Fatty acids in coconut oil

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When the fatty acid profile of a cultivar is compared across locations or seasons, variations were observed particularly in long chain fatty acids. The fatty acid profile in kernel during the development of maturity indicated that the concentration and content of lauric acid increased rapidly with maturity from 6th month to 10th month. But the concentrations of myristic acid remain more or less same during the nut development, even though its content increases. The concentrations of long chain fatty acids are high in 6 month old nuts. But with nut development their concentration decreased.

Abstract

Coconut oil has high commercial value for its multifarious industrial uses. Coconut fatty acids are life line for the soap, dye, cosmetic and pharmaceutical industries. It is important to have a thorough knowledge on fatty acids in coconut oil for optimal commercial exploitation. The variation in fatty acid composition of oil among the coconut germplasm was analysed in samples from different agro-climatic zones, which represent coconut growing areas in India. Mature nuts, harvested from the tagged bunches at periodical intervals, were processed for copra and oil. The data indicated that the relationship between copra and oil concentration had seasonal variations. This finding has significant implication in germplasm evaluation for copra yields. The copra yield/nut varied with cultivar, season and location. Analysis of fatty acid profile in coconut oil was done in a Gas Chromatograph fitted with auto-injector and using a capillary column. The results showed variations in fatty acid profile depending on the cultivar and season. So far, the variation found in lauric acid, a major fatty acid in coconut oil, concentration is from 41 per cent to 51 per cent. The data indicate that the fatty acid profile of a given cultivar varies with season and location indicating the environmental impact to certain extent, even though it is a highly conserved character. For the first time traces of new fatty acids such as palmitoleic acid, arachidic acid, behenic acid and lignoceric acid were detected, which were erstwhile not reported in coconut oil. When the fatty acid profile of a cultivar is compared across locations or seasons, variations were observed particularly in long chain fatty acids. The fatty acid profile in kernel during the development of maturity indicated that the concentration and content of lauric acid increased rapidly with maturity from 6th month to 10th month. But the concentrations of myristic acid remain more or less same during the nut development, even though its content increases. The concentrations of long chain fatty acids are high in 6 month-old nuts. But with nut development their concentration decreased. Abiotic stress like water stress in rainfed palms adversely affected the copra yields, however, oil percentage was high in these nuts compared to those in irrigated palms. The profile of long chain fatty acids also varied due to rainfed and irrigated condition. Biotic stress like *eriophyid* mite

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infestation decreased the oil concentration in copra. The results so far indicated that the fatty acid composition of coconut oil, even though a conservative character, is variable with cultivar, season and location.

Introduction

Lipids are the saponifiable esters of long chain fatty acids. Generally, lipids, if in liquid form at room temperature are called oils while those solidify at around 18-24°C are called fats. In the world source of oils and fats, around 20 per cent are contributed from the animal source while the bulk (around 80 per cent) are contributed from the plant source. There are more than 100 plant species, which can be considered as the oil yielding ones. Of these 14 plant species are commercially exploited as oil crops. These include well known annual crops like ground nut, sunflower, mustard, safflower, sesame, as well as the perennial crops like oil palm, coconut and olive.

The lipids contain three types of acyl glycerols (fatty acid + glycerol) viz., mono acyl glycerol (glycerol attached with one molecule of fatty acid), diacyl glycerol (glycerol attached with two molecules of fatty acids) and triacyl glycerol (glycerol attached with three molecule of fatty acids). The vegetable oils consist of 95 per cent triacyl glycerides. A typical triacyl glycerol of stearic acid (C18:0) is called tristearin. Like wise a mono acyl glycerol of lauric acid (C12:0) is called monolaurin.

In the human diet, oils or fats are essential components for the reason that these provide the body with essential fatty acids like linoleic acid and linolenic acids. These fatty acids are called essential fatty acids as human body cannot synthesize them but requires them for proper metabolic activity and functioning. Apart from this, oils or fats are energy rich compounds and each gram of oil, on digestion, provides 9 Kcal equivalent of energy. Further, fats act as the transporting agents in body for the fat-soluble substances like vitamin A, D, E and K. No need to specially mention that oil provides better taste and palatability of the food.

Generally, it is said that in a diet we have two types of fats viz., visible fat and invisible fat or oil. Visible oil is that which is added while cooking the food. Cooking oils, ghee, vanaspathi (hydrogenated oil), etc., form this group. Apart from this visible intake of oil daily, invariably we all take oil from other sources, unknowingly, but in considerable amount. These are called invisible fats, since they are from staple food like rice, wheat, pulses, vegetables, etc. Food grains like rice and wheat contain 3-4 per cent of oil. Similarly small quantities of oil are present in pulses, vegetables and fruits. When we take the diet, one has to account for this invisible but indispensable oil source also, since it contributes to the total fat requirement of the human body. The calorie requirement and recommended oil or fat intake, after taking into account of the invisible oil intake, is given in *Table 1.*

From the available information it can be calculated that on an average around 600 g of oil can be consumed by an adult per month. For example, for a family of two adults and two children, the oil requirement in a month is estimated to be around 2.7 kg or three liters. However, specific food habits like amount and frequency of intake of non-vegetarian food, fast food, etc. should be taken into consideration while coming to an approximate intake of oil or fat with in safe limits.

