EDIBLE OILS: AN OVERVIEW WITH DIABETES PERSPECTIVE

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ABSTRACT
Metabolic syndromes including diabetes, obesity along with dyslipidemia have become a growing health problem affecting the quality and wellbeing of human life globally. Changes in the world food economy are reflected in shifting dietary patterns, which has undergone so many swings over the ages, for example, increased consumption of energy-dense diets high in fat, particularly saturated fat, and low in unrefined carbohydrates. This shift in dietary habit, accompanied by reduced physical activity and leisure period lead to increase in diabetes and obesity over time. Edible oils derived from plant sources like olive, canola, avocado, palm, rice bran etc. have been suggested for their positive impacts in diabetes mellitus. These edible oils contain different proportions of fat along with minor components like tocotrienols, tocopherols, oryzanol, phytosterols which are likely related to insulin resistance and metabolic control. In this context, awareness and strategic pricing of edible oils are important to regulate its cheap availability and immoderate consumption which can consequently lead to adverse health effects.

KEYWORDS: Diabetes Mellitus, Vegetable oils, PUFA, MUFA.

INTRODUCTION
Diabetes mellitus and its associated life threatening complications are major and increasing metabolic disorder that can affect an individual’s psychological and physical wellbeing.[1] In the current scenario, it is becoming one of the most common Non Communicable Disease (NCD), which is mainly characterized by hyperglycemia in association with defects in insulin secretion or action or both.[2] Low and middle income countries are overburdened with the
alarming increase of diabetes. In 2013, 619,000 adults died in Europe due to diabetes whereas the count reached up to 1.2 million in South-East Asia.\textsuperscript{[3]}

The nutritional transitioning from healthy, traditional, high-fiber, low-fat, low-calorie diet toward food items containing high amount of trans-fatty acids is capturing our cities due to increasing domination of fast food culture. Global trade liberalization has made food products, such as edible oil and sugar, more accessible and relatively cheaper than in the past. To reduce the rising burden of NCDs, a diet low in fat, sugar, salt and comprising of fruits, vegetable, whole grains and nuts is recommended by WHO.\textsuperscript{[4,5]}

Although, excessive fat intake and an imbalance between energy intake and physical activity are considered as the primary risk factor for Type 2 Diabetes Mellitus (T2DM), still people had made a mindset for blaming fats and fatty oils for any metabolic consequences.\textsuperscript{[6]} Fats and oils, both are recognized as essential nutrients in both human and animal diets as they are providing most concentrated source of energy, essential fatty acids (which are precursors for important hormones, the prostaglandins), fat soluble vitamins and also gives the feeling of satiety.\textsuperscript{[7]} All oils and fats are 100% fat, but the building components that make up the fat structure of a particular oil are important in determining whether or not oil or fat is considered healthy.\textsuperscript{[8]} Over the past 30 years (1973–2004), a 7% decrease in energy derived from carbohydrates and a 6% increase in energy derived from fats occurred due to nutrition transition.\textsuperscript{[9]} Higher economic growth raises incomes and hence demands. There have been a number of major developments in the field of fats and fatty acids in human nutrition during the past fifteen years. Global data on fat supply, as well as individual food intake data, contribute to an understanding of the relationship between fat intake patterns and health outcomes. The Foreign Agricultural Service of the United States Department of Agriculture (USDA), provide valuable information on the domestic consumption of vegetable oils. The global domestic consumption of vegetable oils increased considerably between 2010 and 2014. Country-wise consumption of specific vegetable oils between 2010-11 and 2013-2014 are shown in Fig. 1.
**Fatty acid components: Emphasizing Diabetes**

Fats are basically mixture of saturated and unsaturated fatty acids.\(^{10}\) (Table 1). Table 1 shows the source and roles of different fatty acids in terms of determining the health and nutritional well being along with the possible mode of action.

