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Quality evaluation of virgin coconut oil extracted from different processing methods

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Abstract
Virgin coconut oil (VCO), the purest form of coconut oil, is growing in popularity as a functional food. VCO is extracted from different cold and hot methods. In this study, VCO was extracted from fresh and mature kernels of west coast tall (WCT) coconut variety using hot, cold centrifugation and enzymatic methods. Based on the organoleptic evaluation, VCO extracted from the hot process showed the maximum mean score of 8.99 for overall acceptability. Physicochemical properties of VCO were statistically analysed and compared with the guidelines for edible oils established by the Asian Pacific Coconut Community (APCC). The results showed that there was a significant difference in oil recovery, moisture content, saponification value, iodine value, fatty acid profile, tocopherol, total phenol content and total antioxidant activity of VCO extracted from hot (HVCO), cold centrifugation (CCVCO) and enzymatic methods (EVCO). The oil recovery was higher in EVCO and lowest moisture content was detected in HVCO. Fatty acid profile demonstrated that lauric acid was the major fatty acid present in VCOs with a range of 45.05 to 47.05%. CCVCO contained more lauric acid (47.05%), tocopherol (27.68 μg/g), total phenol content (9.97 GAE μg/g) and total antioxidant activity (μg/mg) than EVCO and HVCO.

Keywords: Virgin coconut oil, organoleptic evaluation, physicochemical properties, fatty acid composition, tocopherol, total phenol content, total antioxidant activity

Introduction
Coconut (*Cocos nucifera*) is an important and versatile crop, which provides all necessities for human life. About one-third of the world's population depends on coconuts for food and economic needs. The coconut, also known as the "*Kalpavriksha*" or "Tree of Heaven," that provides food security and opportunities for livelihood to the people through farming, processing, marketing, and trade-related activities. As a result, it has a significant impact on rural economics (DebMandal and Mandal, 2011) [9]. Virgin coconut oil (VCO) is a recent high-value coconut product that is gaining popularity worldwide as a functional food.

VCO is the purest form of coconut oil with a fresh coconut aroma. It is extracted naturally, with or without the use of heat, from fresh and mature kernel of coconuts (APCC, 2003) [3]. VCO has a higher nutritionally beneficial effect than copra oil because it preserves the majority of its active components. VCO contains lauric, myristic, palmitic, capric, stearic, oleic, and linoleic acids and is rich in medium-chain fatty acids (MCFA) at about 63 per cent (DebMandal and Mandal, 2011) [9]. It is easily digestible due to the presence of medium chain fatty acids (Che Man and Marina, 2006) [6]. VCO is unique among all the vegetable oils because of its high content of lauric acid, vitamin E, polyphenols and antioxidants. Monoglyceride form of lauric acid is called monolaurin that gives immunity to the body and protects infants from bacterial, viral, and protozoal illnesses (Nasir *et al*., 2018) [22]. VCO has number of benefits including the health benefits from the retained antioxidants and vitamins, antimicrobial and antiviral properties from the lauric acid, and anti-mutagenic, anti-proliferative and anti-carcinogenic properties from phenolic compounds present in VCO.

There are various methods for extracting VCO. It is directly extracted from the coconut kernel by using controlled temperature, chilling and centrifugation, enzymatic, pH method, or any of these methods in combination to destabilize the coconut milk emulsion (Raghavendra and Raghavarao, 2010) [26]. These methods can be largely divided into wet and dry methods.

In dry method, the coconut milk is heated under specific conditions to remove the moisture in it while in wet method, coconut milk does not undergo heating process but involves fermentation of milk and further centrifugation at high speed. There are variations in the qualities of VCO extraction by different methods. Hence the present study aimed to assess the quality of VCO extracted using hot, cold centrifugation and enzymatic processes on organoleptic evaluation and its physicochemical properties.

Materials and Methods

Collection of raw materials

The matured coconuts of the west coast tall (WCT) variety was procured from the Instructional farm of Kerala Agricultural University (KAU), Vellanikkara, Thrissur, Kerala.

Extraction of VCO

Preparation of coconut milk

The matured coconuts (10-11 months old) were selected for milk extraction. The coconut kernel was grated using a coconut grater after being dehusked. Coconut milk was extracted from the grated coconut kernel manually using a white muslin cloth. The coconut milk obtained from the first extraction was used for the preparation of oil.

Hot extraction method (HVCO)

In the hot extraction process, coconut oil was extracted from coconut milk by heating according to the method suggested by Manikantan *et al*. (2016) [17]. VCO was extracted by heating coconut milk at 100-120 °C for 60 minutes until the water was completely evaporated. Due to heating, the proteins in coconut milk get denatured and destabilizes the milk emulsion. The coagulated protein was separated by filtering through muslin cloth and the remaining residue was further heated to extract more oil.

