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Chemistry of Oils & Fats & Its Relation To Health-Indian Cenario

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ABSTRACT

There is a poor understanding of facts regarding oils and fat amongst people and the basis of choice of oils and fats, is generally television commercials. There is awareness regarding reducing fat intake but not about the source and its effects. Structural variations of fatty acids elicit different physiological functions which impacts human health. It is believed since long that saturated and trans fats source of LDL, whereas, diets rich in PUFA and Omega 3 Fatty Acids, promote formation of HDL cholesterol. Nutritionists have recommended the ratio of PUFA: MUFA: SFA to be 1:1:1. Complete absence of saturated fat is not recommended. Not a single dietary source or oil has got such combination of fats, a blend of all these three in appropriate proportions is needed. Oils high in SFA increase LDL but recent studies indicate that oils high in short/medium-chain SFA (like coconut oil) have not demonstrated adverse health effects. Groundnut, mustard and sesame oils, the popular traditional oils used in India, have been largely replaced with sunflower oil, possibly due to the aggressive commercial advertisements in the 1980-90s promoting their cholesterol-lowering effect. Mustard and rapeseed oils, due to their favorable LA/ALA ratio, low SFA, and high MUFA content along with their relative stability during cooking – can be a preferred choice, particularly mustard oil in its non-refined (cold-pressed) form. Ghee [refined butter] in upto 10% energy share is also good for health.

KEY WORDS : Canola oil. Edible oil, Mustard oil, N-6/N-3 ratio, Saturated fats

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INTRODUCTION

A survey of consumers, dealers and dieticians from a Mumbai locality showed that there is a poor understanding of facts regarding oils and fats. After an initial search of in the database for papers that studied the composition and effects of edible oil on health, a total of 40 papers that included the key terms were studied and information on composition of fats and oils, their usage and benefits and disadvantages were pooled together. The purpose of this review is to provide for a broad overview of the potential benefits and risks of array of commonly marketed edible oils on physiology, particularly in Indian context, where cooking methods are different then in the west.

1.1 Types Of Lipids & Their Importance In Diet

Fats help in building the cell membranes, neurotransmitters, hormones, and provide energy. But fats get accumulated in the blood vessels of heart and brain sometimes in arteries of limbs as they are not the fastest moving energy resource of the body. Changes in lipid metabolism can result in change of membrane composition resulting in changes in its permeability. It may also cause disruption of signaling networks and could be associated with cancer, CVD, neurodegenerative & metabolic diseases, and inflammation. Energy balance is required to maintain healthy body weight. HDLs scavenge cholesterol from heart, brain, arteries and bring them back to the liver. Whereas LDL cholesterol concentration in the blood is directly related to mortality due to cardiovascular events. Hence fat intake should be directed in reducing LDL and increasing HDL.

Lipids are classified according to the presence or absence of double bonds as saturated (SFAs—without double bonds), monounsaturated (MUFAs—with one double bond) and polyunsaturated fatty acids (PUFAs—with two or up to six double bonds). As cis or trans based on the configuration of the double bonds and as n-3 or n-6 PUFAs depending on the position of first double bond from the FAs methyl-end. Humans cannot synthesize PUFAs with the first double bond on C3 and C6 from the methyl-end due to absence of appropriate enzymes, making them essential (EFAs). FA with cis configuration is found in most naturally occurring unsaturated fatty acids, trans configuration is the result of processing, such as hydrogenation. Main PUFAs are α-linolenic (ALA, 18:3, n-3) and linoleic acid (LA, 18:2, n-6) from which other important PUFAs are synthesized. Transformation of n-3 PUFA to docosahexaenoic acid (DHA, 22:6, n-3) depends on the activity of Δ5 and Δ6 desaturases which could be influenced by several factors, such as high-fat diet, low insulin levels, protein and minerals deficiency. Eicosanoids derived from n-6 and n-3 are antagonistic, eicosanoids from n-6 promote inflammation & from n-3 are anti-inflammatory. Conversion of dietary n-3 PUFA into eicosapentaenoic acid (EPA, 20:5, n-3) is limited because of the competition for common desaturation and elongation enzymes of n-3 PUFA and n-6 PUFA. Also

