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Study of fatty acid composition of fruit seed oils

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Abstract
All oils and fats are 100% fat. However, the components that make up that fat structure of each oil are important in determining whether or not the oil or fat is considered healthy. It is a myth to believe that consuming fat makes you fat. A fat are necessary to provide a concentrated source of energy and is necessary to make up a healthy diet. All oils are high in calories (about 120 per tablespoon) and therefore should be consumed in moderation. Cold-pressed or expeller-pressed oils are recommended to insure maximum purity, flavor, and nutrition. Seed oils containing only small amounts of beneficial fatty acids but significant quantities of other valuable components (natural antioxidants) are also included.

Keywords: oleic acids, linoleic acids, α-linolenic acids, and γ -linolenic acids

1. Introduction

Edible seed oils are important common food ingredients. Fatty acids are primary nutritional components found in edible seed oils. Growing evidence has suggested that individual fatty acids may play different roles in human health. Diets rich in a specific fatty acid may provide potential prevention of a number of health problems or diseases. For instance, ω_3 (n-3) unsaturated fatty acids may have health benefits including the prevention of cancer, heart disease, hypertension, and autoimmune disorders. Currently, consumer's growing interest in improving their dietary nutrition is driving the development of novel seed oils having unique fatty acid profiles and other beneficial components, including phytosterols and natural antioxidants. It is the purpose of this chapter to summarize the edible fruit, spice, or herb seed oils with unique fatty acid profiles. Physicochemical properties and other beneficial components of these oils, such as phytosterols and tocopherols, may also be included. The seed oils are presented according to their primary or distinguishing fatty acid (s), including oleic, linoleic, α-linolenic, and γ-linolenic acids.

2. Edible Seed Oils Rich In A -Linolenic Acid

Alpha-linolenic acid (18:3n-3) is an 18-carbon fatty acid with three double bonds at carbons 9, 12, and 15. It is an essential n-3 fatty acid that is a required nutrient for human beings and can be obtained through diets including both plant and animal sources. Alpha-linolenic acid can be converted by elongases and desaturases to other beneficial n-3 fatty acids, such as eicosapentaenoic acid (EPA) and docosa-hexaenoic acid (DHA), which are implicated in normal brain development, normal vision, and a decreased risk of heart disease. Novel dietary sources of n-3 fatty acids are desired for those who do not consume adequate amounts of fish or fish-based food products rich in long-chain n-3 fatty acids. This section summarized fruit, spice, and herb seed oils rich in α-linolenic acid (18:3n-3). These include black raspberry, red raspberry, boysenberry, marionberry, blueberry, cranberry, sea buckthorn, basil, and hemp seed oils.

2.1 Black Raspberry Seed Oil (*Rubus occidentalis* L., cv Jewel)

Black raspberry is a member of the genus Rubus from the *Rosacea* family, which is also known as caneberries. The majority of black raspberry crops are located in the Northwest region of the United States, predominantly in Oregon. The annual harvests for black raspberries in Oregon in 2002 and 2003 were 3.02 million pounds and 2.70 million pounds, respectively.

The fatty acid profile of two cold-pressed black raspberry seed oils demonstrated high concentrations of both n-3 and total unsaturated fatty acids. The concentration of a-linolenic acid (18:3n-3) was 35% of total fats, and unsaturated fatty acids comprised 98–99% (Table 1). Linoleic acid was the predominant fatty acid (Table 1); however, the ratios of n-6 to n-3 fatty acids were very low at 1.6:1. The other measurable fatty acids included oleic (18:1n-9) and palmitic (16:0) acids (Table 1). The overall fatty acid composition of black raspberry seed oil was very similar to red raspberry seed oil (Table 1).

2.2 Red Raspberry Seed Oil (Rubus *ideaus*)

Red Raspberry is a production crop grown throughout the world, and the total worldwide annual production is typically around 250,000 metric tons. The majority of commercial raspberries are grown in Eastern Europe, followed by Northern and Western Europe, the United States, and Chile. Like black raspberries, red raspberries are also grown in the Northwest region of the United States, and total production in the years 2002 and 2003 was 42.2 metric tons (MT) and 38 MT, respectively.