Table 1. The calorific requirement of different types of working and age groups of people and recommended oil or fat intake

Group	Cu unit	Kcal/day	Max. from fats (Kcal/day)	Max. Fat, Oil/day (g/day)	Recommended oil, fat/ day (g)
Adult male					
(Sedentary worker)	1.0	2400	480	53.3	
(Moderate worker)	1.2	2880	576	64.3	20
(Heavy worker)	1.6	3840	768	85.3	
Adult female					
(Sedentary worker)	0.8	1920	384	42.7	
(Moderate worker)	0.9	2160	432	48.0	
(Heavy worker)	1.2	2880	576	64.0	20-45*
Adolescents (12-21 years)	1.0	2400	480	53.3	22
Children					
(9-12 years)	0.8	1920	384	42.7	
(7-9 years)	0.7	1680	336	37.3	
(5-7 years)	0.6	1440	288	32.0	
(3-5 years)	0.5	1200	240	26.7	25
(1-2 years)	0.4	960	192	21.3	

* for pregnant women (Source: Rao *et al.*, 1995)

It is important to consider the quality of fat or oil when used either for industrial purposes or for human consumption. The vegetable oils have different fatty acid composition depending upon the source. Fatty acid profile of different vegetable oils is given in *Table 2*. This indicates clearly the existence of variation in fatty acid profile, and also the concentrations of unsaturated fatty acids, saturated fatty acids, etc.

The proportion of poly- and mono- unsaturated fatty acids and saturated fatty acids in different vegetable oils and animal fats are presented in *Table 3*.

These indicate that the vegetable oils in general contain more unsaturated fatty acids. In case of coconut oil the proportion of saturated fatty acids is more. However, major portion of these saturated fatty acids in coconut oil are of short and medium chain fatty acids (Oo and Stumpf, 1979; Padua-Resurrection and Banzon, 1979; Naresh Kumar *et al.*, 2000a). These are easily digested and absorbed in to the metabolic activities of the human body (Kauntiz, 1971 and 2001). Thus coconut oil possesses distinctive advantage. In fact, monolaurin, a monoacyl glyceride of lauric acid is widely used as infant feed for easy absorption and for providing energy. Further, medium chain glycerides are widely used for curing the patients suffering from digestive disorders (Bach and Babayan, 1982; Enig, 2001).

It is known that the oils are rich in unsaturated fatty acids, because of which they remain in liquid form at room temperature. Whereas, fats contain higher proportion of saturated fatty acids and thus remain solid even at higher temperatures. It is desirable that human diet consists of a mixture of small and medium chain fatty acids, mono- and poly-unsaturated fatty acids and essential fatty acids (Enig, 1996; Fife, 1999; Kabara, 2000).

Table 2. The fatty acid profile of various vegetable oils

Crop	Saturated fatty acids										Unsaturated fatty acids				
	C6:0	C8:0	C10:0	C12:0	C14:0	C16:0	C18:0	C20:0	C22:0	C24:0	C16:1	C18:1	C18:2	C18:3	C20:1	C22:1
Coconut	0.15	4.8	5.1	48.5	18.6	8.7	2.4	0.05	0.02	0.001	0.02	6.74	1.9			
Palm oil (Kernel)	0.30	3.0	5.0	48.0	16.0	8.0	3.0	0.1				15.0	2.0			
Palm oil (crude)				0.2	1.0	43.0	5.0				0.5	40.0	11.0	0.5		
Groundnut						11.0	3.0	3.0	1.0	2.0		47.0	32.0		1.0	1.0
Sunflower						7.0	5.0	1.0				19.0	68.0	1.0		
Mustard						4.0	1.0	1.0	1.0	1.0	0.5	19.0	15.0	11.0	7.0	41.0
Olive						9.0	3.0				1.0	80.0	6.0	1.0		
Safflower						7.0	3.0					12.0	78.0			
Sesame						10.0	5.0					40.0	40.0			

(Source: Van der Vossen and Umali, 2001)

Table 3. Fatty acid groups in vegetable oils and animal fats

Oil/ fat	Poly unsaturated fatty acids	Mono unsaturated fatty acids	Total unsaturated fatty acids	Saturated fatty acids	Ratio of saturated fatty acids to unsaturated fatty acids
Vegetable oils					
Safflower oil	75	12	86	9	0.105
Sunflower oil	66	20	86	10	0.116
Corn oil	59	24	83	13	0.157
Soybean oil	58	23	81	14	0.173
Cotton seed oil	52	18	70	26	0.371
Canola oil	33	55	88	7	0.080
Olive oil	8	74	82	13	0.159
Peanut oil	32	46	78	17	0.218
Palm oil	9	37	46	49	1.065
Coconut oil	2	6	8	86	10.750
Palm kernel oil	2	11	13	81	6.231
Animal fats					
Chicken fat	21	45	66	30	0.45
Lard	11	45	56	40	0.714
Mutton fat	8	42	49	47	0.959
Beef fat	4	29	46	50	1.087
Butter fat	4		33	62	1.879