the affinity of Δ6 desaturase for n-3 PUFA is greater than for n-6 PUFA. Essential fatty acids (EFAs) are considered as functional food and nutraceuticals. A lot of research studies have documented their significant roles in reducing the risk of serious diseases, especially cardiovascular diseases, cancer, osteoporosis, diabetes and other health promotion activities; as they influence concentrations of lipoproteins, fluidity of biological membranes, function of membraned enzymes and receptors, modulation of eicosanoids production, blood pressure regulation, and metabolism of minerals. EPA and DHA are associated with the protection against mental disorders like Alzheimer's disease, aging and dementia, chronic daily headache and attention-deficit hyperactivity disorder in children.

1.2 Management Of Diatary Lipids In Health & Disease

Lipid consumption in most Western countries is relatively high, particularly of trans fatty acids from super market foods, with the contribution of approximately 40% of total calories [up to 25% recommended by WHO]. The role of dietary fats in cardiovascular disease and many other disorders is not simple, but rather a consequence of complex factors. Each group of fatty acids—SFAs, MUFAs, PUFAs and individual FAs—has a specific role and imbalance in their dietary intake could be result in many serious diseases. Recommended ratio of PUFA: MUFA: SFA is 1:1:1. Saturated fats should not be completely absent. Not a single dietary source or oil has got such combination of fats; a blend of all these three in appropriate proportions is needed. The guidelines for cholesterol management is using statin [HMG-CoA reductase inhibitors] therapy affecting cholesterol synthesis pathway. However there are side effects such as myalgia, and this decreases their patient compliance. Many vegetable oils, like sunflower or olive oils, also show hypo-cholesterolemic effects when ingested [Wilson TA, et al. 2000].

To replenish energy after a decrease in fat intake, carbohydrate intake is increased. However, Low-fat, high-carbohydrate diets are known to reduce both LDL and HDL cholesterol and raise triglycerides associated with increased CHD risk. Short-chain SFAs, e.g., from dairy fat, can influence gene expression of several hormonal including insulin and leptin regulating overall energy metabolism in the human body. Reducing SFA by itself has no effect on CHD and stroke. There is a positive relationship between SFA intake and increased diabetes risk but there is insufficient evidence for establishing relationship of SFA consumption with cancer. There is convincing evidence that replacing carbohydrates with MUFA increases HDL cholesterol concentrations but not on replacing SFA with MUFA. SFAs when replaced with PUFAs, decreased the risk of CHD. Therefore, it is recommended that SFA should be replaced with PUFA in the diet and the total intake of SFA not exceed 10%. The minimum intake levels for essential fatty acids to prevent deficiency symptoms are 2.5% LA plus 0.5% alpha-linolenic acid (ALA). Minimum recommended level of total

PUFA is 6% for a healthy heart. Based on experimental studies, risk of lipid peroxidation may increase with high (>11%) PUFA consumption, particularly when tocopherol intake is low. There is convincing evidence that TFA from commercial partially hydrogenated vegetable oils increase CHD events, metabolic syndrome and diabetes. There also is evidence of an increased risk of fatal CHD and sudden cardiac death. (Jakobsen et al., AJCN:89, 2009), (Siri-Tarino et al., AJCN:91, 2010).

Statistical evaluation of impact of dietary intakes of fat in various countries shows that relatively high number of CHD and CVD mortality are there in some European countries, perticularly in the Czech Republic, Germany and Austria, with values >300 events per 100,000 habitants. However, though there is highest consumption of total fat in Greece, yet relatively low value of CVD mortality was documented. Also, the highest PUFAs intake in Austria did not correlate with the high number of CHD and CVD mortality. Moreover there was higher correlation between MUFA intake and mortality than correlation between SFAs and mortality. Hence, dietary SFAs reduction itself cannot suppress the risk and do not clearly support cardiovascular guidelines promoting high consumption of MUFA & n-6 PUFA. [Jana Orsavova, et al. 2015].

