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Fatty acid profile of coconut oil in relation to nut maturity and season in selected cultivars/hybrids

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Abstract

Purpose – The objective of this work is to study the fatty acid profile of coconut oil in the kernel in relation to maturity of the nut and season of fertilization in five selected varieties of coconut.

Design/methodology/approach – The coconut oil from the popular cultivars/hybrids were studied in post-monsoon, pre-monsoon and monsoon seasons at 7, 8, 10 and 12 months after fertilization.

Findings – Nuts that fertilized in the post monsoon season were found to have higher oil contents. Of the five varieties, COD × WCT had lesser amounts of caprylic, capric and lauric acids and greater amounts of the long chain fatty acids. Though significant differences were observed in fatty acid concentrations in nuts differing in their variety and season of tagging, the trend remained the same.

Originality/value – The study helps to ensure the safety of the usage of coconut oil as dietary oil, from the nature of fatty acids present.

Keywords Fuits, Food products, Edible oils

Paper type Research paper

Introduction

The coconut (*Cocos nucifera*) is a perennial palm, is chiefly cultivated in the humid tropics for the nuts from which are obtained the edible fresh kernel, its desiccated form – copra, and coconut oil. It is one of the most important sources of vegetable oil in the world. Copra, the main product of the palm, which has an oil yield of about 65 percent, is perhaps the richest material for vegetable oil extraction. Kernel formation starts around the 7th month after emergence of spadix, previous to which time there is no kernel and only coconut water is present. The coconut palm at any time bears seven to eight bunches of coconuts of different maturity and therefore varying proportions of kernel. The solid endosperm, kernel, undergoes biochemical changes as it matures during its 12-month growth period after fertilization. An understanding of these changes would be useful for not only the scientists and nutritionists but also the farmers, to determine the specific end use to which the nut can be put to.

The traditional use of coconut oil as a dietary oil in the tropical areas where it is grown, has been discouraged since the second half of the last century, allegedly due to its role in its contribution to hyper-cholesteremia and therefore to coronary heart diseases, due to its highly saturated nature. A fact that has been largely disregarded is that coconut oil consists predominantly of the small to medium chain fatty acids and glycerides, and that most studies used hydrogenated coconut oil for the ease with which it blended into animal feed. The epidemiological evidence does not support this in relation to high serum cholesterol or incidence of coronary heart disease.

The objective of this study was to look at the qualitative changes (as opposed to just the quantitative data available) in the fatty acid profile of the coconut oil in relation to

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the maturity of the nut and season of fertilization in five promising cultivars (cv)/hybrids of coconut.

Methodology

Plant material

Freshly fertilized bunches of West Coast Tall (WCT), Lakshadweep Ordinary Tall (LCT) × Gangabondam Dwarf (GBGD), Chowghat Orange Dwarf (COD) × WCT, WCT × GBGD and LCT × COD palms, ten years of age, were tagged in three seasons: post-monsoon (November), pre-monsoon (May) and monsoon (August). (The South east monsoon in Kerala, India, extends from end May to early August and an average of 1800-2000 mm of rain is received during this period. About 750 mm of rain is also received in end October to mid-November, during the receding North West monsoon.)

The nuts were harvested at different maturity stages: 7, 8, 10 and 12 months after fertilization. Two replications of each treatment were analyzed for their fatty acid profile, each replication being a composite of two nuts.

Analysis of fatty acid composition

The solid endospermous kernel of the nuts was dried to constant moisture content and oil was obtained from the copra by Soxhlet extraction. The percentage of oil in kernel was quantified gravimetrically.

The oil was methyl esterified by incubating 0.2 g of oil in 2 ml of 5 percent HCl (8.3 ml of acetyl chloride in 100 ml of methanol), at 70^{0}C, for ten hours (Banzon and Resurreccion, 1979.) The fatty acid methyl esters were extracted into diethyl ether and 1 μl of this sample was injected into a gas chromatograph (Chemito 8610 HT, India), to resolve the constituent fatty acid methyl esters (FAME). The eluants were detected on a hydrogen flame ionization detector (FID 861). The 6' × 1/8" stainless steel column was packed with SE 30, nitrogen carrier gas flow rate was 3 mb, hydrogen and air were 1 mb, temperature of the oven was 190^{0}C, injector 200^{0}C and detector 220^{0}C. The recorder was a Chemito 5000 Data Processor, and the standards of FAME were obtained from Sigma Chemicals, USA.