**Table 1: Fatty acid components\(^{15-21, \text{11}}\)**

<table>
<thead>
<tr>
<th>Types</th>
<th>Effect on Diabetes</th>
<th>Best Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saturated Fatty Acids</td>
<td>Impair both blood lipids and insulin sensitivity</td>
<td>Full fat milk and cheese, prepared potatoes (such as potato patties, potato salad, mashed potato and hot chips), pastries, meat and butter, palm and coconut oils and their products, palm kernel oil, coconut milk and coconut cream.</td>
</tr>
<tr>
<td>Monounsaturated Fatty Acids (MUFA)</td>
<td>Promotes healthy blood lipid profiles, mediates blood pressure, improves insulin sensitivity and regulates glucose levels</td>
<td>Vegetable oils from oilseed crops, fish, tahini, avocados, margarine spreads based on olive and canola oils, canola oil, olive oil, pine nuts, hazelnuts, almonds, cashews, peanuts, macadamias, pecans and pistachios.</td>
</tr>
<tr>
<td>Polyunsaturated Fatty Acids (PUFA)</td>
<td>Modulate immune responses and may ameliorate insulin sensitivity</td>
<td>Cold water fish (especially wild salmon), flaxseed, hemp seed, walnuts, green leafy vegetables</td>
</tr>
<tr>
<td>Omega-3 fatty acid</td>
<td>Improve Insulin resistance and reduce the incidence of diabetes</td>
<td>Vegetable and seed oils, such as canola, sunflower, soybean, peanut and sesame oils nuts, such as walnuts, pecans, peanuts, brazil and pine nuts seeds, such as sunflower seeds fish.</td>
</tr>
<tr>
<td>Omega-6 fatty acid</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Trans unsaturated fatty acids

Alter the expression of different genes associated with insulin sensitivity in adipose tissue, increases concentration of LDL cholesterol and decreases concentration of HDL cholesterol

Partially hydrogenated vegetable oils, milk, butter, and beef fat.

There was a substantial increase in the people’s knowledge of fatty acids over the past decades. Scientific evidence that emerged over the past two decades shows that trans fatty acid consumption has unique adverse effects on serum lipids, including increase in low density lipoprotein, lowering the high density lipoprotein along with increasing ApoB levels, and decreasing ApoA1 levels (Table 1). In dietary practice, exchanging non hydrogenated polyunsaturated fat for saturated and trans-fatty acids could appreciably reduce risk of type II diabetes. Animal studies suggested that the type of fat in the diet may impair insulin sensitivity by changing the fatty acid composition of membrane lipids. However, a high proportion of unsaturated fatty acid may improve insulin signaling by increasing membrane fluidity along with the alteration of enzyme activity and gene expression. Technically, trans fat is worse than saturated fat. These chemically altered (made by adding hydrogen to vegetable oil) fats improves shelf life and crispiness of foods like crackers and baked goods but raise bad cholesterol (LDL) and lower good cholesterol (HDL).

Despite the existing pharmacotherapy, it is still difficult to attain adequate glycemic control amongst diabetics. So, the main purpose of the present review is to identify and critically assess the current body of evidences providing compositions, utility, efficacy as well as the pharmacological aspects of few vegetable oils and fats in order to improve understanding in their applicability for diabetic patients.

Benefits edible oils suggestive in diabetes and their composition

In order to translate food intake data into fatty acids consumed, information from food composition databases is required. Table 2 outlines the composition of fatty acids in some beneficial edible oils.

<table>
<thead>
<tr>
<th>Edible oils</th>
<th>Energy (KCal)</th>
<th>SFA (g)</th>
<th>MUFA (g)</th>
<th>PUFA (g)</th>
<th>Trans Fat (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avocado oil</td>
<td>884</td>
<td>11.56</td>
<td>70.55</td>
<td>13.49</td>
<td>--</td>
</tr>
<tr>
<td>Rice bran oil</td>
<td>884</td>
<td>19.70</td>
<td>39.30</td>
<td>35.00</td>
<td>--</td>
</tr>
<tr>
<td>Oil Type</td>
<td>Calories</td>
<td>Polyunsaturated Fat</td>
<td>Monounsaturated Fat</td>
<td>Saturated Fat</td>
<td>Trans Fat</td>
</tr>
<tr>
<td>----------</td>
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<td>--------------</td>
<td>-----------</td>
</tr>
<tr>
<td>Safflower oil</td>
<td>884</td>
<td>7.54</td>
<td>75.22</td>
<td>12.82</td>
<td>0.10</td>
</tr>
<tr>
<td>Canola oil</td>
<td>884</td>
<td>7.36</td>
<td>63.28</td>
<td>28.14</td>
<td>0.40</td>
</tr>
<tr>
<td>Sesame oil</td>
<td>884</td>
<td>14.20</td>
<td>39.70</td>
<td>41.70</td>
<td>--</td>
</tr>
<tr>
<td>Olive oil</td>
<td>884</td>
<td>13.81</td>
<td>72.96</td>
<td>10.52</td>
<td>--</td>
</tr>
<tr>
<td>Palm oil</td>
<td>884</td>
<td>49.30</td>
<td>37.00</td>
<td>9.30</td>
<td>--</td>
</tr>
</tbody>
</table>