Red raspberry seed oils, extracted by either hexane or cold-pressing, were examined for their fatty acid compositions.

Both methods detected very similar fatty acid profiles and high concentrations of α-linolenic acid, an n-3 fatty acid (Table 1). The crude oil from the hexane extract contained 29.1% α-linolenic acid and the extra virgin cold-pressed seed oil had 32.4% a-linolenic acid. Both of these samples were also very comparable in their fatty acid compositions compared with the black raspberry seed oil discussed above (Table 1). In addition to its a-linolenic acid content, red raspberry seed oil may contain a significant level of tocopherols and other natural antioxidants. Total tocopherol was 97-mg/100-g oil and 61-mg/100-g oil in the hexane-extracted and the cold-pressed oils, respectively, whereas the antioxidant activity, measured as the oxygen radical absorbing capacity (ORAC), was 48.8-µmmoles trolox equivalents per gram of oil. Trolox, 6-hydroxy-2, 5, 7, 8-tetramethylchroman-2-carboxylic acid, is a water-soluble analog of α-tocopherol and widely used as a standard antioxidant compound.

Table 1: Fatty Acid Compositions (g Fatty Acid/100-g Oil) of Fruit Seed Oils Relatively High in a-Linolenic Acid (18:3n-3).*

Fatty Acid	Black Raspberry	Red Raspberry	Boysenberry	Marionberry	Blueberry	Cranberry
16:0	1.2-1.6	1.2-2.7	4.2	3.3	5.7	3.0-7.8
18:0	Trace	1.0	4.5	3.1	2.8	0.2-1.9
18:1	6.2-7.7	12.0-12.4	17.9	15.1	22.8	20.0-27.8
18:2n-6	55.9-57.9	53.0-54.5	53.8	62.8	43.5	35.0-44.31
18:3n-3	35.2-35.3	29.1-32.4	19.5	15.7	25.1	22.3-35.0
Other	nd	nd	nd	nd	nd	2.58
n-6/n-3	1.59-1.63	1.64-1.87	2.75	3.99	1.73	1.16-2.0

*Black raspberry, Red raspberry, Boysenberry, Marionberry, Blueberry, Cranberry, Buckthorn sinesis, Buckthorn rhamnoides, and Buckthorn mongolica, stand for black raspberry, red raspberry, boysenberry, marionberry, blueberry, cranberry. Numbers correspond to the references cited. ‘‘nd’’ stands for not detected.

2.3 Boysenberry Seed Oil (Rubus hybrid)

Like the other caneberries (black raspberry, red raspberry, marionberry), boysenberry also prefers the growing conditions found in the Northwest region of the United States. However, aside from Oregon, boysenberry is also grown in Northern California as a production crop. In 2002 and 2003, the total boysenberry production in the United States was 2665 tons and 2350 tons, respectively.

Also, like the other cold-pressed caneberry seed oils, boysenberry seed oil had a high percentage (19.5%) of n-3 a-linolenic acid and a low n-6 to n-3 ratio of 2.8:1.

Total unsaturated fatty acids constituted over 91% of the seed oil and polyunsaturated fatty acids (PUFA) were very high at 73.3%, but stearic, palmitic, and total saturated fatty acids were higher than all other caneberry seed oils (Table 1). Interestingly, the boysenberry seed oil demonstrated the best antioxidative potential using the oxygen radical scavenging capacity (ORAC) test compared with eight other seed oil samples, including blueberry, black raspberry, and red raspberry seed oils, which are known to be rich in antioxidants.

2.4 Marionberry (Rubus hybrid) Seed Oil

Marionberry is a blackberry hybrid. It is another member of the caneberry family and is also grown in the Northwest United States, specifically in Oregon. The production in 2002 was 15,000 MT and in 2003 it was 12,910 MT. Marionberry comprises almost one-half of the total caneberry production in Oregon.