Results

Oil content

Table I gives the oil content of the maturing kernels of different varieties of coconut. As already known the oil content increases with nut maturity and in the present study it increases from a low of 24 percent in the 7th month nut of the LCT × COD hybrid to a high of 72 percent in the fully mature nut of WCT. Oil content stabilizes around the 10th month (60-65 percent). The oil contents of nuts tagged in the pre-monsoon and monsoon seasons were on par, while that of nuts tagged in the post-monsoon season was significantly higher. Oil content was least in LCT × COD (24-68 percent) and maximum in LCT × GBGD and WCT (43-72 percent). The contents in WCT × GBGD and COD × WCT were on par (40-70 percent). The difference in oil contents of nuts differing in maturity was significant at both 5 and 1 percent levels.

Fatty acid profile

The predominant fatty acids were the medium chain fatty acids lauric acid (C12:0) (31-47 percent) followed by myristic acid (C14:0) (18-25 percent), the concentrations of which increased with maturity and were on par in the nuts of 10th and 12th month maturity (Tables II, III, IV and V). The concentrations of the small chain saturated fatty

Table I.
Oil content (%) in coconut cvs/hybrids at different maturity stages and seasons of fertilization

Cvs/hybrids	Maturity (months)	Season of fertilization Post-monsoon	Pre-monsoon	Monsoon
WCT	7	48.5	45.5	45.8
	8	60.0	57.4	45.5
	10	63.6	61.5	71.1
	12	69.5	71.8	72.2
LCT × GBGD	7	57.1	52.2	43.2
	8	59.2	64.1	51.6
	10	62.0	65.0	64.0
	12	67.8	72.1	67.2
COD × WCT	7	55.3	49.2	40.0
	8	58.0	53.9	47.5
	10	65.8	59.1	65.3
	12	69.3	70.5	66.4
WCT × GBGD	7	54.0	33.7	51.0
	8	61.6	43.7	55.6
	10	63.0	64.0	63.7
	12	65.7	64.7	68.1
LCT × COD	7	55.3	24.7	34.0
	8	58.5	46.0	51.2
	10	64.0	68.9	61.8
	12	67.6	68.4	64.4

Notes: $CD_{0.05}$: Season = 0.77; Variety = 0.99; Maturity = 1.01

acids, namely, caprylic acid (C8:0), ranging between 1 to 7.5 percent, and capric acid (C10:0), ranging between 2 to 7.7 percent, were also found to significantly increase with the increasing maturity of the nut. Though significant differences were observed in fatty acid concentrations of nuts of different treatments, the trend remained the same.

All the above fatty acids, except C14:0 were least in nuts tagged in post-monsoon season, while those tagged in pre-monsoon and monsoon seasons were on par, in all except C8:0. Of the five varieties, COD × WCT had lesser amounts of C8:0, C10:0 and C12:0 fatty acids; concentration of C8:0 and C10:0 were on par in COD × WCT, LCT × GBGD and LCT × COD, the varieties WCT and WCT × GBGD were on par.

The long chain fatty acids, palmitic (C16:0) and stearic (C18:0) acids ranged between 7 to 24 percent of the total fatty acids, while the unsaturated fatty acids oleic (C18:1), linoleic (C18:2) and linolenic (C18:3) acids together made up only 2 to 6 percent. C16:0 and C18:0 were lesser in the more mature nuts, while the unsaturated fatty acids increased marginally with nut maturity, but the concentrations were on par among the 10 and 12-month-old nuts. The concentration of these fatty acids was higher in nuts tagged in the post-monsoon season, while those tagged in pre-monsoon and monsoon seasons were on par. No marked difference in concentrations of long chain fatty acids was found among the varieties.

Discussion

Oil and fatty acid composition

The oil content stabilizes around the 10th month after fertilization, as seen from the data. As already reported, coconut oil consists predominantly of lauric acid, a medium