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Of the listed only safflower and canola oil contain a negligible quantity of trans fat. However, all are MUFA rich dietary oils.

**Avocado oil**

Avocado oil is obtained from the fruit pulps of *Persea Americana* (Lauraceae). It is mainly grown in temperate regions and sparsely grown in tropical regions of the world. The word avocado originates from the Aztec word *ahuacatl* which is interpreted by the Spaniards as aguacate signifying "testicle" because of its shape. The avocado fruit is rich in supplements, high in proteins, dietary filaments, and ended up being exceedingly favorable for human wellbeing because of its healthy fat composition. It contains high measures of vitamins A, B, C, E along with different supplements like folacin, niacin, iron (Fe), Magnesium (Mg), folate, pantothenic corrosive etc. It also contains 60% more potassium than bananas. This decency of avocado is all around protected in avocado oil and this displays a magnificent option for use of the fruit. It is a rich potential source of monounsaturated fatty acids and also contains some high levels of antioxidants including polyphenols, proanthocyanidins, tocopherols and some carotenoid antioxidants including lutein, antheraxanthin, neoxanthin and violaxanthin of which lutein has been proposed to exert favorable impacts in diabetic retinopathy and vascular illnesses by modulating ROS generation. Chlorophylls and carotenoids (non-lipid components) are also present in the oil. Chlorophylls contributes to the characteristic emerald green color of the oil. Also, it act as the sensitizer for photo-oxidation but does not have any impact on oil stability. Studies in humans and animal models had likewise demonstrated positive outcomes of avocado oil in lessening the risk of diabetes through improvement of diabetic dyslipidemia, normalizing blood cholesterol levels, weight control, and its inclusion in liver metabolism.
Rice bran oil
Rice bran, a brown external layer of the rice kernel is procured as a coproduct amid processing of rice (*Oryza sativa*), and its oil (10-23%) is gaining commercial importance in the world as it has numerous valuable biological and nutritive values due to the rich source of phytoceuticals, for example, oryzanol, lecithin, tocopherols, tocotrienols, phytosterols, ferulic acid and phytic acid. Rice bran oil is unique among edible oils and also a promptly accessible source of natural antioxidants, negligible amounts of water-soluble glucans and larger amounts of insoluble dietary fiber. The vast majority of research has focused on chronic disease prevention and control, whereby the presence of curious components such as g-oryzanol and g-tocotrienol may contribute to the cholesterol lowering effect by increasing fecal neutral sterol and bile acid excretion, by means of upregulating cholesterol synthesis and catabolism. Phytosterols having the comparative chemical structure to cholesterol may interfere with cholesterol movement into micelles and lessen its absorption in the intestines. Researchers suggested that consumption of a rice bran oil diet significantly suppresses the hyperlipidemic and hyperinsulinemic responses to a high-fat diet in diabetic rats possibly due to the increase in LDL-receptor and HMG-CoA reductase mRNA expressions. Rice bran also attenuates hyperglycemia in humans with diabetes mellitus.