In 2004, Parry *et al*. examined the chemical composition and physico-chemical properties of cold-pressed marionberry seed oil. The oil was shown to contain a relatively high percentage of n-3 fatty acids in the form of a-linolenic acid (15.7%) (Table 1). This amount was lower than that of other caneberry seed oils, including black raspberry, red raspberry, and boysenberry seed oils, tested under the same conditions. The n-6 to n-3 fatty acid ratio was 4:1, which was the highest among the tested caneberry group.

2.5 Blueberry Seed Oil (Vaccinium corymbosum)

Blueberries are grown in temperate climates throughout the world; however, the largest producers are the United States and Canada. Approximately 42,000 MT are produced annually outside of the United States and Canada. In 2002 and 2003, the United States harvested 87.3 MT and 86.200 MT, respectively. The cold-pressed blueberry seed oil investigated by Parry and Yu. demonstrated a high concentration of n-3 fatty acids. Alpha linolenic acid was the sole source of the n-3 and comprised 25.1% of the total fatty acids (Table 1). The ratio of n-6 to n-3 fatty acids was 1.7:1. Linoleic acid (18:2n-6) was the most prevalent fatty acid in the blueberry seed oil followed by α-linolenic, oleic, palmitic (16:0), and stearic (18:0) acids (Table 1). The blueberry seed oil also showed a significantly higher antioxidant capacity compared with marionberry, black raspberry, cranberry, and pumpkin seed oils using the oxygen radical absorbance capacity (ORAC) test. Therefore, blueberry seed oil may serve as an excellent dietary source of n-3 fatty acids and natural antioxidants.

2.6 Cranberry (Vaccinum macrocarpon) Seed Oil

The North American cranberry, Vaccinum macrocarpon, is best adapted to grow at higher latitudes and in bog terrains. It is grown for production in Wisconsin, Maine, New Jersey, Oregon, and Washington in the United States, and British Columbia and Quebec in Canada. Cranberries are also grown in Europe, but are a different species of Vaccinum. The total production in the United States for the year 2002 was 284,200 tons and was projected to be 291,500 tons in 2003.

Several studies have confirmed that the seed oil from the North American variety of cranberry contains significant levels of α-linolenic acid. In a U.S. patent, Heeg *et al*. reported the α-linolenic acid content of cranberry seed oil to be between 30% and 35% of total fatty acids. In 2003, Parker *et al*. found 22.3% α-linolenic acid in the cold-pressed cranberry seed oil, and in 2004, Parry *et al*. determined the oil to contain 32.0% α-linolenic acid from two different lots of the seed oil. The ratios of n-6 to n-3 fatty acids in all were low from 1.2:1 to 2:1. Also, all of the studies documented similar ratios among the rest of the common fatty acids found in cranberry seed oil, including, in order of higher amount present: linoleic, oleic, palmitic, stearic, and eicosadienoic (20:2) acids (Table 1). In addition to α-linolenic acid, cranberry seed oil is rich in natural antioxidants. These antioxidants may directly react with free radicals and prevent lipid oxidation in human low-density lipoprotein.

3. Edible Seed Oils Rich in Linoleic Acid (18:2n6)

Linoleic acid (18:2n-6) is an essential fatty acid that must be obtained through diets. In this section, fruit, spice, and herb seed oils rich in linoleic acids are summarized. These seed oils include watermelon, melon (Cucumis melo and Colocynthis citrullus), *goldenberry*, grape, rose fruit, paprika, red pepper, onion, black cumin, and *Onagraceae* seed oils. Several seed oils may be listed in other sections if they contain significant level of a special fatty acid. For example, pumpkin seed oils rich in both oleic acid and linoleic acid, are listed under the section named, ‘‘Edible seed oils rich in oleic acid (18:1n-9).’’

3.1 Watermelon (Citrullus vulgaris) Seed Oil

Watermelon (Citrullus vulgaris) is taxonomically classified as a member of the Cur-cubitaceae family, which is also known as the gourd family. Other gourds include pumpkins, cucumbers, squash, and other melons. It prefers warm climate growing conditions and is produced worldwide where conditions permit.