(Source: Fifc, 2000)

Of the essential fatty acid groups, it is known that the 3-Omega and 6-Omega fatty acid groups are important. Historically, the change in food habits seems to have caused an imbalance in the intaken proportion of 3- and 6- Omega fatty acids (*Fig. 1*). Metabolically, it is desirable to have the diet consisting of 3-Omega and 6-Omega fatty acids in equal proportions, since the end products of the metabolic processes that are generated using 3-omega fatty acids qualitatively differ from those derived from 6-omega fatty acids. Hence it is desirable that the ratio between both types of essential fatty acids is maintained at 1:1 ratio, which currently seems to be difficult (Ben Best, 2004 and references therein). A list of fatty acids indicating their qualitative nature is presented in *Table 4*.

These essential fatty acids are very important in human metabolism as they are involved in the synthesis of lipoxins, thromboxanes, prostaglandins, leucotriens, etc. These metabolic products play important roles in immune system, blood clotting, membrane activity, etc. in human body. Hence it is essential that one must take note of quality aspects of oil intake apart from being conscious about the quantity of oil that is being used in the diet.

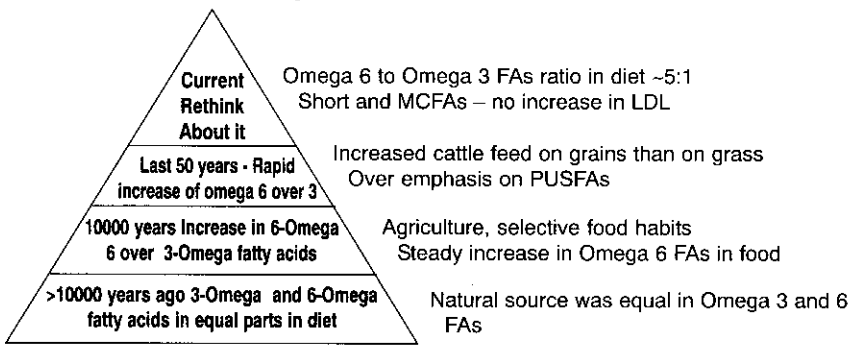

Fig 1. Change in food habits and concurrent change in the ratio of Omega 3 and Omega 6 fatty acids in human diet

Table 4. Qualitative aspects of fatty acids

Fatty acid	Number of carbon atoms in fatty acid chain	Number of double bonds	Omega = bond position
Oleic acid	18	1	Omega-9
Linoleic acid	18	2	Omega-6
Conjugated Linoleic acid (CLA)	18	2	Omega-6
Alpha Linoleic acid	18	3	Omega-3
Gamma Linoleic acid (GLA)	18	3	Omega-6
Dihomo-Gamma-Linoleic acid (DGLA)	20	3	Omega-6
Arachidonic acid	20	4	Omega-6
Eicosa Pentanoic acid (EPA)	20	5	Omega-3
Docasa Hexanoic acid (DHA)	22	6	Omega-3

(Source: Ben Best, 2004)

Qualitative aspects of coconut oil

Coconut oil has mild delicate flavour and is resistant to heat with long shelf life. It is a non-drying oil. The calorific value of coconut oil is lower (6.4 Kcal/g oil) than the other oils (9 Kcal/g oil). It is known to function as an antioxidant. Coconut oil is the richest source of glycerol with around 13.9 per cent. It had low cholesterol levels (5-24 ppm) compared to other oils and fats (*Table 5*). Because of its composition of more short and medium chain fatty acids, coconut oil is easily digestible and is a fast source of energy. Further, the short and medium chain triacyl glycerides are metabolized differently from long chain triacyl glycerides. The medium chain triacyl glycerides are directly absorbed by the intestinal cells and carried by portal circulation to liver for further oxidation for energy release (*Fig. 2*). Hence the medium chain triacyl glycerides do not contribute to the low-density lipoprotein (bad cholesterol) in the body (Kuntiz and Dayrit, 1992; Enig, 1996, 2001; Blackburn *et al.*, 2001).