Cold centrifugation method (CVCO)

VCO was extracted according to Raghavendra and Raghavarao (2010) [26] with some modifications. Coconut milk was centrifuged at 5000 rpm for 10 minutes at 4 °C and the upper layer of cream was removed for chilling. Chilling was done at 4 °C for 24 h and then chilled cream was thawed slowly in a water bath at 50 °C. Then oil was filtered using Whatman filter paper no. 1 and stored in glass bottles.

Enzymatic method (EVCO)

The enzymatic method of VCO extraction was prepared according to Raghavendra and Raghavarao (2010) [26] with some modifications. The milk of the coconut was mixed with papain enzyme at 0.1% (w/w) of the milk. The mixture was made into a homogenous solution by stirring. It was left to stand for 3 h at 55 °C as this is the optimum temperature for papain enzyme. The mixture was later centrifuged at 4900 rpm for 25 min to obtain the oil. Oil was collected from the centrifuge tube and filtered using Whatman filter paper no. 1 to remove some debris that escaped into the oil.

Organoleptic evaluation

The extracted VCOs were evaluated for sensory characteristics. A panel of fifteen judges were selected by standard procedure (Jellinek, 1985) [12]. Organoleptic qualities of VCO were evaluated by the selected panel of judges using a nine point hedonic scale.

Physicochemical properties

Physicochemical properties such as oil recovery (AOAC, 2012) [2], moisture content (AOAC, 1997), saponification value (Sadasivam and Manickam, 2017) [28], iodine value (Sadasivam and Manickam, 2017) [28], fatty acid profile (Cocks and Van Rede, 1996) [7], tocopherol (Sadasivam and Manickam, 2017) [28], total phenol content (Malick and Singh, 1980) [16] and total antioxidant activity (Prieto *et al*., 1997) [24] of VCOs were analysed using standard procedures.

Statistical analysis

The data was recorded and analysed as a completely randomized design (CRD). The scores obtained for organoleptic evaluation were evaluated by Kendall's coefficient of concordance (W). Physicochemical properties of VCOs were statistically compared by Duncan's multiple range test (DMRT).

Results and Discussion

In this study sensory characteristics and physicochemical properties of the VCOs were evaluated. The findings were confirmed with suitable statistical analysis and discussed under the following sub headings.

Organoleptic evaluation

The sensory evaluation was carried out using nine hedonic scale with a panel of fifteen judges. It considered six sensory parameters including appearance, colour, flavour, texture, taste and overall acceptability. The mean scores obtained for the organoleptic qualities of each treatment were statistically analysed using Kendall's coefficient of concordance and the mean scores were worked out and is given in Table 1. The maximum mean score for organoleptic qualities were obtained for HVCO followed by CCVCO and EVCO. The organoleptic score for appearance and colour of HVCO was low compared to other two methods. Lisna and Purnama (2010) [15] also reported that the organoleptic evaluation of VCO extracted from the heating process showed the lowest score for the colour parameter. They also noted that the turbid colour of the VCO due to the prolonged heating process and constant stirring.

Table 1: Mean scores for organoleptic evaluation of VCO extracted by different methods

Sensory attributes	HVCO	CCVCO	EVCO	Kendall's [W] Value
Appearance	8.93 (1.90)	9 (2.05)	9 (2.05)	0.10**
Colour	8.95 (1.70)	9 (2.15)	9 (2.15)	0.30**
Flavour	9 (2.90)	8.33 (2.10)	8.3 (1.00)	0.96**
Taste	9 (2.05)	8.95 (1.90)	8.87 (2.05)	0.10**
Texture	9 (2.30)	8.98 (1.90)	9 (2.30)	0.175**
Over all acceptability	8.99 (2.80)	8.95 (2.20)	8.83 (1.00)	0.884**
Total score	53.87	53.21	53.0	

Values in parentheses are mean rank scores based on Kendall's W. (** significant at 1% level).

Physicochemical properties
Physicochemical properties such as oil recovery, moisture, saponification value, iodine value, tocopherol, fatty acids, total phenol content and total antioxidant activity of HVCO, CVCO and EVCO are summarised in table 2 and 3.

Oil recovery
Oil recovery depends on various factors such as time of harvesting the coconuts, age of coconuts, age of copra etc. (Carandang, 2008) [5]. It gives a quantitative assessment on the effectiveness of the various extraction techniques on the amount of oil produced. All the VCO samples had notably significant differences (p<0.05). From Table 2, it is evident that oil recovery was higher in EVCO followed by HVCO and CCVCO. This result was agreed with Muhammed *et al.* (2021) who reported the application of enzymatic treatment for the VCO production and obtained the highest yield. Mansor *et al.* (2009) obtained 60.9% oil using 0.1% papain enzyme and 93% oil was extracted by Senphan and Benjakul (2016) [29] using crude protease enzyme from white shrimp. It was noted that VCO yield depended on the extraction techniques.