Cvs/hybrids	Maturity (months)	C8	C10	Fatty acid concentration (%) C12	C14	C16	C18	C = C[a]
WCT	7	1.72	3.14	36.99	21.08	14.10	15.44	3.26
	8	1.90	3.28	39.73	22.85	13.06	13.58	3.84
	10	1.93	3.65	40.88	23.46	13.31	13.50	2.88
	12	2.51	3.76	42.17	21.24	13.90	12.33	3.32
LCT × GBGD	7	1.56	2.86	37.35	21.62	13.08	16.90	3.36
	8	1.84	3.57	40.77	22.15	12.42	15.24	3.48
	10	2.24	3.86	41.98	22.32	12.01	13.22	3.50
	12	2.63	3.89	40.19	23.19	12.40	13.12	3.75
COD × WCT	7	1.23	2.48	35.84	20.69	15.17	18.86	3.89
	8	1.41	2.75	36.19	23.55	14.73	16.63	4.59
	10	2.36	3.56	41.52	22.61	12.61	12.56	4.74
	12	2.81	3.06	40.78	22.66	13.32	11.92	3.58
WCT × GBGD	7	1.84	2.69	37.31	20.73	13.51	19.18	3.50
	8	1.81	3.35	38.21	21.58	13.51	16.96	3.59
	10	2.11	4.01	42.11	22.59	11.27	13.39	3.39
	12	3.08	3.98	42.86	23.44	11.89	11.36	3.15
LCT × COD	7	1.32	2.78	35.82	23.43	13.99	16.13	3.59
	8	1.54	3.15	39.15	23.99	14.10	12.78	4.85
	10	2.16	3.41	40.68	25.04	12.92	12.34	3.31
	12	2.39	4.00	40.95	23.27	13.23	11.73	3.93
$CD_{0.05}$	Season	0.16	0.21	2.47	0.44	0.74	1.04	0.42
	Variety	0.21	0.27	3.19	0.57	0.95	1.35	0.54
	Maturity	0.18	0.14	0.67	0.27	0.30	0.57	0.19

Note: [a] Unsaturated fatty acids: C18:1, C18:2 and C18:3

Table II. Fatty acid profile in coconut oil of different cvs/hybrids and maturity stages, fertilized in post-monsoon season

chain fatty acid (Child, 1974), and this oil remains one of the few commercially available oils with such a high content of lauric acid, the other being palm kernel oil. From this study it is clear that over 40 percent of the total fatty acids is lauric acid, for this reason coconut oil is called the lauric oil commercially. Lauric acid and its monoglyceride, monolaurin (which is more effective), have been identified as the principle components contributing towards the antimicrobial (antiviral, antibacterial, antifungal/protozoal), immune-modulating, antitoxic and metabolic-enhancing properties of coconut oil, duplicating the beneficial properties of human milk (Enig, 1998).

Monolaurin's antimicrobial activity against *Staphylococcus aureus* is reported to be even more significant from the study of Gamboa and Carandang (1998) that reports that the bacteria developed no resistance to penicillin when combined with monolaurin. Monolaurin is reported to inhibit the production of β-lactamase (and thus interfere with penicillin resistance in *S. aureus*), toxic shock syndrome toxin-1 and other *S. aureus* exoproteins (Projan *et al.*, 1994.)

Autoimmune deficiency syndrome (AIDS) patients consuming coconut and/ or coconut oil alone or in combination with protease inhibitor drugs reported a significant drop in their HIV viral load (Kabara, 1985). The authors (Kabara, 1985) are of the view that it is unfortunate that a nontoxic food source with such beneficial immunity-enhancing properties should be unrecognized by the mainstream nutritionists and branded by the misinformation surrounding its hyper-cholesteremic label.

Table III.
Fatty acid distribution in coconut oil of different cvs/hybrids and maturity stages, fertilized in pre-monsoon season

Cvs/hybrids	Maturity (months)	Fatty acid concentration (%) C8	C10	C12	C14	C16	C18	C = C[a]
WCT	7	5.74	5.35	37.84	18.88	12.61	14.92	3.14
	8	5.42	5.90	41.11	20.49	10.76	11.75	2.96
	10	6.31	6.48	42.17	21.32	9.27	10.68	2.81
	12	6.42	6.97	42.03	21.10	8.02	10.85	3.94
LCT × GBGD	7	4.19	4.14	34.56	20.10	13.96	19.60	2.68
	8	5.27	4.28	41.11	21.34	10.11	12.18	3.05
	10	6.39	5.96	43.90	21.79	9.92	8.35	3.63
	12	6.77	6.46	47.10	20.67	7.76	6.8	3.05
COD × WCT	7	4.25	4.17	35.00	20.94	13.80	18.37	3.22
	8	6.24	5.47	39.41	21.23	10.95	11.65	3.40
	10	6.44	5.55	42.34	20.45	10.37	10.66	3.41
	12	6.89	5.35	45.72	19.15	9.28	9.55	3.08
WCT × GBGD	7	4.27	3.83	31.18	18.90	14.54	23.66	2.39
	8	5.41	5.53	41.54	20.19	10.44	12.81	2.79
	10	5.77	6.04	45.56	20.68	8.84	9.06	2.81
	12	6.87	6.25	45.63	21.14	7.64	8.49	3.23
LCT × COD	7	4.00	3.96	33.66	19.62	14.63	19.78	2.95
	8	6.29	5.83	44.03	20.44	10.00	9.67	3.66
	10	7.41	6.08	45.94	20.41	8.12	8.40	3.26
	12	7.52	6.05	44.38	22.28	8.15	7.90	3.14
$CD_{0.05}$	Season	0.16	0.21	2.47	0.44	0.74	1.04	0.42
	Variety	0.21	0.27	3.19	0.57	0.95	1.35	0.54
	Maturity	0.18	0.14	0.67	0.27	0.30	0.57	0.19

