$^{d}$ | 1.14$^{e}$ | 0.32$^{acf}$ | 1.35$^{beg}$ | 1.16b$^{eg}$ | 0.59$^{ch}$ | 1.36$^{deg}$ | 1.00±0.46 |
| MCFA | 69.65$^{a}$ | 63.39$^{b}$ | 65.5$^{c}$ | 63.08$^{b}$ | 63.14$^{b}$ | 63.81$^{b}$ | 62.01$^{d}$ | 64.94$^{c}$ | 64.79$^{c}$ | 61.94$^{d}$ | 63.65±1.34 |

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, MYS& 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.

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.

### 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. Rossell *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 *et al*., 1985; Laureles *et al*. 2002). In this study the lauric acid value of all the UCNOs (49.11 to 51.66%) and RBDCNO (50.90%) of Indian origin were comparable with the results reported by Rossell *et al*., (1985) and Laureles *et al*. (2002). But, the VCNO showed a significantly higher lauric acid content (55.75%) as compared to UCNOs and RBDCNO. 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 capric acid (C10:0) level ranged from 5.16–6.13% for UCNOs, 6.38% for VCNO and 5.25% for RBDCNO. The lowest value was observed for MYS4 (5.16%) and highest value was observed for VCNO (6.38%). The myristic acid (C14:0) content was lower in VCNO (18.74%) by about 2 units. The C14:0 contents of the UCNOs (20.29–22.45%) were comparable with the C14:0 content of the RBDCNO (21.38%). Similarly, the palmitic acid (C16:0) contents of the UCNOs (8.49% to 9.90%) were comparable with the value for RBDCNO (9.22%) while, the VCNO showed a slightly lower value (7.90%). The sample MYS4 showed the lowest stearic acid (C18:0) content which was 0.17% as compared to other coconut oils. The highest C18:0 content was observed for MYS5 (1.22%). The VCNO showed the C18:0 content of 0.3% and RBDCNO 0.4%, which is lower than that of the average C18:0 value of the UCNOs (0.67%). The oleic acid (C18:1) content showed a low value for VCNO (3.31%) and a higher value for MYS5 (5.23%). The C18:1 content of RBDCNO was higher than that of the average value of UCNOs. The linoleic acid (C18:2) content was negligible in VCNO (0.13%) as compared to the average value for UCNO (1.03%) and RBDCNO (0.81%).

Coconut oil contains high amounts of saturated fatty acids (SAFA) as compared to other edible oils. This high SAFA composition provides protection to coconut oil against oxidative rancidity. Thus, coconut oil is considered a suitable source for the frying medium. In this study the SAFA levels for coconut oils ranged from 93.67% for MYS2 to 96.56% for VCNO. The SAFA level for RBDCNO showed 94.37% which is comparable to the SAFA level shown by the UCNOs. The major part of the SAFA is made up of medium chain fatty acids (MCFA). In this study the MCFA ranged from 61.94% for MYS8 to 69.65% for VCNO. The MCFA of VCNO was significantly higher than the other coconut oils used in the study. MYS1 showed the highest MCFA (65.50%) among the UCNOs. The RBDCNO showed an MCFA content of 63.39% which is within the range of MCFA shown by the UCNOs. The monounsaturated fatty acids (MUFA) of the UCNOs ranged from 4.01% to 5.23%. The MYS1 showed the lowest MUFA (4.01%) among the UCNOs. The VCNO showed the lowest amount of MUFA (3.31%) among 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 (Fig. 1). In this study these TAG all together contributed 75.5%–81.3% of the total TAG composition of the coconut oil. The VCNO sample showed the highest LaLaLa content (21.88%) compared to RBDCNO (19.63%) and UCNO. The CCLa was lowest in MYS4 (11.24%) and the highest in VCNO (14.32%) compared to the other samples. The CLaLa was the highest in VCNO (18.59%) and the lowest in UCNO4 (16.34%). The UCNOs showed an average of 17.56% of CLaLa composition. The LaMM content was the lowest in VCNO (9.62%) and the highest in MYS8 (12.67%) as compared to the other oils used for the study. The LaLaM content of VCNO (17.20%) and RBDCNO (17.27%) was similar to the average LaLaM value of the UCNOs (17.41%) and there is no significant difference among VCNO, RBDCNO and UCNOs. The other TAG species contributed 18.3% of the total TAG composition of the VCNO. In RBDCNO, 24.5% were contributed by other TAG species. In the UCNOs these TAG compositions ranged from 18.8–24.6% of the total TAG composition. Monolauricmonomyristicmonopalmitin (LaMP) is the major part (4.90%–5.96%) of this constitution.