Moisture content
Oil quality is greatly influenced by moisture. According to APCC regulations, the moisture content of the VCOs should be less than 0.5% (APCC 2009) [4]. Among all the VCO samples, it was discovered that the HVCO had the least amount of moisture. This may be due to the high temperature that significantly remove the water components from the VCO. As shown in the table 2, the moisture content was higher in enzymatic method. High moisture content lead to hydrolytic rancidity of fats and oils and reduces the shelf life of the VCO samples (Raghavendra and Raghavarao, 2011) [25].

Saponification value (SV)
This measures the mean molecular weight of fatty acids present in the oil. All of the samples had high SV values with significant differences (p<0.05), ranging from 254.50 to 259.86 mg KOH/g of fats (Table 1). According to the Codex standard (2001), the SV for edible coconut oils must be between 248 and 265 mg KOH/g oil. The highest SV was from CCVCO followed by HVCO and the lowest was from EVCO. SV is directly proportional to the shorter chain fatty acids on the glycerol backbone. The VCOs had a higher SV than the other vegetable oils, which indicated that they had more number of short-chain fatty acids than the other vegetable oils.

Table 2: Physicochemical properties of VCO extracted by different methods

	HVCO	CCVCO	EVCO	CD value	APCC standard
Oil recovery (%)	39.53 b	38.8 c	49.6 a	0.038*	-
Moisture (%)	0.09 c	0.14 b	0.22 a	0.036*	0.1 - 0.5
Saponification value (mg KOH/g fat)	258.07 b	259.86 a	254.50 c	0.061*	250 - 260
Iodine value (I_2/100 g)	4.95 c	5.49 a	5.23 b	0.042*	4.10 - 11.00
Tocopherol (µg/g)	14.82 c	27.68 a	18.53 b	0.042*	-
Total phenol content (GAE µg/mg)	8.82 b	9.97 a	9.82 a	0.038*	-
Total antioxidant activity (µg/mg)	17.23 b	27.45 a	27.28 a	0.042*	-

DMRT Row wise comparison
*Significant at 5%

Iodine value (IV)
IV measures the degree of unsaturation present in the oils and fat samples. It was expressed as the grams of iodine that was absorbed by 100 g fats under the conditions used for the test. In this study, the IV of the VCO samples ranged between 4.95 and 5.49 g of I_2/100 g of oil. The rise in iodine value could be due to the slightly higher amount of unsaturated fatty acids. All the VCO samples showed a significant difference between the IV values (p<0.05). The CCVCO showed the highest IV value while the HVCO showed the lowest IV value. Similar results were reported by Mohammed *et al.* (2021) [20]. The low level of IV demonstrated that the VCO has a higher saturation level, increasing its resistance to the oxidative rancidity (Rohman *et al.*, 2011) [27]. The IV values of the samples were within the limits recommended by the APCC (2007) and Codex (2001) [8] guidelines for edible coconut oils.

Table 3: Fatty acid composition of VCO extracted by different methods

Fatty acids (%)	HVCO	CCVCO	EVCO	CD value	APCC standard
Caprylic acid (C8: 0)	7.36 a	5.54 c	6.97 b	0.049*	5.00 - 10.0
Capric acid (C10: 0)	6.58 a	5.01 b	6.64 a	0.041*	4.50 - 8.00
Lauric acid (C12: 0)	46.86 b	47.05 a	45.05 c	0.044*	43.0 - 53.0
Myristic acid (C14: 0)	20.13 b	21.68 a	21.66 a	0.038*	16.0 - 21.0
Palmitic acid (C16: 0)	8.66 b	9.57 a	8.97 b	0.042*	7.50 - 10.0
Stearic acid (C18: 0)	1.84 a	1.85 a	1.47 b	0.036*	2.00 - 4.00
Oleic acid (C18: 1)	7.39 b	8.08 a	8.05 a	0.036*	5.00 - 10.00
Linoleic acid (C18: 3)	1.18 b	1.22 a	1.19 b	0.036*	1.00 - 2.50