Watermelon seed oil was prepared and evaluated for its physicochemical properties. The seed oil consisted of 59.6% linoleic acid (18:2n-6) and 78.4% total unsaturated fatty acids (Table 4). The predominant fatty acid in the oil was linoleic acid, which was followed by oleic, palmitic, and stearic acids. Linolenic, palmitoleic, and myristic acids were minor constituents. The refractive index, acid value, peroxide value, and free fatty acids of watermelon seed oil were determined to be 1.4696 (25 C), 2.82 (mg KOH/g oil), 3.40 (mequiv oxygen/kg oil), and 1.41 (% as oleic acid), respectively. The saponification value of watermelon seed oil was 201 (mg KOH/g oil), and its iodine value was 115 (g iodine/100-g oil), which was significantly higher than pumpkin at 109 (g iodine/100-g oil).

3.2 Melon (Cucumis melo) Seed Oil

Melon, Cucumis melo, is a member of the Cucurbitaceae family and grows best in tropical regions. The pulp of the fruit has pleasant flavor and taste, and the seeds are generally treated as waste; however, medicinal effects have been reported for the seeds. Hexane-extracted seed oil of Cucumis melo hybrid AF-522 was determined to contain 64 g of linoleic acid per 100 g of total fatty acids (Table 4). Significant amounts of oleic, palmitic, and stearic acids were also detected in the melon seed oil. The specific gravity (28 C), refractive index (28 C), and iodine value of the seed oil were 0.9000, 1.4820, and 112, respectively, under the experimental conditions. Earlier in 1986, Lazos extracted the oil from Cucumis melo seeds and examined its physicochemical properties. Linoleic acid was the primary fatty acid and accounted for 64.6% of the total fat (w/w), along with 20.1% oleic acid, and 14.7% total saturated fatty acids (Table 4). Iodine value and refractive index of the seed oil were 124.5 and 1.4662, respectively.

3.3 Melon (*Colocynthis citrullus* L.) Seed Oil

Colocynthis citrullus L (melon) is a tropical vine that is native to West Africa. The flesh from the fruit of this melon is bitter and inedible; the edible part of the fruit is the seed. Nwokolo and Sim examined the fatty acid composition of Colocynthis citrullus seed oil and found that it contained a relatively high percentage of linoleic acid that accounted for 57.7% of total fatty acids (Table 2). Oleic acid was the second major fatty acid (14.5%). The seed oil contained about 25.3% saturated fatty acids (Table 4). Moussata and Akoh also reported a similar fatty acid profile of Colocynthis citrullus L. seed oil. The primary fatty acid was linoleic acid, contributing 65.4% of total fats. The other significant fatty acids included oleic (13.5%), palmitic (12.1%), and stearic (9.0%) acids (Table 3).

Table 2: Fatty Acid Composition (g Fatty Acid/100-g Oil) of Fruit Seed Oils Relatively High in Linoleic Acid.*

Fatty Acid	Watermelon	Melon (cucumis melo)	Melon (*colocynthis citrullus* L.)	*Goldenberry*	Grape
16:0	11.3	9.0-9.5	11.8-12.1	7.3	5.8-14.2
18:0	10.2	4.9-5.6	9.0-10.7	2.5	≤8.6
18:1	18.1	19.4-20.1	13.5-14.5	11.7	13.7-31.9
18:2n-6	59.6	64.1-64.6	57.7-65.4	76.4	50.1-77.8
18:3n-3	0.4	0.2-0.3	≤2.1	0.3	≤5.0
Total saturated	21.5	14.7-15.2	21.1-25.3	11.9	8.4-14.4
Total unsaturated	78.4	84.4-85.1	74.6-77.5	88.1	85.5-91.5

* Watermelon, Melon (Cucumis melo), Melon (Colocynthis citrullus L.), *Goldenberry*, Grape, Rose, and Paprika stand for Watermelon, Melon (Cucumis melo), Melon (Colocynthis citrullus L.), *goldenberry*, grape, rose, and paprika seed oil, respectively. Numbers correspond to the references cited. ‘‘nd’’ stands for not detected.

