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Quality analysis of virgin coconut oil processed through different methods

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Abstract
Value addition sector in coconut is gaining momentum as a result of spiraling demand for coconut products in internal and international market. Among these, Virgin coconut oil (VCO) is growing in popularity as a functional food supplement, neutraceutical and cosmetic with therapeutic properties and has extremely good prospects for investment. In order to analyze whether there is variation in quality parameters among the different methods of its production, hot extracted virgin coconut oil (HVCO), cold extracted virgin coconut oil (CVCO) and coconut oil (CO) has been analyzed for various quality parameters like moisture and volatile matter, FFa, iodine value, acid value, saponification value, peroxide value, specific gravity, color, refractive index, Vitamin E content, insoluble impurities and test for the presence of mineral and palm oil. Among the physicochemical properties analysed, saponification value, specific gravity and refractive index of the VCO extracted from different methods showed some significant differences, while the acid value, free fatty acid, iodine values did not differ significantly among samples. Moisture and volatile matter, Colour, Peroxide value, Insoluble value, Vitamin E have significant (p<0.0001) effect on VCO extracted through different methods. Attempts were made to select the best quality oil based on the response predicted by the Design – Expert software. Based on optimization of quality parameters recorded and analysed, CVCO *i.e.,* cold extracted virgin coconut oil was selected as the best in quality in comparison to HVCO and CO samples.

Keywords: HVCO, CVCO, vitamin E, iodine value, colour

Introduction
Coconut is the mainstay of economy and provides lively hood options for majority of the farming community in coastal Kerala and other south Indian states. Being a small holder's crop, gyrations and price instability has often confronted the market. Even now, the market price of raw coconuts did not commensurate with its production cost. This is primarily because, coconut processing sector in India is largely confined to copra, oil extraction and desiccated coconut, and the price of nut is vulnerable to fluctuations in copra and oil price in the market which is mostly regulated by other edible oil prices.

Currently, one third of the annual coconut production is used by processing industry for copra and coconut edible oil production, while rest is processed into desiccated coconut and other products. Value addition and product diversification has a vital role in stabilizing price of coconut, which paves way for enhancing the income of the growers. Recently, value-addition sector in coconut is gaining momentum as a result of increased local and international demands and consequent requirement for domestic supply and export, and this is currently arousing investors' interest. Among the newly emerging value added products from coconut, the most sought after product is the VCO, which is gaining popularity in the western world, USA and other developed countries due to its properties as a food supplement, nutraceutical, and use in therapeutic applications.

Coconut oil is extensively used for food and industrial purposes. The oil is rich in medium chain fatty acids (MCFA) and exhibits good digestibility (Che Man and Marina, 2006) [2]. It is produced by crushing copra, the dried kernel, which contains about 60- 65% of the oil. The oil has the natural sweet taste of coconut and contains 92% of saturated fatty acids (in the form of triglycerides) and most of them (about 70%) are lower chain saturated fatty acids known as medium chain fatty acids (MCFAs). The recent high value coconut product, which is becoming globally popular, is Virgin Coconut Oil (VCO).VCO is rich in medium-chain fatty acids (MCFA) of about 63%, and contains lauric, myristic, palmitic, capric, stearic, oleic, and linoleic acids which are easily digestible (DebMandal and Mandal, 2011) [5].

VCO is the purest form of coconut oil with natural distinctive coconut taste and smell. It is solidified at low temperature and becomes colourless like water when liquefied (Marina *et al.*, 2009) [17, 18]. Virgin Coconut Oil (VCO) is extracted from fresh, mature kernel of the coconut by natural means with or without application of heat.

It has more nutritionally beneficial effect than copra oil because it retains most of its functional components. VCO is unique among all the other vegetable oils because of its high lauric acid content. The lauric acid present in VCO is converted to monolaurin which provides immunity to body and keeps infants away from getting viral or bacterial or protozoal infections. It has many advantages, which include the health benefits from the retained vitamins and antioxidants, antimicrobial and antiviral activity from the lauric acid components and through its easy digestibility from the medium chain fatty acids (MCFA). VCO is rapidly gaining immense importance due to various health benefits, and therefore, there is a large potential to develop VCO as an important product in functional health food sector in the world market.