In this study, the medium chain triglyceride ($M_3$) contents ranged from 51.47% for MYS4 - 59.27%

TABLE 3. Triacylglycerol composition of the Indian coconut oils used in the study

| TG species | VCNO | RBDCNO | MYS1 | MYS2 | MYS3 | MYS4 | MYS5 | MYS6 | MYS7 | MYS8 | Average* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Unidentified | 0.02$^{a}$ | 0.30$^{b}$ | 0.04$^{ac}$ | 0.10$^{d}$ | 1.75$^{e}$ | 0.30$^{b}$ | 0.03$^{acf}$ | 0.01$^{afg}$ | 0.05$^{cfh}$ | 0.06$^{ch}$ | 0.29±0.60 |
| Unidentified | 0.03$^{a}$ | 0.45$^{b}$ | 0.04$^{a}$ | 0.05$^{a}$ | 0.82$^{c}$ | 0.27$^{d}$ | 0.14$^{g}$ | 0.03$^{a}$ | 0.32$^{f}$ | 0.03$^{a}$ | 0.21±0.27 |
| Unidentified | 0.13$^{a}$ | 0.41$^{b}$ | 0.20$^{c}$ | 0.09$^{d}$ | 0.54$^{e}$ | 0.27$^{f}$ | nd | 0.04$^{g}$ | 0.21$^{c}$ | 0.07$^{d}$ | 0.20±0.17 |
| CpCC | nd | 1.03$^{a}$ | nd | 0.19$^{b}$ | nd | 0.44$^{c}$ | nd | 0.14$^{d}$ | 0.19$^{b}$ | 0.17$^{b}$ | 0.23±0.12 |
| CpCpLa | 0.81$^{a}$ | 1.36$_{b}$ | 0.86$^{c}$ | 0.79$^{a}$ | 1.02$^{d}$ | 0.85$^{e}$ | 0.74$^{f}$ | 0.82$^{a}$ | 0.75$^{f}$ | 0.74$^{f}$ | 0.95±0.38 |
| CpCLa | 3.67$^{a}$ | 3.20$^{b}$ | 3.46$^{abc}$ | 3.07b$^{c}$ | 3.38$^{abcd}$ | 2.85$^{b}$ | 2.98$^{bd}$ | 3.40$^{bcde}$ | 3.10$^{bcd}$ | 3.06$^{bcd}$ | 3.16±0.20 |
| CCLa | 14.32$^{a}$ | 11.57$^{b}$ | 13.44$^{c}$ | 12.26$^{bd}$ | 12.36$^{de}$ | 11.24$^{bf}$ | 12.41e | 13.38$^{cg}$ | 12.65$^{de}$ | 12.53d$^{eg}$ | 12.53±0.69 |
| CLaLa | 18.59$^{a}$ | 16.47$^{b}$ | 18.31$^{a}$ | 17.30$^{c}$ | 17.02$^{c}$ | 16.34$^{b}$ | 17.75$^{c}$ | 18.27$^{a}$ | 17.77$^{c}$ | 17.70$^{c}$ | 17.56±0.66 |
| LaLaLa | 21.88$^{a}$ | 19.63$^{b}$ | 20.67$^{c}$ | 20.27$^{bc}$ | 19.48$^{bd}$ | 19.74$^{bcde}$ | 20.96$^{acf}$ | 20.59$^{bcef}$ | 20.69$^{cef}$ | 20.71$^{cef}$ | 20.39±0.52 |
| LaLaM | 17.20$^{a}$ | 17.27$^{a}$ | 16.95$^{ab}$ | 17.70$^{abc}$ | 16.41$^{abd}$ | 17.92$^{abce}$ | 18.13$^{acef}$ | 16.92$^{abceg}$ | 17.55$^{abcdefg}$ | 17.72$^{abcefg}$ | 17.41±0.59 |
| LaLaO | 1.97$^{a}$ | 2.28$^{ab}$ | 2.28$^{ab}$ | 2.33$^{ab}$ | nd | 2.43$^{bc}$ | 2.28$^{abc}$ | 1.97$^{abd}$ | 2.40$^{bc}$ | nd | 2.28±0.16 |
| LaMM | 9.62$^{a}$ | 10.60$_{b}$ | 9.77$^{abc}$ | 10.52$^{abcd}$ | 11.93$^{e}$ | 10.30$^{abcd}$ | 10.85$^{bd}$ | 10.14$^{abc}$ | 10.14$^{abcd}$ | 12.67$^{e}$ | 10.79±1.00 |
| LaPL | nd | 0.22$^{a}$ | 0.23$^{a}$ | 0.33$^{b}$ | 0.37$^{c}$ | 0.79$^{d}$ | nd | 0.26$^{a}$ | 0.27$^{a}$ | 0.27$^{a}$ | 0.36±0.20 |
| LaMO | 1.70$^{a}$ | 2.18$^{b}$ | 2.01$^{b}$ | 2.13$^{b}$ | 2.07$^{b}$ | 2.13$^{b}$ | 1.85$_{a}$ | 2.00$^{b}$ | 2.05$^{b}$ | 2.11$^{b}$ | 2.04±0.09 |