3.4 *Goldenberry* (*Physalis peruviana L.*) Seed Oil

Goldenberry, (*Physalis peruviana L.*), also known as cape gooseberry, is a perennial native to the Andes. It is also cultivated in the United States, South Africa, East Africa, India, New Zealand, Australia, and Great Britain. It is related to both tomatoes and chile peppers and prefers growing in well-draining soils like tomatoes. *Goldenberry* has a pleasant flavor that is similar to tomatoes and is eaten in many ways, including in salads, cooked dishes, chocolate covered desserts, jams, preserves, and natural snacks. The fruit is an excellent source of Vitamins A and C as well as minerals. *Goldenberry* seed oil was prepared by extracting lyophi-lized ground seed meal with chloroform-methanol and was characterized for fatty acid composition. The fatty acid composition of the seed oil is shown in Table 4. Linoleic acid was the predominant fatty acid and constituted 76.1% of total fat. Combined monounsaturated fatty acids were 12.2%, linolenic acid was 0.33%, and total polyunsaturated fatty acids were 76.1%. These data suggest that *goldenberry* seed oil may serve as an excellent dietary source for linoleic acid, the essential n-6 fatty acid, and may be a good choice for consumers seeking a greater intake of total unsaturated fatty acids.

The fat-soluble Vitamins E and K, carotene, and phytosterols were also detected in the *goldenberry* seed oil. Total tocopherols were 29.7 mg/g oil, including 0.9-mg α-, 11.3-mg β-, 9.1-mg γ-, and 8.4-mg δ-tocopherols. The total Vitamin K content was 0.12-mg/g oil, and the β-carotene concentration was 1.30-mg/g oil. In addition, significant levels of phytosterols were also detected. The major phytosterol in the *goldenberry* seed oil was campesterol, having a concentration of 6.5-mg/g oil. Other phytosterols, including ergosterol, stigmasterol, lanosterol, β-sitosterol, Δ5-avenosterol, and Δ7-avenosterol, were also detected in the seed oil.

3.5 Grape Seed Oil (Vitis spp.)

Grape seeds are byproducts from the manufacturing of grape juice, jam, jelly, and wine. In 1998, Abou Rayan *et al*. investigated the characteristics and composition of Egyptian-grown Cabarina red grape seed oil. Crude grape seed oil was extracted with hexane at room temperature. Linoleic acid was the major fatty acid detected and comprised more than 50% of the total fatty acids (Table 2). Oleic acid was the second major fatty acid in the seed oil, along with significant levels of palmitic and stearic acids. This finding is consistent with a previous observation in which linoleic acid accounted for 62% of the total fatty acids in grape seed oil (Table 2). Iodine value (IV) and peroxide value (PV) were also determined according to the methods described in AOCS, 1983. The measured IV was 130-g iodine/100-g oil, and the PV was determined to be 2.92-mequiv peroxide/kg oil.

3.6 Apple Seed Oil

Apple seeds are a byproduct of processing. In 1971, Morice *et al*. investigated the seed oils from three different varieties of apples: Granny Smith, *Sturmer*, and Dougherty, and compared them with the seed oils prepared from other apple varieties. The results showed similarities in the fatty acid profiles among the varieties (Table 3). Oleic and linoleic acids consisted of 85–95% of the total fatty acids in all tested samples. The investigators also examined other physicochemical properties of apple seed oils. The Granny Smith apple seed oil had an iodine value of 127-g iodine/100-g oil; the *Sturmer* had an IV of 122.4-g iodine/100-g oil, and the Dougherty's IV was 119-g iodine/ 100-g oil. Apple seed oils may be useful as a dietary source for linoleic and oleic acids.