Safflower oil
*Carthamus tinctorius*, ordinarily known as safflower belongs to the family Asteraceae. Superb palatable oil of safflower is extracted from its florets rich in polyunsaturated fatty acids (linoleic acid), and is gaining popularity due to its medicinal value. Safflower oil contains around 75% linoleic acid that is essential for human sustenance. Along with, carotene, riboflavin and Vitamin C are also present in the leaves of plant. Conventional safflower seed oil has a fatty acid content made up of palmitic acid (6-8%), stearic acid (2-3%), oleic acid (16-20%), and linoleic acid (71-75%). A previous study showed that the use of safflower oil as a source of PUFA specifically increased the arachidonic acid levels in Sprague-Dawley rats which results in the reduced incidence of diabetic embryopathy. Heega et al. additionally demonstrated in his study that safflower oil supplementation reduced the resorption and malformation rates in maternal diabetes, most likely because of their ability of both regulating arachidonic acid and NO homeostasis in embryos and deciduas which prevent developmental damage during early organogenesis. It might also be valuable for weight loss, glycemic control, or both. *Carthamus tinctorius* had already been evidenced for its antioxidant as well as hypoglycemic effects conceivably intervened through
the potentiation of pancreatic discharge of insulin from β-cell of islets or due to enhanced transport of blood glucose to the peripheral tissue.\cite{45,46}

**Canola oil**

Canola oil, naturally bred from *Brassica napus* (rapeseed) is a bright, yellow-flowering plant belonging to the family Brassicaceae. In 1979, Canada registered the word “canola” to depict a new seed found to be oil, which was low in erucic acid and low in glucosinolates \cite{47} It has now attained the position of third largest consumed vegetable oil in the world after palm and soyabean oil. In the United States, it is the second most consumed vegetable oil next to soyabean oil and has been endorsed for Generally Recognized as Safe (GRAS) status by the U. S. Food and Drug Administration (FDA). Canola oil can be viewed as one of the healthiest consumed vegetable oils with an attractive fatty acid profile distinctively low in saturated fats, and rich in MUFA and n-3 PUFA α-linolenic acid (ALA) \cite{18,48}. It chiefly contains 36% PUFA, 58% MUFA and 6% saturated fatty acid \cite{49}. Also, it is a good dietary source of omega-3, with an existing 3:1 ratio of omega-6 to omega-3 in its composition. \cite{50} Ion Canolol extracted from canola had been proposed for antioxidant activity. \cite{51,52} Uusitupa et al.\cite{35} compared a canola oil-based diet with a high-SFA diet on the human subjects. After an intravenous glucose tolerance test, the results reported lower levels of glucose and steeper glucose disappearance rates in subjects on canola oil-based diet \cite{53} It was also reported by He et al. that canola oil influenced the azoxymethane induced hyperglycemia in kunning mice by reducing the blood glucose levels. The possible mechanism was diminished hepatic insulin extraction or increased C-peptide clearance \cite{49} A randomized, controlled study carried out in 48 male and female patients with type 2 diabetes also mentioned that canola oil (high MUFA diet) realized a noteworthy decrease in fasting plasma glucose as well as increase in HDL-cholesterol and insulin sensitivity.\cite{54} It was also depicted in a study, performed on weight-stable hyperlipidaemic subjects, that replacing SFA from high-fat dairy foods with unsaturated fats from canola oil for 3 weeks resulted in clinically pertinent beneficial impacts on the serum lipid profile. It might also improve insulin sensitivity and glucose tolerance.\cite{55}