Table 5. Cholesterol levels in some oils and fats

Source of fat or oil	Range of cholesterol (ppm)
Coconut	5-23
Palm oil (Kernel)	9-40
Sunflower	8-44
Palm	13-19
Soybean	20-25
Mustard	25-80
Corn	18-95
Beef	800-1400
Butter	2200-4100
Lard	3000-4000

Source: Watkins, 2002

Since coconut oil is relatively heat stable, the formation of trans-

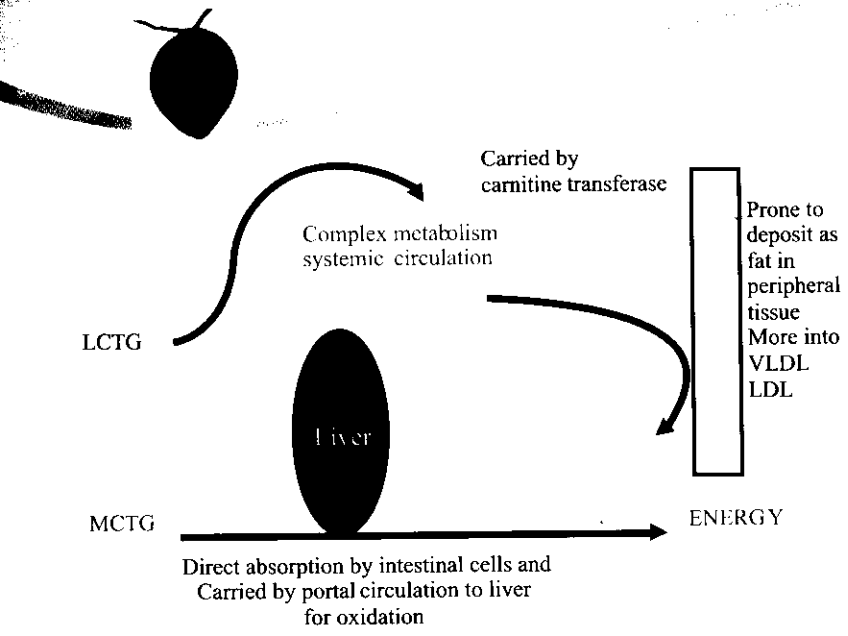

Fig 2. Medium chain triacyl glycerides (MCTG) are metabolized differently from long chain triacyl glycerides (LCTG)

fatty acids up on heating when used as frying oil is very less compared to other cooking oils. The coconut oil has a specific gravity of 0.918-0.926 at 25°C with a viscosity of 1.45. The iodine value of coconut oils is in the range of 8 to 9.6 and the saponification value generally ranged from 251 to 263. The melting point of coconut oil ranges from 23 to 26°C. Since the quality of coconut oil is largely dependent on quality of milling copra, it is essential that copra-processing needs to be done with utmost care. All these special qualitative characters of coconut oil make it an excellent base material for various oil based industries and pharmaceutical industries. It is well known that coconut oil is being used in Indian medicines for ages.

Medicinal uses of coconut oil

Even though the value of coconut is immense because of its numerous medicinal properties, here only a few are given. They include anti-microbial activity, anti-carcinogen (Lim-Sylianco, 1987; Enig, 1995; 1997), helps to prevent osteoporosis, reduces risk of atherosclerosis, acts as a support to the immune system, helps in skin health maintenance and promotes hair growth and its health (Rele and Mohile, 2000). It is used widely for correcting the digestive disorders (monolaurin) and is used for reducing the body weight because of its low calorific values compared to other oils (Kabara, 1978, 2000; Wang and Johnson, 1992).

Industrial uses of coconut oil

Coconut oil and its derivatives (oleo-chemicals) are widely used in various industries. Main usage of coconut oleo-chemicals is in soap and non-soap detergent industries (Conrado *et al.,* 1992). In these industries the fatty alcohol sulfates, fatty alcohol alkanolamides, etc., are used. Similarly, in textile industry the alkyl sulfates are used for pre-treatment of fibers. Since coconut oil is a non drying oil, alkyl resins are used in painting and varnish manufacturing industries. Myristic acid, a fatty acid which is present in substantive concentration (20 per cent) in coconut oil, is widely used in the cosmetic industry. The oleo-chemicals of coconut oil like fatty acid glycerides and fatty acid esters are used in food industry. Similarly, coconut oil derivatives are used in petroleum industry as surfactants. Methyl esters of coconut oil are used as bio-fuel (Carandang *et al.,* 1991; Machacon *et al.,* 2001). As metioned earlier, monolaurin is produced from the coconut oil as it contains around 48 per cent of lauric acid, a medium chain saturated fatty acid. Further, coconut oil forms the base substance for many of the pharmaceutical products like ointments, (Iyer, 2004). The coconut cultivars have been categorized based on oil fatty acid profile for their suitability for specific industrial uses (Naresh Kumar *et al.,* 2000, 2000a)

Recently, the demand for virgin coconut oil is increasing because of its pure flavour and superior quality. The virgin coconut oil is generally produced from fresh kernel by wet mill and cold press processes. The flavour component in coconut oil is b-gamma-Decalactone and this seems to be not affected while making the virgin coconut oil, hence the flavour is intact.

Experiments on oil quality

It is known that in India, 40 per cent of the total coconut oil produced is used for edible purpose and remaining is used for various industries like soap (48 per cent) and other industries. It is essential to know the quality of coconut oil in terms of fatty acid composition and the variations in fatty acid composition due to cultivars, season and agro-climatic zone for optimizing the commercial exploitation and for exploring new avenues for product diversification. In this direction, at CPCRI, Kasaragod, work has been initiated

and all available cultivars are being evaluated for fatty acid composition in oil during different seasons and also at different agro-climatic zones. The samples were collected from the research centers located in Maharastra, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, Orissa, West Bengal, Chattisgarh and Assam covering the entire coconut growing region in India.