| LaMP | 4.74$^{a}$ | 5.35$^{b}$ | 4.90$^{ab}$ | 5.36$^{b}$ | 5.00$^{ab}$ | 5.96$^{c}$ | 5.28$^{b}$ | 5.04$^{ab}$ | 4.98$^{ab}$ | 5.12$^{ab}$ | 5.21±0.34 |
| MPL | 0.44$^{a}$ | 0.87$^{b}$ | 0.73$^{b}$ | 0.84$^{b}$ | 0.88$^{b}$ | 0.67$^{b}$ | 0.48$^{a}$ | 0.80$^{b}$ | 0.72$^{b}$ | 0.77$^{b}$ | 0.74±0.12 |
| LaOO | 1.09$^{a}$ | 1.59$^{b}$ | 1.41$^{b}$ | 1.55$^{b}$ | 1.55$^{b}$ | 1.67$^{b}$ | 1.25$^{a}$ | 1.38$^{b}$ | 1.43$^{b}$ | 1.47$^{b}$ | 1.46±0.13 |
| LaPP | 1.68$^{a}$ | 1.93$^{ab}$ | 1.82$^{ab}$ | 1.88$^{ab}$ | 1.84$^{ab}$ | 2.18$^{b}$ | 1.57$^{a}$ | 1.63$^{ab}$ | 1.68$^{ab}$ | 1.75$^{ab}$ | 1.79±0.19 |
| LaSO | nd | 0.11$^{a}$ | nd | 0.16$^{a}$ | 0.20$^{a}$ | 0.09$^{a}$ | nd | 0.23$^{a}$ | 0.11$^{a}$ | 0.13$^{a}$ | 0.15±0.05 |
| MOO | 0.27$^{a}$ | 0.68$^{b}$ | 0.61$^{b}$ | 0.69$^{b}$ | 0.75$^{b}$ | 0.64$^{b}$ | 0.69$^{b}$ | 0.72$^{b}$ | 0.62$^{b}$ | 0.64$^{b}$ | 0.67±0.05 |
| MPO | 0.63$^{a}$ | 0.91$^{b}$ | 0.74$^{a}$ | 0.85$^{b}$ | 0.90$^{b}$ | 1.01$^{b}$ | 0.88$^{b}$ | 0.75$^{b}$ | 0.82$^{b}$ | 0.81$^{b}$ | 0.85±0.09 |
| OOO | 0.46$^{a}$ | 0.51$^{a}$ | 0.37$^{a}$ | 0.44$^{a}$ | 0.52$^{a}$ | 0.59$^{a}$ | 0.50$^{a}$ | 0.39$^{a}$ | 0.44$^{a}$ | 0.40$^{a}$ | 0.46±0.08 |
| POO | 0.11$^{a}$ | 0.36$^{b}$ | 0.19$^{a}$ | 0.22$^{a}$ | 0.17$^{a}$ | 0.07$^{c}$ | 0.15$^{a}$ | 0.16$^{a}$ | 0.20$^{a}$ | 0.13$^{a}$ | 0.16±0.05 |
| POP | 0.14$^{a}$ | 0.41$^{b}$ | 0.37$^{b}$ | 0.30$^{b}$ | 0.42$^{b}$ | 0.34$^{b}$ | 0.42$^{b}$ | 0.39$^{b}$ | 0.38$^{b}$ | 0.33$^{b}$ | 0.37±0.40 |
| Unidentified | 0.50$^{a}$ | 0.72$^{a}$ | 0.60$^{a}$ | 0.59$^{a}$ | 0.66$^{a}$ | 0.73$^{a}$ | 0.67$^{a}$ | 0.56$^{a}$ | 0.48$^{a}$ | 0.60$^{a}$ | 0.61±0.80 |
| $M_3$ | 59.27$^{a}$ | 52.96$^{b}$ | 55.75$^{c}$ | 53.87$^{bcd}$ | 53.25$^{bde}$ | 51.47$^{bde}$ | 54.82$^{bcde}$ | 56.59$^{acdf}$ | 55.15$^{cdef}$ | 54.91$^{cdef}$ | 54.60±1.74 |
| $S_3$ | 92.51$^{a}$ | 88.41$^{b}$ | 90.18$^{abc}$ | 89.34$_{bc}$ | 88.44$^{bc}$ | 87.82$^{bcd}$ | 90.67$^{abce}$ | 90.33$^{abcde}$ | 89.49$^{abcde}$ | 92.17$^{ace}$ | 89.80±1.35 |
| $S_2U$ | 4.88$^{a}$ | 6.98$^{b}$ | 6.36$^{b}$ | 6.94$^{b}$ | 4.84$^{a}$ | 7.46$^{bc}$ | 5.91$^{ab}$ | 6.40$^{bc}$ | 6.75$^{bc}$ | 4.42$^{a}$ | 6.14±1.04 |
| $SU_2$ | 1.47$^{a}$ | 2.63$^{b}$ | 2.21$^{c}$ | 2.46$^{bc}$ | 2.47$^{bc}$ | 2.38$^{bc}$ | 2.09$^{c}$ | 2.26$^{bc}$ | 2.25$^{bc}$ | 2.24$^{c}$ | 2.25±0.31 |
| $U_3$ | 0.46$^{a}$ | 0.51$^{a}$ | 0.37$^{ab}$ | 0.44$^{ab}$ | 0.52$^{ab}$ | 0.59$^{ac}$ | 0.50$^{abcd}$ | 0.39$^{bd}$ | 0.44$^{abcd}$ | 0.40$^{abcd}$ | 0.46±0.08 |