Different processes and production methods were reported for the extraction of VCO. VCO is directly extracted from the coconut meat/kernel by chilling and centrifugation, fermentation, enzymatic, pH method, or any of these combinations to destabilize the coconut milk emulsion without the drying process (Raghavendra and Raghavarao, 2010). VCO processing technologies can be generally categorized into hot processed virgin coconut oil (HVCO) and cold processed virgin coconut oil (CVCO). In HVCO method, the coconut meat/milk were heated under specific conditions to remove the moisture in it while in CVCO method, the coconut meat/milk does not go through heating process but involves fermentation of milk and further centrifugation at high speed. The yield and quality of VCO mainly depends on the method of extraction along with several other factors, including age of nuts, variety, location of plantation, and pre treatments before the extraction.

VCO has been used traditionally for treating the skin and hair growth since centuries ago. VCO contains high medium chain saturated fatty acids and unsaturated fatty acids, which are mostly lauric acid that has a high resistance against oxidation and inhibits rancidity due to its stability and functionality. The quality characteristics of VCO can be identified through its physical and chemical properties such as iodine value, free fatty acid and peroxide value. VCO contains lauric acid (49%), which has an antimicrobial property on certain bacteria such as *Listeria monocytogenes* and *Propionibacterium acnes* (*P. acnes*) (Nakatsuji *et al.*, 2009) [21]. VCO has many benefits including high phenolic compound and better antioxidant activity compared with coconut oil. The phenolic compound in VCO exhibits its antioxidant activities such as "antimutagenic", "antiproliferative" and "anticarcinogenic" that benefits the human being (Marina *et al.,* 2009) [17, 18].

An important deciding factor in the assessment of the quality of VCO is its physicochemical properties. VCO contains high medium chain fatty acids, which are mostly lauric acid (49%). Physicochemical properties of VCO have been standardized by the Asian and Pacific Coconut Community (APCC, 2009) [1] for parameters such as moisture content, fatty acid content, free fatty acid content, iodine value, peroxide value, saponification value, and viscosity. However, not all of the quality and nutritional characteristics of VCO in Kerala are analyzed and compared to APCC standards. It is therefore necessary to determine the quality of VCO produced in Kerala and to see whether they conform to the required standards. Keeping these points in view the present study was designed to analyze the physicochemical properties of virgin coconut oil extracted through different processing methods and compared to that of coconut oil at the Regional Agricultural Research Station, Kerala Agricultural University, Pilicode.

Materials and Methods

Raw materials

Freshly harvested fully matured Coconuts are collected from the research fields of Regional Agricultural Research Station Pilicode, Kasargod, Kerala, India for VCO production. The variety used was West Coast Tall. The extraction of VCO was carried out using both cold and hot processes, involving fermentation, centrifugation and hot extraction methods.

The process protocol for different processing methods is given below:

Hot processed virgin coconut oil (HVCO): In this method, 11-12 months old fully matured coconut is selected for VCO production. Coconuts are dehusked using an electrically operated dehusking machine. The nuts are cleaned and the shell is removed without disfiguring the kernel using a deshelling machine. Testa, the brown outer layer of coconut kernel, is removed by using a testa removing machine. After removing the brown layer, coconut is washed in clean water and cut into 4-6 pieces and subjected to blanching in hot water at 50 °C for 5 minutes for reducing the enzyme activity. Blanched coconut pieces are pulverized using a disintegrator. The disintegrated coconut is fed to screw press milk extractor to recover coconut milk. Coconut milk is placed in an uruli roaster/VCO cooker to coagulate the protein and release the oil. After slow heating for about 2 to 2.5 hours, coconut cream will begin to coagulate and exude oil. In the first hour of heating, temperature can be allowed to reach 100 °C. Thereafter, the temperature is brought down to 90 °C for the protein to coagulate and when the temperature is reduced to 60 °C, oil starts to separate. The heating source used was LPG. The VCO is filtered from the protein rich residue (VCO cake) by straining the mixture through a muslin cloth or stainless steel mesh. VCO cake is pressed in hydraulic press to recover the remaining oil.