A meta-analysis of randomized trials suggested a 17% reduction in risk of CHD in studies that reduced SFA from about 17% to about 9% of energy [Hooper L., et al. 2015]. However, short- and medium-chain SFA are not harmful, as they do not affect the serum lipids. Recent applications of medium-chain triglycerides [MCTs] in epilepsy, obesity, and other special areas of application are cited. The use of medium-chain mono-diglycerides for dissolving cholesterol gallstones is presented. The contraindications for the use of MCTs in ketosis, acidosis, and cirrhosis are also discussed. Suggestions for use of MCTs in a variety of medical and nutritional applications are presented [Bach & Babayan 1982]. N6 PUFA lowers not only LDL but can also decreases HDL, whereas N3 PUFA may lower triglycerides, blood pressure, inflammation, improve vascular function, and sudden death [Ristic-Medic D., et al. 2013] [Ghafoorunissa, et al. 2002] N6 and N3 PUFA should be present in adequate and balanced proportion in the body because both compete for the enzymes that convert them into more active compounds. Several dietary recommendations suggest that the ratio of n6:n3 PUFA should be 5–10:1 or lower to prevent heart disease. [ICMR Hyderabad, India: 2010] [AO/WHO FAO; 2010]. WHO recommends N-6: N-3 ratio to be 5:4 Foods that are good sources of N-3 generally are also good sources of N-6. Walnuts have ratio closer to 4:1. Interestingly, with almonds the ratio is 1689:1. The only common foods where the ratio is reversed are the green leafy vegetables like lettuce, spinach, kale, broccoli, rapini [sarso], etc. They have N-6: N-3 ratio less than 1 and these are the foods which should be consumed more to improve the ratio. Among the cooking oils also it is very clear that those oils which are derived from green leafy vegetables, for example those derivedfrom the Brasicca family like mustard oil or canola oil have the best N-6:N-3 ratio.

Popular oils like olive oil & corn oil have adverse ratios. There is evidence that in humans when omega-6 intake is kept low, plant-based omega-3 can be converted to long-chain n3 fatty acids as found in fish oils (eicosapentaenoic acid) in limited amounts. Common sources of plant oils containing ALA include walnut, edible seeds, clary sage seed oil, algal oil, flaxseed oil, Sacha Inchi oil [inca nut], Echium oil [borage], and hemp oil, while sources of animal omega−3 fatty acids EPA and DHA include fish, fish oils, eggs from chickens fed EPA and DHA, squid oils, and krill oil.

Trans fats are associated with CHD, probably because of higher levels of intake of industrial trans fats than ruminant trans fats [De Souza R.J.,et al. 2015]. Several reviews have demonstrated that high intake of TFA was associated with increased CHD events and mortality and also possibly other chronic diseases like Alzhiemer's disease, cancer, diabetes, obesity, inflammation, depression, etc.

1.3 COMPOSITION OF EDIBLE OILS & THEIR EFFECTS

Presently, the most commonly used cooking oils in India are Sunflower (64%) followed by Palmolein oil (23%), whereas the traditional oils such as Groundnut (peanut) (7%) and Gingelly (sesame) (2 %) are used less often [Prasada Rao N et al 2016].