Note: [a] Unsaturated fatty acids: C18:1, C18:2 and C18:3

Epidemiological data from populations whose diets are rich in coconut oil do not support the hypothesis that it leads to high serum cholesterol or to high coronary heart disease mortality or morbidity (Kaunitz and Dayrit, 1992.) Despite the presence of such high concentrations of saturated fatty acids (above 90 percent), it is still safe for use as a dietary fat, since it is composed chiefly of the medium chain fatty acids – lauric and myristic acids (over 60 percent). These fatty acids, unlike the long chain fatty acids are not deposited in adipose tissue and do not require to be transported by chylomicrons in the blood to tissues (Enig, 1990). When examining the metabolism of small to medium chain triglycerides, they produce ~10 percent less energy (8.3 kilocalorie per gram), compared to the long chain fats, which yield 9.0 kilocalorie per gram on digestion. The small chain fatty acids C6:0, C8:0 and C10:0 and their derivatives, of which coconut oil is a significant source, are important for the industry.

Traditionally, the risk of Coronary Artery Disease (CAD) from dietary fats has been estimated from their effects on serum total cholesterol (Keys *et al.*, 1957; Hegsted *et al.*, 1965). As a result, fats such as dairy fat and tropical oils high in lauric, myristic and palmitic acids, were considered the largest risk factors for CAD. This overlooks the fact that fats also affect HDL cholesterol, and the ratio of total to HDL cholesterol is considered a more specific marker of CAD than total cholesterol and lipoprotein content (Kinosian *et al.*, 1995; Assmann *et al.*, 1996.) It is vital to study the effects of individual fatty acids in the diet on health, as they do not have the same effects. Mensink *et al.* (2003) reported that lauric acid – a major component of tropical oils such as coconut and palm kernel fat – greatly increased total cholesterol, but much of its

Cvs/hybrids	Maturity (months)	C8	C10	Fatty acid concentration (%) C12	C14	C16	C18	C = C[a]
WCT	7	5.28	4.77	39.30	18.12	12.39	16.43	2.29
	8	5.48	4.95	42.52	20.26	11.81	11.85	2.67
	10	5.64	5.92	45.68	19.95	9.68	9.64	3.29
	12	6.63	6.39	44.75	19.60	9.48	8.45	4.28
LCT × GBGD	7	4.38	4.11	37.85	19.07	12.77	17.11	2.67
	8	5.09	5.28	41.21	20.63	11.00	12.61	3.41
	10	6.22	5.85	45.20	21.43	9.30	8.58	2.43
	12	6.61	6.34	45.70	21.12	10.23	6.35	3.39
COD × WCT	7	3.76	3.81	35.31	19.32	14.08	18.42	2.89
	8	4.90	4.94	38.57	20.70	10.94	13.97	3.47
	10	5.59	5.24	44.32	20.72	10.44	9.20	3.67
	12	6.50	5.67	44.98	21.41	9.74	7.53	3.33
WCT × GBGD	7	5.87	5.24	41.54	19.30	11.66	13.03	2.22
	8	6.07	6.13	43.35	20.06	10.08	10.31	2.70
	10	6.52	6.19	45.31	21.06	9.01	8.19	3.36
	12	7.21	6.67	41.96	22.00	7.67	7.91	3.63
LCT × COD	7	4.60	5.01	38.80	19.55	12.17	15.50	2.34
	8	4.79	5.03	40.82	21.18	11.72	12.43	2.19
	10	6.18	5.79	45.33	22.83	9.41	7.16	3.25
	12	6.65	6.60	45.44	22.02	7.70	6.63	3.47
$CD_{0.05}$	Season	0.16	0.21	2.47	0.44	0.74	1.04	0.42
	Variety	0.21	0.27	3.19	0.57	0.95	1.35	0.54
	Maturity	0.18	0.14	0.67	0.27	0.30	0.57	0.19