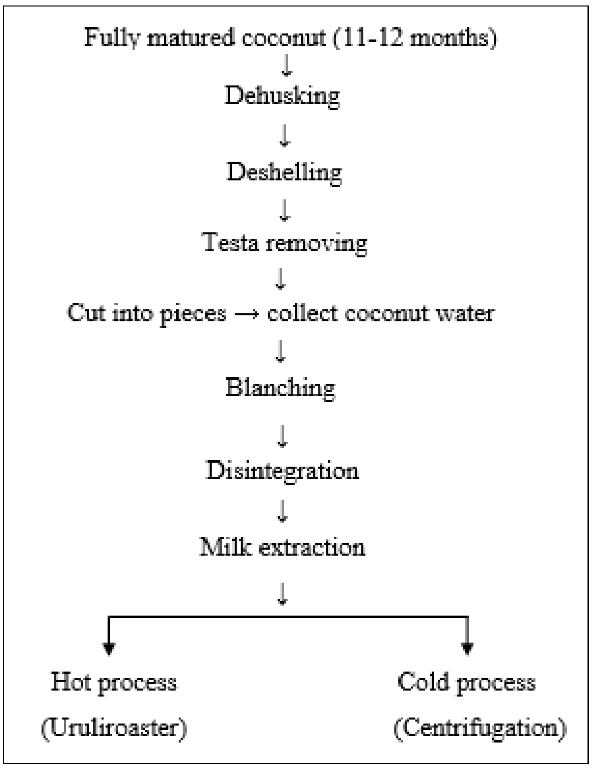

Fig 1: Process flow chart for the production of virgin coconut oil

Cold processed virgin coconut oil (CVCO): In this method, the extracted coconut milk is allowed to stand for 20-24 hours in a food grade plastic barrel and subjected to natural fermentation. The fermented coconut milk was filtered with muslin cloth prior to centrifugation and clarified in a clarifier. There were no chemicals involved in the process of producing virgin coconut oil. The clarified samples were allowed for centrifugation process repeatedly using tubular centrifuge with 16000 rpm speed for 2 hours. During this process the oil and water will be separated based on density difference. The cream portion is separated and used for further value addition. The oil is filtered through filter paper and seven stage vacuum filters, packed in polyethylene terephthalate (PET) bottles and stored.

Coconut oil (CO): For extraction of coconut oil from copra, coconuts after dehusking was cut open into halves are sundried properly for 6-7 days or dried in copra drier and the shells are removed in between. Properly dried coconut kernel is pressed in a hydraulic press to extract oil. This yields practically all the oil present, amounting to more than 60% of the dry weight depending on the variety of the coconut used. Usually oil will be light yellow in color and it is filtered two or three times for making it more clear.

Determination of physicochemical properties of virgin coconut oil

The physicochemical properties of HVCO, CVCO, CO studied were moisture and volatile matter, Free fatty acid, iodine value, Acid value, saponification value, specific gravity at 30 °C, refractive index at 40 °C, Colour in 1" cell on lovibond scale expressed as Y+5R, Peroxide value, insoluble value, Vitamin E and adulteration tests for mineral oil and palm oil.

Determination of moisture content (MC) in the VCO was based on the American Oil Chemists Society (Firestone, 2009) [9] method. About 5.0 g of the VCO sample was placed into a pre-heated and pre-weighed crucible with lid, and then heated at 105 °C for at least 24 hr. The sample was then placed in a desiccator and allowed to cool down to room temperature. The crucible containing the VCO was then re-weighed. The moisture and volatile content was calculated using the following formula;

MC =(Initial weight -final weight)/ initial weight ×100%

Free fatty acid, iodine value, Acid value, saponification value, specific gravity at 30 °C, Colour in 1" cell on lovibond scale measured using tintometer expressed as Y+5R, Peroxide value, insoluble value, and refractive index at 40 °C were measured as per the standard method given by Bureau of Indian standards IS: 548 part I, 1964 (Methods of sampling and test for oils and fats: Part I Methods of sampling, physical and chemical tests) Reaffirmed 2015. Vitamin E of oil was determined through the method proposed by Commission Directive 2000/45/EC of 6 July 2000 establishing Community methods of analysis for the determination of vitamin A, vitamin E and tryptophan in feeding stuffs.

The samples were also tested for the presence of mineral oil by the method described by Bureau of Indian standards IS:548 part II 1976 (Methods of sampling and test for oils and fats: Part II Purity tests) reaffirmed 2015, and presence of palm oil tested by the method as described in Indian coconut journal May 1999-P.6 respectively.

Statistical analysis

Factorial completely randomised design (FCRD) was adopted for analyzing the data by using Design-Expert software. Statistical significance was examined by analysis of variance (ANOVA) for each response.

Results and Discussion

This study reports the physicochemical and quality characteristics of the VCO, including moisture content, free fatty acid content, iodine value, acid value, saponification value, peroxide value, specific gravity, color, refractive index, Vitamin E and insoluble impurities in the VCO produced by both methods and are compared with that of the coconut oil in Kerala. The samples were also tested for adulteration with mineral oil and palm oil and the experimental results obtained from the present study have been discussed in the following headings:

Moisture and volatile matter: These are important determinants of oil quality (Choe and Min, 2006) [2]. It is desirable to keep the moisture content low as it will increase the shelf life by preventing oxidation and rancidity processes. The moisture content recorded in CVCO and HVCO were 0.21 and 0.22% respectively and the values are within the limits prescribed by APCC (2009) [1] set standards. The moisture content in coconut oil (CO) was higher (0.37%) compared to CVCO and HVCO. Higher moisture content in oils leads to rancidity and affects its keeping quality. Raghavendra and Raghavarao (2011) [22] reported hydrolytic rancidity of fats and oils due to presence of high moisture.