M3 – Medium chain triglyceride, S3 – Trisaturated triglyceride, S2U – Disaturated triglyceride, SU2 – Monosaturated triglyceride, U3 – Triunsaturated triglyceride. Values are mean ± standard deviation (n = 4).
*Average value of UCNOs- MYS1, MYS2, MYS3, MYS4, MYS5, MYS6, MYS7 and MYS8.
The average value with the same superscript within the row indicates there is no significant different (P≤0.05) in the TAG composition. Average values with different superscript within the row indicate p value is <0.001, considered significant changes in radical scavenging activity.

for VCNO. The highest $M_3$ of VCNO may be contributed by the highest MCFA composition (69.65%) of VCNO. The highest $M_3$ content is shown by MYS6 (56.59%) among the UCNOs. The three saturated fatty acid containing TAG ($S_3$) 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 ($S_2U$) was the lowest in MYS8 (4.42%) and the highest in MYS4 (7.46%). The one saturated fatty acid containing TAG ($SU_2$) was the lowest in VCNO (1.47%) and the highest in RBDCNO (2.63%). The three unsaturated fatty acid containing TAG ($U_3$) 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

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

| Coconut oil | Phytosterols (mg·100g$^{-1}$)* | Phenolics (mg·100g$^{-1}$)* | RSA (% inhibition)* |
|---|---|---|---|
| VCNO | 54.9±2.2$^{a}$ | 1.8±0.00$^{a}$ | 11.6±0.6$^{a}$ |
| RBDCNO | 81.4±1.8$^{b}$ | 2.1±0.19$^{b}$ | 14.0±0.2$^{b}$ |
| MYS1 | 74.5±2.6$^{bc}$ | 8.2±0.13$^{c}$ | 20.8±0.5$^{c}$ |
| MYS2 | 96.8±1.8$^{d}$ | 5.7±0.01$^{d}$ | 22.9±0.5$^{d}$ |
| MYS3 | 76.8±3.3$^{bc}$ | 11.4±0.04$^{e}$ | 27.0±0.5$^{e}$ |
| MYS4 | 83.7±2.6$^{bef}$ | 2.7±0.01$^{f}$ | 13.8±0.0$^{f}$ |
| MYS5 | 82.7±2.9$^{bdef}$ | 19.1±0.09$^{g}$ | 50.2±0.4$^{g}$ |
| MYS6 | 80.7±4.6$^{bcfghi}$ | 8.1±0.15$^{c}$ | 28.0±0.3$^{e}$ |
| MYS7 | 85.1±2.7$^{bghij}$ | 11.7±0.04$^{h}$ | 17.8±0.7$^{h}$ |
| MYS8 | 89.5±3.5$^{fgij}$ | 8.1±0.08$^{c}$ | 21.0±0.3$^{c}$ |
| Average** | 83.8±7.1 | 9.4±4.90 | 25.2±11.1 |

*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.

cholesterol levels. The total phytosterol contents of the unrefined coconut oils (UCNOs) were in the range of 74.5 mg·100 g$^{-1}$ oil for MYS1 to 96.8 mg·100 g$^{-1}$ oil for MYS2. The phytosterol content of unrefined coconut oil showed that the content was higher than that present in the VCNO (54.9 mg·100 g$^{-1}$ oil). The phytosterol contents of the UCNOs (except MYS2 and MYS8) (74.5–85.1 mg) and RBDCNO (81.4 mg) showed no significant difference ($p<0.05$). This may be due to no or less loss in phytosterols during the refining of the oil. The lowest phytosterol content of the VCNO may be due to the process employed for the preparation of VCNO. There is no literature on this aspect that can explain why the phytosterol level is lower in VCNO than in UCNO and RBDCNO. The values obtained for all the samples were within the range of values given for coconut oil under the Codex Alimentarius Commission Specification (40–120 mg %) (Codex Alimentarius, 2003).