Methods of analysis

Four mature nuts (12 months old) from each palm and at least six palms/cultivar were taken for the study. Earlier, the freshly opened bunches were tagged for determining the nut age precisely. Copra was processed using dryers to uniform 6 per cent moisture. Solvent extraction (petroleum ether, 60-80 °C) of oil was done using solvent apparatus. More than four thousand palms of different cultivars, hybrids and over ten thousand nuts were used for the study.

Column chromatography

The silicic acid column (20 cm length and 1cm diameter) chromatography was performed to obtain the neutral-lipid (chloroform fraction), glyco-lipid (acetone fraction) and phospho-lipid (methanol fraction) from the 500 mg sample in chloroform. The temperature of the column was maintained at 25 °C and the rate of flow was maintained at 5 drops/min. Quantification of the lipid fractions was made by gravimetric estimation (Rouser *et al.,* 1967).

GC analysis for fatty acid profile

The oil samples (500 mg) were methylated, as per the method of Padua-Resurrection and Banzon (1979), by adding 5 per cent HCl reagent (prepared by adding 8.3 ml acetyl chloride to 100 ml absolute methanol). After mixing thoroughly, they were incubated at 70 °C for 10 hours and were allowed to cool. To these 5ml double distilled water and 1 ml hexane was added and was vigorously shaken. When two layers were separated the hexane layer was aspirated into snap-cap microtube for storing at 4 °C till the samples were injected into a GC (GC2010, Shimadzu, Japan) fitted with a auto injector (AOC-20) and a capillary column (phase: BPX 70) of 30mts length, 0.25 mm internal diameter and 0.25 m film thickness. The temperatures of column, injector port and FID, flow rates of N_2, air and H_2 gases, etc., were set as standardized for the coconut samples (Naresh Kumar, 2006). Fatty acid methyl ester standards (Sigma, USA) were injected in the same conditions. The concentration of each fatty acid was calculated by using the GC-Solutions software after setting the margins for peaks and also after subtracting the solvent peak proportions. The results were compared with the standard peak run times for identifying the specific fatty acid. Each analysis was carried out in triplicate and the mean values were used for comparisons. The data were statistically analyzed in CRD. Critical difference at 5 per cent confidence level was used for comparing the means.

The results indicted variations in the relationship between copra yield/ nut and oil concentration in copra harvested during four seasons i.e., harvests during January, April, July and October. This implies that the quantity of copra and oil yield varies with the season even at a location, apart from the variations due to cultivars. Copra and oil yield were also influenced by the genotype x environment (G x E) interaction as variations were observed not only in different seasons at a location but across the agro-climatic zones as well.

The lipid fractionation by silicic acid column chromatography indicated that the neutral -lipids formed major fraction (about 94 per cent) followed by the glyco-lipids (3.5

Table 6. Lipid fractions of oil samples from different cultivars

Cultivar	Lipid fractions		
	Neutral lipids	Glyco – lipids	Phospho- lipids
A. Local Talls			
WCT	97.10	0.85	2.05
LCT	97.80	1.12	1.08
ADOT	96.40	1.98	1.62
BENT	94.99	3.19	1.82
B. Released and Promising Hybrids			
COD x WCT	93.10	3.85	3.05
WCT x COD	92.80	4.31	2.89
LCT x COD	94.10	4.15	1.75
LCT x GBD	93.20	3.92	2.88
MYD x WCT	97.12	1.33	1.55
WCT x GBD	90.12	8.41	1.33
CD at P=0.05	1.31	1.43	0.86

(Source: Naresh Kumar et al., 2000b ;2005)

per cent) and phospho-lipids (2.5 per cent) (*Table 6*). Lipid fraction content varied with cultivar. The neutral-lipid (storage lipid) fraction was maximum in WCT, LCT, MYD x WCT, JVT, FIJT and PHOT, whereas, it was least in ZANT. In general, hybrids had lower concentrations of neutral-lipids (90 – 94 per cent) (Naresh Kumar *et al.,* 2000b). Krishnamurthy and Chandrasekhara (1983) revealed that besides neutral-lipids, coconut oil contains polar lipids which are not extracted by cold pressing or by extraction with a non polar solvent. Polar lipids contain higher amounts of unsaturated fatty acids than the neutral lipids.