Free fatty acid (FFA): This is the most crucial characteristic in the VCO production and product sales (Kamariah *et al.*, 2008) [13]. The FFA is an indicator of the hydrolytic rancidity of the oil which causes an undesirable flavor, off taste and aroma in the oil. (Mansor *et al.*, 2012) [15]. FFA obtained from this study for different oil samples ranges from 0.23 to 0.57% which were relatively low and indicated that the oils were of good quality. All the oils samples recorded FFA within the range of the APCC standard and are acceptable for use (see Table 1).

Iodine value (IV): This is the generally an accepted parameter for expressing the degree of unsaturation, the number of carbon-carbon double bonds in oils or fat. It is also reported that the higher the amount of unsaturation, the more iodine is absorbed; therefore the higher the iodine value the grater the degree of unsaturation. Iodine values above 100 are classified as drying while those below are classified as non-drying (Julius *et al.*, 2013) [12]. The iodine values obtained for the VCO samples in this study was in a range of 6.75 to 8.77 (see table 1). Although oils maybe classified as non-drying, cold processed oil had a higher iodine value when compared to HVCO and CO oil. The increase in iodine value may be due to the slightly higher number of unsaturated fatty acids. This value was found to be within the recommended range for coconut oil by the Codex Standards (6.3-10.6), while for APCC it is 4.1 to 11. The values correspond to those reported by Marina *et al.*, (2009) [17, 18] and Henna *et al.*, (2009) [11].

Acid value: This defined as the number of milligrams of potassium hydroxide required to neutralize the free fatty acids present in one gram of fat. It is a relative measure of rancidity as free fatty acids are normally formed during decomposition of oil glycerides. Acid value was calculated for all samples and it was observed that, the acid value was minimum for HVCO (0.64), CVCO (0.66) and maximum for CO (1.60). The low acid value indicates that the oil contains relatively little or no water. More deviation in acid values indicates the more oxidation of that substance and less the good quality of oil. The observed values were in agreement with the trend reported by Kumar, *et al.* (2010) [10] for coconut oil (2.1mgKOH/g).

Saponification value (SV): This 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 with the other edible oils coconut oil has a higher SV. Table 1 shows the SV of different coconut oils. In this study, CVCO presented the highest value of SV (263.29 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 by Marina *et al.* (2009b) [16]. All the oil samples had saponification value within CODEX standard of 248 to 265 mg KOH/g of oil (FAO, 2009) [8].

Table 1: Physicochemical properties of HVCO, CVCO and CO

Sl. No.	Properties	HVCO	CVCO	CO
1	Moisture and volatile matter (%)	0.22	0.21	0.37
2	FFa (%)	0.23	0.24	0.57
3	Iodine value	8.02	8.77	6.75
4	Acid value	0.64	0.66	1.60
5	Saponification value (mg KOH/g of oil)	262.70	263.29	256.87
6	Peroxide value (milli equivalent/kg oil)	0.56	0.40	1.35
7	Specific gravity at 30 °C	0.9179	0.9198	0.9193
8	Colour in 1” cell on lovibond scale expressed as Y+5R	0.1	0	0.2
9	Refractive index at 40 °C	1.4487	1.4483	1.4488
10	Vitamin E (ppm)	1.23	1.76	1.095
11	Insoluble impurities	Nil	Nil	0.01%
12	Test for the presence of mineral oil	Negative	Negative	Negative
13	Test for the presence of palm oil	Negative	Negative	Negative

Peroxide value (meq/kg oil): Peroxide value is an indicator for the measurement of the initial stages of oxidation in oils. One of the first products formed by oxidation of oil is a hydroperoxide. CO had significantly higher peroxide value 1.35 compared to the VCO samples. All oil samples had peroxide values below the APCC limit (<3). This indicates that samples were highly stable against oxidative rancidity. Lowest peroxide values of CVCO (0.40) and HVCO (0.86) indicates that VCO samples do not undergo significant oxidation during processing.