**Sesame oil**

Sesame oil is an edible vegetable oil derived from sesame (*Sesamum indicum*) seeds, member of family Pedaliaceae.\cite{56} It grows in both tropical and subtropical countries. India and China are the major producers accounting for 70% of world production. It is a good source of omega-6.\cite{57} Advantageously sesame oil possesses fiber, vitamin E, tocopherols and bioactive
lignans including sesamin, sesamolin, sesamol and sesaminol. It also exhibit potent antioxidant effect due to the presence of sesamol.\textsuperscript{[56]} in seeds. Sesamin, one of the major lignans in sesame seed and oil, along with its isomers have beneficial physiological effects. It acts as antioxidant, anti-carcinogen, anti-hypertensive and is capable of reducing serum lipids.\textsuperscript{[58]} Many pharmacological studies on \textit{Sesamum indicum} seed had reported its role as hypoglycemic agent in genetically inherited diabetes. Also, it has antitumor and antihypertensive effect along with antiestrogenic activity. The plant also depicts therapeutic benefits in the Parkinsonism disease, and is also influential in increasing the vitamin E concentration.\textsuperscript{[59]} The prevailing fatty acids in sesame oil include oleic acid (43\%), linoleic acid (35\%), palitic (11\%), and stearic (7\%) acid.\textsuperscript{[60, 61]} Phytochemically, the plant consisted of phenolic compounds (Phenols, Sterols, Flavonoids and lignans), non-protein amino acids, cyanogenic glucoside, alkaloids, unsaturated fats, lipids, glazes, phospholipids and vitamin E, B1 and B2. Minerals or trace elements such as calcium, iron, magnesium, zinc, copper and phosphorus also exist in the plant.\textsuperscript{[62]} Despite of its high PUFA/SFA ratio, it is least prone to rancidity.\textsuperscript{[63]} Clinical and preclinical studies on the oil support its favorable effects on lipid profiles, and chronic diseases including cardiovascular and diabetes. Pharmacologically, sesame seeds had already been accounted for its antihyperglycemic property in streptozotocin induced diabetic rats.\textsuperscript{[64]} In an open label, pilot study on mild to moderate hypertensive diabetic subjects, researchers indicated an additive effect of sesame oil, in lowering blood pressure and plasma glucose of subjects, when given with atenolol and glibenclamide.\textsuperscript{[65]} Further, one more study on type 2 diabetic patients reported synergistic effect of oil on hyperglycemia, when treated in combination with glibenclamide as compared with their monotherapies.\textsuperscript{[66]} Sesame oil consumption influences beneficially the blood glucose, insulin sensitivity, glycosylated hemoglobin, lipid profiles, lipid peroxidation, and antioxidant levels in diabetic rats.\textsuperscript{[67-69]}

\textbf{Olive oil}

Olive oil, a product of the mechanical extraction from the fruit of \textit{Olea europaea} L. (Oleaceae).\textsuperscript{[70]} is considered as the mainstay of the Mediterranean diet since it has been traditionally used in hypertonia, arteriosclerosis, rheumatism, gout, diabetes mellitus, and fever.\textsuperscript{[71, 72]} Furthermore, it had also been found to improve the major risk factors such as the lipoprotein profile, blood pressure and glucose metabolism.\textsuperscript{[73]} For its production, olives are crushed to create a pomace, which is further homogenized and pressed subsequently to produce oil. The first oil extracted is of high quality extra virgin olive oil and is produced
using centrifugation and water only. The pomace can be processed again to yield the lower quality refined virgin olive oil. It is composed of a glycerol portion (making up to 90–99%) and a non-glycerol or unsaponifiable part (making up to 0.4–5%) which contains phenolic compounds like vanillic, gallic, coumaric and caffeic acids, tyrosol and hydroxytyrosol and more complex compounds like the secoiridoids (oleuropein and ligstroside), and the lignans (1-acetoxypiosiresinol and pinoresinol). The glycerol portion of oil mainly credited to its beneficial effects on health with its high concentration of monounsaturated fatty acids (MUFAs) (especially oleic acid). It had been evidenced that oleuropein, a secoiridoid inferred from olive oil possesses high antioxidant activity and have positive impacts on serum glucose, haemoglobin A1c, lipid profile when tested on diabetic rats. The mechanism, behind these activities, might be due to the potentiation of glucose induced insulin release, increase in the peripheral uptake of glucose and attenuation of oxidative stress. Oleuropein, present in oil inhibits low-density lipoproteins (LDL) oxidation in vitro and lipid peroxidation in vivo. It also scavenges free radicals, hypochlorous acid-derived radicals, hydroxyl radicals and superoxide anions. A randomized study conducted on type 2 diabetic patients reported a significant improvement in hyperlipidemia and blood glucose after receiving olive oil for four weeks. High content of monounsaturated oleic acid makes olive oil less susceptible to oxidation and contributes to its antioxidant action, high stability, and long shelf life (long timeframe of realistic usability). Leaf extract of olive had demonstrated improvement in beta cell viability and protection against cell death after cytokine exposure through suppression of caspase 3/7 activity, prevention of insulin secretion, and reduction in production of reactive oxygen species. It has also been proposed that olive leaf extract potentiates glucose-induced insulin release and increases peripheral glucose uptake.