The gas chromatographic analysis of fatty acid methyl esters indicated that the coconut oil mainly contains the saturated fatty acids viz., 6-C (caproic), 8-C (caprylic), 10-C (capric), 12-C (lauric), 14-C (myristic), 16–C (palmitic), 18-C (stearic) and 20-C (arachidic) acids (*Table 7*). It also contains the unsaturated fatty acids viz., 16-C:1 (palmitoleic), 18-C:1 (oleic) and 18-C:2 (linoleic) in fewer quantities. Apart from these some other longer chain fatty acids like 18-C:3 (linolenic), 22-C (behenic), 24-C (lignoceric) and others with a retention time of 24.8 min. and 27.7 min. during a 30 min run period were also detected. The concentration of lauric acid, the major component of the fatty acids in coconut oil has ranged from 41 to 53 per cent depending on the cultivar and their interaction with season and agro-climatic zone. The variations in fatty acid profile are indicated by the range of percentage for each fatty acid in Table 7. These variations were found among the cultivars, and also due to the influence of environment and genotype interaction. Such G x E interactive influence is reported for the first time in coconut. Further, for the first time, our experiment revealed the presence of long chain fatty acids beyond 20C in coconut oil.

endosperm of coconut was done in USA by Oo and Stumpf (1979).

Balachandran *et al.,* (1985) studied the fatty acid distribution in different regions of coconut endosperm and found that the fatty acids (6:0 C to 12:0 C) were concentrated in the inner regions and

Table7. A comparative table indicating the fatty acid profile in coconut oil

Fatty acid	Hilditch & Williams, 1964	Padua Ressurection & Benzon, 1979	Naresh Kumar, 2005
C6 (Caproic)	-	0.67 (mature nut)	0.2 - 1.0
C8 (Caprylic)	9.5	8.98	3-8
C10 (Capric)	4.5	6.24	3-7
C12 (Lauric)	51.0	48.15	41.53
C14 (Myristic)	18.4	18.96	16-22
C16:0 (Palmitic)	7.5	8.8	7-11
C16:1(Palmitoleic)	-	-	0.4 in 6th month; in COD mature nut (0.019)
C18:0 (Stearic)	3.0	4.5	2-4
C18:1 (Oleic)	5.0	3.07	5-9
C18:2 (Linoleic)	1.0	0.63	1-4
C20 (Arachidic)	-	-	0.01 to 0.50
C22 (Behenic)	-	-	0.13 in 6th month; in mature nuts (some cultivars) 0.02
C24 (Lignoceric)	-	-	1.5 - 0.04 (developing nut) ~0.01 (mature nuts)
Others			
1) 24.8 min ret	-	-	0.05
2) 27.7 min ret	-	-	0.2 to 3

A few pioneering reports are available on the triglyceride composition of coconut oil by fractional crystallization since 1920 and later the use of GLC led to an extensive analysis of the triglycerides present in the oil leading to its fractionation into different groups based on their carbon atoms from 28 to 52 (Bezard *et al.,* 1971). Thus, 79 types of triglycerides could be identified in coconut oil which represent 99.8 per cent of the total glycerides. The classic work on fatty acid biosynthesis in the developing their contents decreased towards the outer regions with a corresponding increase in the longer carbon chain fatty acids and unsaturated fatty acids. Information on the variation in oil composition with respect to cultivars is available for some cultivars even earlier (Padua-Resurrection and Banzon, 1979; Rodriguez *et al.,* 1998; Marikkar *et al.,* 2004). But so far, no information is available on the variation in oil composition and quality among the coconut germplasm and influence of G x E interaction on oil quality. The current study at CPCRI is expected

to provide such information in enormous detail.

The typical chromatogram of coconut oil (*Fig 3*) indicates a clear separation of fatty acids (saturated and unsaturated).

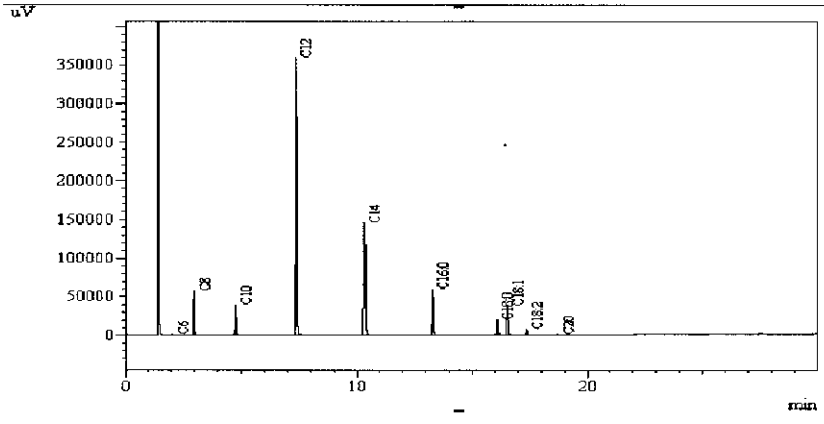

Fig 3. A typical chromatogram of coconut oil fatty acids

Table 8. Seasonal variation in fatty acid composition in coconut oil from two cultivars