Specific gravity at 30 °C: This is the ratio of the weight in air of a given volume of the oil at 30 °C to the weight in air of an equal volume of water at 30 °C. Specific gravity of HVCO, CVCO and CO was found to be 0.9179, 0.9198, and 0.9193 respectively which are within the range of standard (0.9150-0.9200) proposed by Asian and Pacific Coconut Community (APCC) 2009 [1]. This result was in agreement with that obtained by Srivastava *et al.*, (2016) [25].

Colour in 1” cell on lovibond scale expressed as Y+5R: Color is one of the quality indicators of vegetable oils (Indian Standard Specification for Coconut oil, 2014). The color values for the oils are given in Table 1. In this study, the CVCO was a clear liquid with color of 0 lovibond units and HVCO has 0.1 lovibond units. Probably this might be due to the removal of the outer brown skin (testa) of the kernel before oil extraction. However, coconut oil was light yellow in color with 0.2 lovibond units and this could be attributed due to the extraction of the copra without the removal of the coconut testa. The present result is also in agreement with the report that coconut oil has distinct yellow color, perceptible aroma, while VCO is almost colorless and has an acid flavor (Dayrit *et al.*, 2007; Villarino *et al.*, 2007) [4, 26].

Refractive index at 40°: This measures the extent to which a beam of light is refracted on passing from air into oil. The refractive index of the coconut oil was found to be 1.4488 and in case of HVCO and CVCO was 1.4487 and 1.4483 respectively. These values were within the limit of codex standard (1.448-1.450). A study on quantitative and qualitative analysis of bioactive components present in virgin coconut oil by Srivastava *et al.* (2016) [25] also reported similar results.

Vitamin E: Tocopherol or Vitamin E is an antioxidant that works at the primary level and is also a free radical scavenger. Tocopherol itself is a term that constitutes eight different subtypes namely alpha tocopherol (α-T), beta tocopherol (β-T), gamma tocopherol (γ-T), delta tocopherol (δ-T) and alpha (α-T3), beta (β-T3), gamma (γ-T3) and delta tocotrienols (δ-T3). Tocopherol analysis was performed on each samples and their findings were presented in Table 1.Vitamin E content of HVCO, CVCO, CO was found to be 1.23ppm, 1.76ppm and1.095 ppm respectively which indicated that CVCO is the best for the presence of Vitamin E.

Insoluble impurities (%): The term refers to extraneous substances such as dirt, debris, and fibers. They are defined as those substances which remain insoluble and can be filtered off after the oil is dissolved in a specific solvent (Hasan *et al.*, 2018) [10]. It was found that there are no insoluble impurities present in CVCO and HVCO but for CO it is 0.01%. The APCC standard range for insoluble impurities is in the region of 0.1 to 0.5%. So, virgin coconut oil is quite good for edible purposes and for cosmetic industry.

Test for the presence of mineral oil and palm oil: The adulteration of coconut oil with other cheaper oils for economic gains are reported frequently in mass media as a deliberate act by traders and sometimes happen accidentally (Shukla *et al.*, 2005) [24] which involves the replacement of high price oils with cheaper ones. The adulteration of fats and oils is not easy to detect when the oil adulterant has a composition similar to that of the original oil (Rossell *et al.*, 1983) [23]. Test for detecting adulteration of virgin coconut oil with palm oil and mineral oil was determined using standard methods and the result revealed that, there was no adulteration found in oil extracted from different methods.

Among the physicochemical properties analysed, Saponification value, Specific gravity and Refractive index of the VCO extracted from different methods showed some significant differences, while the acid value, free fatty acid, iodine values do not differ significantly among the different types of extraction methods used. Statistical analysis showed that, Moisture and volatile matter, Colour, Peroxide value, Insoluble impurities value, Vitamin E have significant ($p<0.0001$) effect on VCO extracted through different methods.

Conclusion

Among the two VCO (hot and cold processed) and CO samples, there was no significant difference in acid value, free fatty acid, iodine value, moisture content and volatile matter, colour, peroxide value and vitamin E. Test for detecting adulteration of VCO with palm and mineral oil revealed that, there was no adulteration in oil extracted from different methods. Further vitamin E and saponification value in both HVCO and CVCO samples are significantly higher than CO samples. Attempts were made to get best quality oil and the response was predicted by the Design – Expert software which would have maximum vitamin E, minimum moisture content, colour value, peroxide value and other parameters like acid value, FFa, iodine value, saponification value, specific gravity, and refractive index in APCC standard range. Under these criteria, based on optimization CVCO *i.e.*, Cold extracted virgin coconut oil was selected as a best combination which could be recommended for the market.

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