### 3.5. Phenolic composition of the different types of coconut oil

Phenolics are one of the most important naturally occurring plant based antioxidants. They are normal antioxidants derived mainly from benzoic acid and cinnamic acid. The direct relation of phenolics with antioxidant capacity has been reported by Robards *et al*. (1999). Phenolics act as a dietary antioxidant, antimutagen, antiproliferative and anticarcinogenic agents. Table 4 shows the total phenolic contents of various commercially available coconut oils. The total phenolic content of unrefined coconut oil showed significant difference as compared to VCNO and RBDCNO. The VCNO had the lowest phenolic content (1.8 mg GAE·100 g$^{-1}$ oil). The RBDCNO had the phenolic content of 2.1 mg GAE·100 g$^{-1}$ oil. The UCNOs except MYS4 had more than 5 mg total phenolic contents. The total phenolic 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 phenolic contents among the UCNOs, VCNO and RBDCNO were most probably due to the extraction method, the de-skinning (removal of testa) of coconut and the moisture removal process for VCNO and the RBD process under gone 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

TABLE 5. Tocopherol and tocotrienol compositions of the Indian coconut oils used in the study

| Coconut oil | Tocopherol (mg·100g$^{-1}$) | | Tocotrienol (mg·100g$^{-1}$) | | Total Tocols | Toco:$T_3$ |
|---|---|---|---|---|---|---|
| | α-Toco | γ-Toco | α-$T_3$ | γ-$T_3$ | | |
| VCNO | 1.6±0.0$^{a}$ | 0.7±0.0$^{a}$ | 2.0±0.0$^{a}$ | 0.6±0.0$^{a}$ | 4.9$^{a}$ | 2.3:2.6 |
| RBDCNO | 0.5±0.0$^{b}$ | 0.3±0.0$^{b}$ | 1.8±0.0$^{b}$ | 0.2±0.0$^{b}$ | 2.8$^{b}$ | 0.8:2.0 |
| MYS1 | 0.6±0.0$^{b}$ | nd | 0.8±0.0$^{c}$ | nd | 1.4$^{c}$ | 0.6:0.8 |
| MYS2 | 2.8±0.0$^{c}$ | nd | 2.9±0.0$^{d}$ | nd | 5.7$^{d}$ | 2.8:2.9 |
| MYS3 | 1.3±0.0$^{d}$ | nd | 0.3±0.0$^{e}$ | 0.1±0.0$^{c}$ | 1.7$^{e}$ | 1.3:0.4 |
| MYS4 | nd | 0.3±0.0$^{c}$ | 1.6±0.0$^{f}$ | 0.2±0.0$^{d}$ | 2.1$^{f}$ | 0.3:1.8 |
| MYS5 | 2.4±0.0$^{e}$ | 0.3±0.0$^{c}$ | 3.4±0.0$^{g}$ | 0.3±0.0$^{b}$ | 6.4$^{g}$ | 2.7:3.7 |
| MYS6 | 2.4±0.0$^{e}$ | nd | 2.4±0.0$^{a}$ | 0.2±0.0$^{b}$ | 4.8$^{h}$ | 2.4:2.6 |
| MYS7 | 2.7±0.2$^{c}$ | nd | nd | 0.2±0.0$^{b}$ | 2.9$^{i}$ | 2.7:0.2 |
| MYS8 | 3.0±0.2$^{c}$ | 0.1±0.0$^{d}$ | 3.3±0.0$^{g}$ | 0.6±0.0$^{a}$ | 7.0$^{j}$ | 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.