Table 1- Approximate fatty acid composition of visible fats (g/100 g) & smoke points

	SFA [saturated fatty acids]			MUFA	linolenic acid [n-6]	alpha linolenic acid [n- 3]	LA/ALA*	Smoke Point °C
	Short chain	Medium chain	Long chain					
Unrefined flaxseed oil	-	-	-	-	-	-	0.25	107°C
Corn	-	-	12	32	55	1	55	160°C
Hemp seed oil	-	-	-	-	-	-	3	165°C
Butter	11	43	14	28	3	<0.5	9	177°C
Coconut	14	63	12	7	2	<0.5	4	177°C
Rapeseed/mustard	-	-	8	70	12	10	1	177°C
Macadamia nut oil	-	-	-	-	-	-	1	199°C
Canola oil- refined	-	4	2	56	26	10	2	204°C
Olive	-	-	13	76	10	<0.5	20	207°C
Sesame	-	-	15	42	42	1	42	210°C
Cotton seed	-	-	21	25	52	1	52	216°C
Groundnut	-	1	23	50	25	<0.5	50	227°C
Soyabean-refined	-	-	15	27	53	5	11	232°C
Sunflower	-	-	13	27	60	<0.5	120	232°C
Palm	-	1	44	44	10	<0.5	20	232°C
Ghee	10	15	40	32	2	0.5	4	252°C
Rice bran	-	-	22	41	35	1.5	23	254°C
Safflower	-	-	13	17	70	<0.5	140	266°C
Avocado oil	-	-	12	76	25	2	12	271°C

Data from various sources. *LA/ALA ratios recommended 5-10:1 or lower preferably 1:3

Olive oil, considered healthy in western diet, has limitation that it does not have ideal n-6: n-3 ratio and may not be suitable for Indian cooking due to relatively lower smoke point. Sunflower oil is very high in omega-6 fatty acids. Whereas traditional oils like groundnut oil provide optimal levels of monounsaturated fatty acids. In a study, it was found that there is a significant increase in Body mass index of sunflower oil consumers when compared to other oil consumers like palmolein, groundnut, coconut and gingelly oil consumers.

Canola oil is oil from a breed rapeseed plant [mustard family]. In Canada, in the early 1970s, traditional plant breeding techniques were employed to create a plant producing oil low [<2%] erucic acid [original 45%] and high oleic acid [63%]. For marketing purposes, oil from this plant was called Canola oil (Canadian Oil Low Acid). It is consumed commonly in Japan where incidence of CVD and associated mortality rate is quite low. Based on earlier studies in rats, there was a concern regarding high erucic acid content of mustard oil; however, later studies showed that in rats there is an inefficient activation of erucic acid to erucyl-CoA coupled with lowered activity of triglyceride lipase and enzymes associated with β-oxidation of erucic acid, which possibly contribute to the accumulation and retention of cardiac lipids. Other species, including humans, have not demonstrated to have such toxic effects. [Lin L., Allemekinders H., Dansby A. 2013] Mustard oil is considered healthy edible oil because it is low in SFA, high in MUFA and PUFA, especially alpha-linolenic acid, and a good n6:n3 ratio. It is also available in nonrefined (cold compressed) form and is relatively stable during cooking at high temperatures. Several studies also suggest that mustard oil may be associated with lower CHD risk as compared to other oils. A double-blind study has demonstrated that in acute MI patients using mustard oil, there was reduction in arrhythmias, heart failure, and angina. [Singh R.B., Niaz M.A., Sharma J.P. 1997]. Sesame oil can decrease low-density lipoprotein (LDL) levels while maintaining high-density lipoprotein (HDL) levels. One study tested the effect of sesamin, a lignan in Sesame oil, in humans and found a significant reduction in LDL-C [Hirata F, Fujita K, Ishikura Y, et al. 1996]. This study also states that sesamin may potentially reduce HMG-CoA reductase activity. Also Sesamin appears to be a potent inducer of hepatic fatty acid oxidation and is an inhibitor of hepatic lipogenic enzyme gene expression [Ide T, et al. 2001]. A study on hypertensive men, showed that sesame oil has both local and short acting benefits such as vasodilation and also longer acting properties involved with the downregulation of the integrin ligand of the ICAM due to change in the gene expression of the ICAM gene [Karatzi K, Stamatelopoulos K, Lykka M, et al 2013].