Fatty acid/ retention time (min)	CGD Season Jan.	April	July	Oct	GBGD x PHOT Season Jan.	April	July	Oct
C6	0.08	0.09	0.15	0.15	0.12	0.04	0.07	0.25
C8	3.88	3.51	3.82	3.09	4.04	3.63	4.78	4.88
C10	4.64	3.85	4.24	3.13	4.46	4.73	5.16	4.79
C12	49.37	47.18	48.93	43.51	47.60	49.91	52.87	45.77
C14	18.7	20.33	19.37	21.72	19.72	20.21	20.29	19.21
C16:0	9.73	10.93	9.87	12.31	9.71	8.90	8.04	9.58
C18:0	2.80	3.33	3.42	3.61	3.07	2.80	2.33	3.26
C18:1	8.80	8.81	8.43	10.73	8.73	7.66	5.22	8.50
C18:2	1.72	1.73	1.68	1.65	2.38	1.99	1.13	2.23
C18:3	-	-	-	-	-	-	-	-
C20:0	0.09	0.10	0.10	0.15	0.07	0.06	-	0.09
C24:0					-	-	-	0.06
Others								
1) 24.462 m					-	0.09	0.06	-
2) 27.602m					0.09	-	-	1.35

(Source: Naresh Kumar, 2005)

The results indicated that the fatty acid profile of a cultivar varies with the season even at a given location, even though, till now it was perceived that the fatty acid profile of coconut oil is stable and does not vary much among the cultivars. However, the findings indicate the possibility of a wider variation.

The data in *Table 8* indicate that the seasonal variation exists for the fatty acid composition in coconut oil. This variation in concentration of important fatty acids like lauric acid, myristic acid, and other fatty acids can be used for commercial exploitation. For example, the results indicate the possibility of choosing a cultivar and or a season and or a location for higher harvest of lauric acid, saturated fatty acids, etc.

The data on different groups of fatty acids indicate that the total saturated fatty acids and unsaturated fatty acid ratio also varies greatly with the season (*Table 9*). These findings imply that qualitative changes in coconut oil in a year can be effectively exploited for specific uses. However, the results shown in the Table essentially pertain to a particular cultivar. Other cultivars may behave differently as far as the seasonal variations in the fatty acid composition is concerned. Under this experiments more than 120 cultivars and around 100 hybrids were analyzed for fatty acid profile and variations were observed among cultivars. Hence the study is expected to provide answers to a variety of questions and to reveal new possibilities in commercial exploitation. Such variations in fatty acid composition of oil also exist in a cultivar grown at different location or agro-climatic zone (*Table 10*). These results clearly indicate the influence of G x E interaction on the oil fatty acid composition in coconut.

Table 9. Seasonal variations in different types of fatty acid groups in coconut oil of GBGD x PHOT hybrid

Group/ character	Seasons January	April	July	October
Short and MCFA	56.23	58.31	62.88	55.68
Long CFA	32.66	32.06	30.72	33.54
Total Sat FAS	88.89	90.36	93.60	89.22
Unsat. FA	11.11	9.65	6.40	10.74
Sat/ unsat FA ratio	8.00	9.36	14.63	8.31

(Source: Naresh Kumar, 2005)

Table 10. Fatty acid composition of oil from LCT cultivar at two locations during a particular season.

FA	Kidu	Ambajipeta
C6	0.3431	0.1113
C8	5.5332	4.7805
C10	4.2049	5.0096
C12	46.9207	51.3065
C14	22.15105	18.6866
C16:0	9.57275	8.7346
C18:0	2.8217	2.4543
C18:1	6.5925	6.7493
C18:2	1.17495	1.8215
Others		
1) Ret time 23.231m	0.1046	-
2) Ret time 24.661m	-	0.89
3) Ret time 27.678m	1.2657	-

(Source: Naresh Kumar, 2005)

Fatty acid composition of popular cultivars and hybrids

The fatty acid profiles of popular cultivars irrespective of season or location are given in *Table 11*. The variations were masked when data is pooled to take overall mean. This highlights the importance of understanding the variability in fatty acid composition at greater depth in order to explore the possibility of viable commercial exploitation.

Table 11. Fatty acid profile of some common cultivars and hybrids grown in India

Fatty acid	WCT	COD X WCT	TT	LCT X GBGD	GBGD	WCT X COD	ECT
C6	0.12	0.13	0.12	0.16	0.17	0.13	0.11
C8	5.25	4.10	4.93	4.87	4.56	4.54	4.68
C10	5.13	4.19	5.17	4.59	4.55	4.57	4.94
C12	50.58	48.17	50.48	48.27	48.32	48.69	51.45
C14	19.52	20.70	20.02	20.41	20.56	20.41	20.32
C16:0	8.12	9.89	8.03	9.09	9.72	9.46	8.11
C18:0	2.76	3.22	2.44	4.04	3.59	2.90	2.80
C18:1	7.93	7.70	6.98	6.59	6.99	7.49	5.94
C18:2	1.57	1.89	1.88	1.74	1.35	1.72	1.47
C18:3	0.06	0.07	-	0.06	0.10	0.07	0.06
C20	0.06	0.08	0.05	0.06	0.10	0.09	0.12
C24	-	-	-	-	0.03	-	0.06
Others							
1) Ret time 24.435m	0.03	-	-	0.19	0.04	-	-
2) Ret time 27.519m		0.08	-	0.08	-	-	-