**Palm oil**

Palm oil is the most widely produced eatable oil derived from the flesh and kernels of the *Elaeis guineensis* L. (palm fruit). Palm oil has eminent oxidation stability and good plasticity at room temperature and it is currently enjoying strong appeal worldwide as a cooking aid in light of the fact of being free of artery-clogging trans-fats. It is the largest natural source of tocotrienol and is additionally high in vitamin K and dietary magnesium content. It also contains light measures of squalene (possible cholesterol lowering and anti-cancer properties), ubiquinone (energy booster) and Carotenoids. Tocotrienol-rich fraction (TRF) of palm oil consisting mainly of tocotrienol (a form of vitamin E) and tocopherol, has
efficient biological properties. It act as potent antioxidant 34 - 36 serving to protect cellular membrane from destruction caused by free radicals catalysed lipid peroxidation. Budin et al. had reported reduction in oxidative stress and pancreatic damage after TRF supplementation for 28 days in streptozotocin as well as in fenitrothion induced diabetic rats. Budin et al. had reported reduction in oxidative stress and pancreatic damage after TRF supplementation for 28 days in streptozotocin as well as in fenitrothion induced diabetic rats. Daily oral supplementation of TRF (200 mg/kg) showed beneficial effects in preventing oxidative damage in diabetes by inhibition of lipid peroxidation and increase in the levels of antioxidant defense system as demonstrated through a significant increase in the SOD activity, and the GSH levels in diabetic rats. Moreover, an alternate study manifested that TRF has capability to prevent the progression of vascular wall changes occurring in diabetes mellitus including hypoglycemic, hypolipidemic and antioxidative effects. These all might be associated with the anticipating prevention of developmental abnormalities in the thoracic aortas of diabetic rats.

In a comparative study on the hypoglycemic and nephroprotective activity of TRF rich fraction obtained from palm oil and rice bran oil in type 1 diabetic rats, palm oil-TRF was found to be more effective. Tan et al. suggested that significant antihyperglycaemic, tissue protective effect of palm leaves was presumably because of its flavonoids contents.

CONCLUSION

Human body requires proper type of fat in adequate amount to function properly. All fats are not bad. The key towards good health is in selecting the healthiest choice for fats. In the quest to reduce fat consumption in present scenario, majority of peoples are unintentionally avoiding the essential fatty acids (EFAs).

The content of fatty acids as well as the ratio between unsaturated and saturated fatty acids is important parameter for determination of nutritional value of certain oil. Saturated fatty acids (SFA), especially trans fat increases low-density lipoprotein (LDL) cholesterol in the blood. Polyunsaturated fatty acids (PUFAs) and monounsaturated fatty acids (MUFAs) reduce LDL cholesterol and increase high-density lipoprotein (HDL) cholesterol, subsequently reducing the risk of type II diabetes at appreciable level. Studies have shown that it is not just a single fat which effects, but a combination of various fats having fatty acid compositions and additional minor components like tocotrienols, tocopherols, oryzanol, phytosterols and a good balance of SFA, MUFA and PUFA that will bring about favorable serum lipid profiles which helps safeguarding the people suffering from diabetes. A important factor to be consider here is the affordability and availability of fats and oils which determine their usage.
in various regions within the countries. For instance, because of the high cost of olive oil, it is used sparingly, while mustard, sunflower, and soybean oils are used widely because of their low cost. Therefore, in developing countries more aggressive public health awareness programs coupled with governmental action and clear country-specific guidelines to promote widespread use of healthy oils are required. Finally, further research into is warranted focusing on head-to-head comparison of various oils regarding effects on diabetes, more clearly identifying the specific properties of specific oils, as well as the possibilities for synergistic interactions not only between the various oils themselves but also between the oils and orthodox anti-diabetic medications.

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