antioxidant properties which are manifested in anti-cancer and neuroprotective actions as well as protection 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 contents of 100 mg·100g$^{-1}$ in the oil extracted from the testa portion of the wet coconut kernel. The VCNO contained 4.9 mg of total tocopherols and the RBDCNO contained 2.8 mg·100 g$^{-1}$ of tocopherols. The MYS1 (1.4 mg), MYS3 (1.7 mg) and MYS4 (1.7 mg) were the lowest in tocopherol content compared to the other samples. The reason is not known and could be due to a variation in copra quality, loss in tocopherols during storage, initially higher moisture content, storage temperature, drying methods such as sun drying or oven drying and or processing conditions employed during the extraction of the oil. Similarly, the low tocopherol content of RBDCNO (2.8 mg/100 g) may be due to the refining process employed for the RBDCNO preparation. α-Tocopherol (α-toco) and α-tocotrienol (α-$T_3$) are the major vitamin-E analogues present in the studied coconut oils with α-toco of 0 to 3.1 mg and α- $T_3$ of 0 to 3.9 mg/100g oil. The sample MYS8 showed the highest total toco (7.0 mg) and MYS1 showed the lowest total toco (1.4 mg) while the highest total $T_3$ was shown by MYS8 (3.9 mg) and the lowest total $T_3$ was shown by MYS7 (0.2 mg). VCNO showed the α-toco of 1.9 mg and RBDCNO of 0.5 mg. The value for RBDCNO was lower than that of the average α-toco level (1.9 mg) of UCNOs. But, the α-$T_3$ level of VCNO (2.0 mg) was similar to that of the average α-$T_3$ level (1.8 mg) of UCNOs and RBDCNO (1.8 mg). The other vitamin E analogues found were γ- toco and γ-$T_3$. In this study 0.6 mg of γ-$T_3$ were found in VCNO. The samples MYS1, MYS2, MYS3, MYS6 and MYS7 did not show the presence of γ-Toco and the RBDCNO showed the γ-Toco of 0.3 mg and the UCNOs showed the average γ-Toco of 0.3 mg which was less than that of the γ-Toco level of VCNO (0.7 mg). The level of γ-$T_3$ was 0 mg for MYS1 and MYS2 and for the other samples the γ-$T_3$ level ranged from (0.1 to 0.3 mg). The MYS8 (0.6 mg) and VCNO (0.6 mg) showed slightly higher γ-$T_3$ compared to the other samples. The reason for these variations is not known and may be taken as insignificant. Generally, the tocopherol level in coconut oil is very low at less than 20 mg·100g$^{-1}$ oil while for other vegetable oils it ranges from 40–150 mg·100g$^{-1}$ oil. In view of this, the minor variations in the vitamin-E analogues such as tocopherols and tocotrienols may be taken as non-significant.

## 4. CONCLUSIONS

In conclusion, the results show that the virgin coconut oil (VCNO) is superior in quality based on the physicochemical properties and the unrefined coconut oils (UCNOs) were superior in quality based on the phytonutrient composition and the RBDCNO was slightly lower in phytonutrient composition 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 phytonutrients might cause differences in biological effects which are not yet understood.

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