(Source: Naresh Kumar, 2005)

Fatty acid profile in the kernel of developing nut

The studies on fatty acid profile in the kernel of a developing nut indicated progressive increase in the concentrations of lauric acid from 6th month after pollination to maturity (Pauda-Resurrection and Banzon, 1979). The results of our experiments on the fatty acid profile in kernel during the nut development indicated that the concentration and content of lauric acid increased rapidly with maturity from 6th to 10 month. But the concentrations of myristic acid remain more or less same during the nut development, even though its content increased. The concentrations of long chain fatty acids are high in 6-month old nuts. But with nut development their concentration decreased due to relatively rapid accumulation of lauric and myristic acids. The data also indicate that the kernel of 6- or 7- month old nuts, which are consumed as tender nuts, possess desirable proportion of all fatty acids. The proportion of lauric acid increased rapidly indicating the preferential biosynthesis of this fatty acid over others. The aspects on biosynthesis of fatty acids, chain elongation, etc. were dealt in depth by Oo and Stumpf (1979). It is shown that the chain elongation and conversion of saturated fatty acids to unsaturated fatty acids do not proceed after some stage of nut development. However, the data of present experiment indicates that the chain elongation and unsaturation does take place even after 10th month as the concentrations of long chain fatty acids like C16:0, C18:1, etc., increased slightly and concurrently the concentrations of C12 decreased slightly as compared to those found during 9th month.

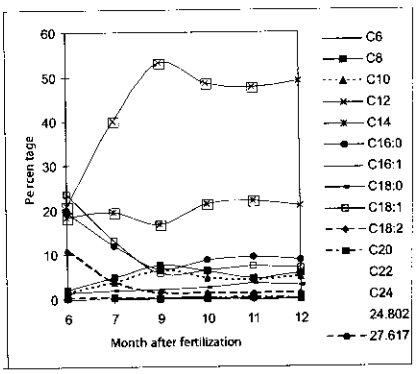

Fig 4. The fatty acid profile of kernel during different stages of nut maturity (Source: Naresh Kumar, 2005)

Influence of abiotic and biotic stresses on fatty acid composition of coconut oil

The results indicated that the fatty acid profile is also influenced by the abiotic stresses like drought

and also due to biotic stresses like *eriophyid* mite (Naresh Kumar, 2005). The oil percentage in copra yield increased under rainfed conditions but the overall copra yield is reduced. The fatty acid composition, particularly that of long chain fatty acid concentrations was affected due to water stress. In the case of *eriophyid* mite, the copra yield and oil percentage in copra decreased significantly depending on the severity of the infestation. The fatty acid composition did not vary much except for slight variations in long chain fatty acid concentrations. The processing temperature of copra also influenced slightly the fatty acid composition of oil. However, at below 70 °C range the effect was not significant (Naresh Kumar, 2005).

The overall results indicate that the fatty acid profile of coconut oil varies due to cultivars and also due to G x E interaction (Naresh Kumar, 2005). Based on the earlier studies (Naresh Kumar *et al.*, 2000a) on oil quality the coconut cultivars were delineated for specific end uses (Table 12).

Table 12. Cultivar suitability for various oil quality based criteria and relevance for specific end uses

Characteristics of oil	Cultivars/ hybrids	More suitable for				
		Soap	Dye	Cosmetics	Pharma-ceuticals	Edible
Low sat/unsat FAs ratio	Hybrids					✓
High lauric acid content, low sat/unsat FAs ratio	LCT x GBD; LCT x COD & COD x WCT	✓	✓	✓		✓
High sat. FAs	ADOT; LCT & SSGT	✓				
High MCFAs	LCT, ADOT & COD x WCT				✓	
High con. of myristic acid	BENT; WAT; FMST; MYD x WCT; WCT x GBD			✓		
High lauric acid conc.	ADOT; LCT; LCT x GBD; LCT x COD	✓			✓	
Low sat/unsat FAs and high MCFAs	LCT x GBD; COD x WCT; LCT x COD; WCT x COD					✓

The criteria given in the above Table about suitability of coconut oil from a particular cultivar for specific use are neither exhaustive nor the list of cultivars given is selected from a full list of cultivars after comparing the fatty acid profile. Full information on these aspects will be available in future as the work on compilation of fatty acid profiles of all available cultivars, seasonal variation and influence of G x E interaction is nearing completion. However, the Table indicates the possibility of delineating cultivars, seasons and agro-climatic zones or locations for specific fatty acid profile. It is also to be noted that the Table is only indicative and by no means it suggests that the oil from other cultivars of coconut (other than hybrids) is not suitable for edible purpose. In fact coconut oil from any cultivar, any location or season is equally good for human consumption. The idea behind providing such in depth information is that there exists a possibility of better exploitation of coconut oil for specific uses. Such information, hopefully, will be beneficial for farmers for putting a price tag for their produce and also for industrialists for optimizing the resources for maximization of profits.

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