Ghee contains high levels of saturated fatty acids and cholesterol, which are considered risk factors for CVD. In a study, ghee, at levels ranging from 0.25 to 10%, was included in a nutritionally balanced diet fed to Wistar rats for a period of 8 weeks. The serum lipid profiles of these animals

showed a dose dependent decrease in total cholesterol, low density lipoproteins and very low density lipoproteins cholesterol, and triglyceride levels when ghee was present at levels greater than 2.5% in the diet. Liver cholesterol and triglycerides also were decreased in these animals. This study revealed that the consumption of ghee up to a 10% level in the diet altered blood lipid profiles in such a manner as not to elevate the risk factors for cardiovascular diseases [Matam Vijaya Kumara Kari Sambaiaha Belur R Lokesha 1999]. DHA content was significantly higher in ghee prepared by traditional curd method. Factors that may be involved in the rise of CAD in Asian Indians include the increased use of vanaspati (vegetable ghee) which contains 40% trans fatty acids, psychosocial stress, insulin resistance, and altered dietary patterns. Both butter & margarine are solid fats and very likely to be unhealthy for the heart Coconut oil has high content of saturated fatty acids (92%). However, lower molecular weight of medium-chain triglycerides facilitates the action of pancreatic lipase. Consequently, medium-chain triglycerides are hydrolyzed faster and more completely than longer-chain triglycerides. MCFAs do not participate in the biosynthesis and transport of cholesterol. Flaxseed oil, though a rich source of ALA, is not commonly consumed; however, blending it with other edible oils is a good strategy. [Deb Mandal M, 2011]. In Indian & West African diets, coconut and palm oils are often used for frying during which the oil temperatures can go above 170 °C. When cooking oils are heated, reactions such as oxidation, hydrolysis, isomerisation and polymerisation occur, resulting in the formation of a variety of products some of which like acrolein and other unsaturated aldehydes, are known to be responsible for the off-flavour and negative effects on human health. The smoke point is the temperature at which a fat or oil produces a continuous wisp of smoke and is a useful indicator of an oil or fat's suitability for frying. Fats with a smoke point below 200 °C are not suitable for frying. The smoke point of unrefined palm oil [235 °C] is higher than unrefined coconut oil [177 °C]. Hence coconut oil is better suited for shallow frying, whilst palm oil is suitable for both deep and shallow frying. Sesame oil [smoke point 400 ^{o}F], can be used to cook without releasing harmful substances into the air. It has been demonstrated that refined oils with high PUFA, can degrade easily to toxic components like free radicals, transfats, melondialdehyde (MDA), etc., which are potentially mutagenic and atherogenic. [Fullana A., Carbonell-Barrachina A.A., Sidhu S. 2004]. Repeated frying of the oil can further damage the oil and produce more toxic components that are highly harmful to the heart. An Indian study has demonstrated that TFA content of oil samples drawn for the halwais, who use same oil for repeated frying, have high TFA. [Jain A., Passi S.J., Pant K.K. 2015 The prevalence of Metabolic Syndrome was higher among sunflower oil users (30.7%) than palmolein (23.2%) and traditional oil (17.1%, $p < 0.001$) users. [N Lakshmipriya, R Gayathri, K Praseena et al. 2012].

Oils high in saturated fats like ghee/coconut are ideal for deep-frying, as they are more stable. Blending of oils combines the potency of two/more edible oils; it offers a balance of fatty acids and antioxidants, and this approach is used to enhance the oxidative and thermal stability of oils. A study has indicated that canola, or in blend with flaxseed oil, effectively reduced serum TC and LDL-c. [Gillingham L.G., Gustafson J.A., Han S.Y., Jassal D.S., Jones P.J.H. 2011]. Mixtures like safflower and rice bran oil or rice bran oil and soybean oil, are marketed in India.