DMRT Row wise comparison
*Significant at 5%

Fatty acids
In order to provide information about the distribution of fatty acids in the VCO, this fatty acid analysis is essential (Kamariah *et al.*, 2008) [13]. DebMandal and Mandal (2011) [9] pointed that lauric acid is the most dominant fatty acids present in VCO followed by myristic, palmitic, capric, stearic and small percentages of unsaturated oil such as oleic and linoleic acids. In this study, it was found that the predominant

fatty acid in VCO was lauric acid (C12:0), with concentrations ranging from 45.05% to 47.05%, which is in agreement with the APCC (2007) standard for VCO (43.0%-53.0%). Mohammed *et al.* (2021) [20] also reported that lauric acid was the predominant fatty acid present in VCO varied from 47.95% to 48.83%. The highest lauric acid was found in CCVCO followed by HVCO and EVCO. The lowest saturated fatty acid was stearic acid with a range between 1.47% and 1.85%. The results showed that fatty acid content can vary with various extraction methods and cold centrifugation is the most effective method for producing high lauric acid composition. Ghani *et al.* (2018) [11] also reported that the fatty acids composition can vary based on the extraction methods. The overall saturated fatty acid content of HVCO, CCVCO, and EVCO was 91.43%, 90.70% and 90.76% respectively while the total unsaturated fatty acid [mono- and di-saturated FA] ranged from 8.85%, 9.3% and 9.24%. Mansor *et al.* (2012) [18] reported that VCO consisted of 91.87% to 93.27% total saturated fatty acids and 6.73% to 8.13% total unsaturated fatty acids.

Tocopherol

Tocopherols are naturally occurring, lipid-soluble antioxidants that are mostly found in vegetable oils. It shows strong antioxidant abilities against lipid peroxidation and the scavenging of reactive oxygen species (Kumar and Krishna, 2015) [14]. Ndifa *et al.* (2019) found that VCO contained 2.92 to 4.28 mg/100g of tocopherol. In this study, tocopherol content of VCO extracted from different methods were ranged from 14.82 to 27.68 µg/g (Table 2). Among the VCO samples, CCVCO showed more tocopherol content than EVCO and HVCO. Srivastava *et al.* (2016) [30] also reported that VCO obtained from cold extraction method (27.65 µg/g) contained more tocopherol than hot extraction method (17.87 µg/g). The concentration of tocopherol in coconut oil is comparatively low to other vegetable oils (Adejumo *et al.*, 2021) [1].

Total phenol content (TPC) and Total antioxidant activity

Polyphenols are secondary metabolites widely distributed in plants. VCO contains high concentrations of polyphenols. In this study, the TPC in the VCOs was found to be in the range of 8.82 to 9.97 GAE µg/mg (Table 2). Ghani *et al.* (2018) [11] found that TPC of VCO extracted from different methods were ranged from 1.16 to 12.4 mg GAE/g. This variation in phenolic content in VCO may be due to the different extraction methods. Compared to the hot process, the TPC in VCO produced by the cold process often tends to be higher. CCVCO contained the highest amount of total phenols followed by EVCO and HVCO. Ghani *et al.* (2018) [11] suggested that the hot process may destroy some of the phenolic compound in the VCO. Dia *et al.* (2005) [10] also reported that VCO extracted from dry method contained the lowest amount of polyphenols, because of the destruction of phenolic compounds during the expulsion step in the dry processing of VCO. Mulyadi *et al.* (2018) [21] also analysed the total phenol content in VCO extracted from various methods and concluded that phenol content was different in different methods.

The antioxidant activity of virgin coconut oil can be attributed to its total phenolic content. The total antioxidant activity of VCO samples ranged from 17.23 to 27.45 µg/mg (Table 2). The highest antioxidant activity was observed in CCVCO and the lowest in HVCO. The different processing techniques could be the cause of the variance in antioxidant activity among the VCO samples. Antioxidant activity can also be affected by thermal treatment. The introduction of heat during extraction of VCO could therefore decrease the antioxidant activity (Marina *et al.*, 2009) [19]. Mulyadi *et al.* (2018) [21] reported that VCO extracted by the dry method showed the lowest antioxidant activity than wet method due to the destruction of the polyphenols by heat.

Conclusion

The study was conducted for analysing the quality of VCO extracted from different extraction methods such as hot, cold centrifugation and enzymatic methods. The results showed that extraction techniques affected the quality of VCO. VCO extracted from hot process showed maximum mean score in organoleptic evaluation. Among the VCO samples, there was a significant difference in oil recovery, moisture, iodine value, saponification value, tocopherol content, fatty acid profile, total phenol content and antioxidant activity. VCO extracted from cold centrifugation method contained more lauric acid, tocopherol, total phenols and antioxidant activity than hot and enzymatic methods. The higher amount of lauric acid, tocopherol, polyphenols and more antioxidant activity gives a significant medicinal value to the oil. Therefore VCO has a great future as a functional oil. It can be incorporated in various food products to improve its nutritional quality.

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