Note: [a] Unsaturated fatty acids: C18:1, C18:2 and C18:3

Table IV. Fatty acid distribution in coconut oil of different cvs/hybrids and maturity stages, fertilized in monsoon season

Factors/interactions	C8	C10	Free fatty acid C12	C14	C16	C18	C = C[a]
A: Season	206.495	60.410	96.585	84.358	76.843	103.983	22.144
B: Cv/hybrid	0.863	1.189	14.718	3.672	4.059	7.496	1.159
C: Nut maturity	21.150	18.790	360.987	29.658	42.372	417.802	4.217
AB	0.927	0.740	3.151	1.138	0.794	5.385	0.481
AC	1.789	0.672	22.179	1.312	6.325	13.573	0.426
BC	0.370	0.169	4.782	0.978	0.877	6.110	0.593
ABC	0.181	0.148	6.468	1.219	1.248	4.818	0.274

Note: [a] Unsaturated fatty acids: C18:1, C18:2 and C18:3

Table V. Error mean square for various factors and their interactions for individual free fatty acids in coconut oil of different cvs/hybrids and maturity stages, fertilized in different seasons

effect was on HDL cholesterol. As a result, oils rich in lauric acid decreased the ratio of total to HDL cholesterol. Myristic and palmitic acids had little effect on the ratio, and stearic acid reduced the ratio slightly. Consequently, lauric acid had a more favorable effect on total:HDL cholesterol than any other fatty acid, either saturated or unsaturated. Mensink *et al.* (2003) cautions that the favorable effects on this ratio by such factors as coconut fat, which is rich in lauric acid, do not exclude the possibility that coconut fat may promote CAD through other pathways, known or as yet unknown. So it is as yet premature to assume that coconut oil promotes CAD.

Analysis of variation in concentration of the individual fatty acids with maturity revealed that the small to medium chain fatty acids increased with nut maturity, while the long chain fatty acids decreased, indicating synthesis of the small to medium chain fatty acids in the coconut endosperm as it matures, at the expense of the long chain fatty acids. The unsaturated fatty acids, which are lowest in concentration, increased marginally with maturity. According to Kartha and Narayanan (1956) the kernel synthesizes coconut oil with the same chemical characteristics, i.e. iodine and saponification values from the beginning to the end of ripening. The greater oil content observed in nuts tagged in the post-monsoon season is indicative of greater synthesis with more availability of water in this rain fed crop.

These results are largely in accordance with the findings of Resurreccion and Banzon (1979), but the essential fatty acids and oleic acid concentration are much lower in our varieties, i.e. not exceeding 6 percent, in comparison with 20-30 percent reported in the youngest bunches by these authors. Besides these authors report a decrease in these fatty acids with increasing nut maturity, contrary to our findings.

The major limitation of the use of coconut oil as dietary fat is its low levels of the essential fatty acid linoleic and linolenic acids (less than 5 percent), even under the present reduced recommendations from the National Research Council, which advices that of an average total fat intake, 33 percent should be of saturated fatty acids, 40-43 percent monounsaturated fatty acids and 23-27 percent polyunsaturated fatty acids (PUFA). The reduction in PUFA recommendation in the diet from the original 33 percent stems from their implication in the promotion of cancer, premature aging and increase in the low density lipoprotein (LDL) and lowering in high density lipoprotein (HDL) in serum, as PUFA is more susceptible to rancidity by oxidation at its unsaturated carbons. In a review by Blackburn *et al.* (1989) on coconut oil's effect on serum cholesterol and atherogenesis, it is concluded that when "fed physiologically with other fats or adequately supplemented with linoleic acid, coconut oil is a neutral fat in terms of atherogenecity."

Conclusion

In conclusion, the predominant fatty acids in coconut oil are lauric acid (31-47 percent) followed by myristic acid (18-25 percent), the concentrations of which were on par in the nuts of 10th and 12th month maturity. The fatty acids, caprylic and capric acids increased significantly with the maturity of the nut. Nuts that fertilize in the post monsoon season were found to have higher oil content; it was least in LCT × COD and maximum in LCT × GBGD, followed by WCT. COD × WCT had lesser amounts of C8:0, C10:0 and C12:0 fatty acids and greater amounts of longer chain fatty acids. Knowledge of the nutrient profile of the coconut endosperm in relation to maturity, variety and season of fertilization is thus useful in determining its end use. The results presented, that is the predominance of small to medium chain fatty acids in coconut oil, reinforces the fact that it is as yet premature to assume that coconut oil consumption could predispose one to coronary artery diseases.

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