1.4 REFINED EDIBLE OILS

Antioxidants present in several oils (like tocotrienols, tocopherols, oryzanol, and phytosteroles) have favorable effects on lipids and oxidative stress and can prevent heart disease. [Cicero A.F., Gaddi A. 2001] [Dermonty I., Ras R.T., van der Knaap H.C. 2009] Oryzanol is an antioxidant found in rice bran oil. It can reduce cholesterol and decrease early atherosclerosis, inhibit platelet aggregation, and increase the fecal bile acid excretion. Refined oils are purified oils from oil cakes high temperatures up to 270 °C in a steam bath for deodorization and to start the oil extraction process. These high temperatures can result in loss of antioxidants (like tocopherols) and sterols, produce free radicals and TFA, and polymers that are potentially atherogenic and mutagenic. Hence cold pressed oils are preffered.

1.5 EFFECT OF DIET ON GUT MICROFLORA

Western diet rapidly changes intestinal microbial community structure, with increased numbers of phylum Firmicutes and decreased abundance of phylum Bacteroidetes. Metagenomic analysis show a concurrent overrepresentation of genes involved in carbohydrate transport [Goodman et al. 2011]. Some products of biochemical conversions, such as short-chain fatty acids, biogenic amines (such as histamine) or other amino-acid-derived metabolites such as serotonin or gamma-aminobutyric acid (GABA), may be biologically active. The production of these compounds may also be able to induce changes in microbial composition. Dietary non-digestible carbohydrates can be fermented in the intestinal lumen, resulting in production of SCFAs such as acetate, propionate and butyrate. SCFAs provide metabolic energy sources for olonic epithelial cells. Fermentation of prebiotic carbohydrates such as inulin and fructo-oligosaccharides induces proliferation of beneficial microbes (*Bifidobacterium spp*. and *Lactobacillus spp*.) in the gastrointestinal tract. Consumption of a fat-enriched diet has been suggested to affect the intestinal microbiota in a recent clinical study where healthy volunteers were subjected to a high-fat, Western-style diet for 1 month. Plasma endotoxin levels were increased in individuals who were fed a high-fat diet, which may be a result of perturbations in the gut microbiome [Pendyala et al. 2012]. Changes in microbiome composition and function may contribute to disease susceptibility. Several studies have

demonstrated associations between intestinal dysbiosis and chronic low-grade inflammation [Cani and Delzenne, 2009]. According to Jumpertz et al. primarily nutrient load influences the gut bacterial community structure over short time scales. Also gut microbiota may play a role in the regulation of the nutrient harvest. It may ultimately result in metabolic syndrome, obesity and diabetes [Pflughoeft and Versalovic, 2012]. Larsen et al. showed that relative abundance of *Firmicutes* in gut was significantly lower, while the proportion of *Bacteroidetes* and *Proteobacteria* was somewhat higher in diabetic persons compared to their non-diabetic counterparts. Higher levels of *Bacilli* and the *Lactobacillus* group are found in diabetic subjects compared to controls & in obese adults

CONCLUSION

In the global context, Indian cooking conditions differ greatly. Oils are often subjected to high temperatures. Refined oils, particularly high in PUFAs, degrade easily and therefore, should be avoided for frying. Also heating during the refining process, results in degradation and generation of toxic substances. On the contrary, saturated fats like ghee & coconut oil can be used for Indian cooking, as they are comparatively stable during frying. Majority of vegetable oils is characterized by higher amount of n-6 PUFAs, so they should not be used as oils for daily consumption. Mustard oil with n-6/n-3 ratio of 1 can reduce the risk of CHD. Further, appropriate blending of edible oils (such as mustard oil and peanut oil; coconut and sesame oil) also appears to be a good option to reduce the plasma lipids, inflammation and, thus, the CHD risk. Edible oil research shows promise in decreasing lifestyle disease incidence.

FUTURE PROSPECTS

Future studies should examine the different oils for their effects on humans in a dose-dependent manner for them to be used as nutraceuticals. Also human diets have direct effects on the intestinal microbiome, which results in changes in biochemical reactions in the intestinal lumen. Treatment modalities, besides manipulate and restore the balance of intestinal microbiome, can also be right diet with right composition of fats and oils to promote growth of desired microflora and it should be explored further.

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