Table 3: Fatty Acid Composition (g/100-g Fatty Acids) of Apple Seed Oils.*

Fatty Acid	Granny Smith	*Sturmer*	Dougherty	Golden Delicious
16:0	6.8-7.1	4.8-6.4	5.7-6.8	8.5
16:1	0.1-0.2	0.1	0.1-0.2	0.5
18:0	1.0-2.1	1.5-2.5	1.3-2.1	Nd
18:1	24.4-27.4	32.8-36.6	34.6-42.1	31
18:2	62.1-64.1	52.1-58.3	48.2-56.1	59
18:3	0.2-0.4	≤0.5	≤0.6	0.5
20:0	0.6-1.1	0.7-1.7	0.6-0.9	0.5
20:1	0.2-0.3	0.2-0.4	0.2-0.3	nd
20:2	0.1-0.7	0.1-0.7	0.0-0.3	nd
22:0	0.1-0.2	0.1-0.3	0.1	trace

*Granny Smith, *Sturmer*, Dougherty, and Golden Delicious stand for seed oil of four varieties of apple. Numbers correspond to the references cited. ''nd'' stands for not detected.

4. Edible Seed Oils Rich in Oleic Acid (18:1n-9)

Oleic acid is an n-9 monounsaturated fatty acid (MUFA). Growing evidence suggests that diets rich in oleic acid may serve as an alternative choice to a low-fat blood cholesterol reducing diet, modulate immune function, and may delay the development of atherosclerosis. Oleic acid is the predominant fatty acid in olive, canola, peanut, and specially produced sunflower seed oils. Oleic acid is not an essential fatty acid; it is synthesized in vivo through the desaturation of stearic acid (18:0). Oleic acid is also rich in a number of other edible oils, including mango, cherry, date, pumpkin, naked seed squash, fluted pumpkin, carob bean germ, American gingseng, Khaya senegalensis, and Moringa oleifera seed oils.

4.1 Mango Seed Kernel Oil

Mango seed kernels contain about 4–12% total fat. Mango seed kernel oil is rich in oleic acid (Table 4), and exhibited 42%, 34–59%, and 41–44% of total fatty acids. Stearic acid is the other major fatty acid in mango seed kernel oil and may account for up to 57% of the total fat. In addition, palmitic and linoleic acids were detected in the oil along with trace amounts of a-linolenic acid.

Table 4: Fatty Acid Composition (g/100-g Fatty Acids) of Fruit Seed Oils Rich in Oleic Acid.*

Fatty Acid	Mango	Cherry	Date
12:0	nd	nd	16.9-17.8
14:0	nd	nd	10.8-12.1
16:0	6-18	6.8-9.4	10.2-10.4
16.1	nd	0.4-0.6	0.2
18:0	26-57	1.6-2.1	2.8-2.8
18:1	34-59	23.9-37.5	43.5-45.0
18.2n-6	1-13	40.0-48.9	8.7-8.2
18:3n-3	nd	<1	0.6
20:0	<4	<1.3	0.5-0.6
Other FA	nd	10.3-13.3	3.6-4.1

*Mango, Cherry, Date, and Fluted pumpkin stand for mango, cherry, date, and fluted pumpkin seed oil, respectively. Carob bean germ stands for carob bean germ oil. Numbers correspond to the references cited. ‘‘nd’’ stands for not detected.

4.2 Cherry Seed Oil

The cherry tree (*Prunus avium* L.) is a member of the Rosaceae family. Cherry seed contains about 18% oil on a dry weight basis. Significant levels of oleic acid were detected in the cherry seed oils prepared by hexane extraction using a Soxhlet apparatus. Oleic acid comprised 24–38% of the total fatty acids from three different varieties of cherry fruits (Table 7). Linoleic acid was the major fatty acid in the cherry seed oil, and ranged 40–49% in the seed oil, along with a-eleostearic (18:n-5), palmitic, stearic, arachidonic, and a-linolenic acids (Table 4). Alpha-eleostearic acid ($\Delta^{9c,11t,13t}$), comprising 10–13% of cherry seed oil, is a conjugated isomer of a-linolenic acid ($\Delta^{9c,12c,15c}$). Alpha-eleostearic acid was not detected in other previously studied seed oils from prunoids including peach, apricot, and plum seed oils.

4.3 Date Seed Oil

Dates (*Phoenix dactylifera* L.) are popular in most Middle Eastern countries and serve as a major source of food and nutrients. Oil contents and fatty acid profiles of date seeds may vary among individual varieties. Date seeds contained 20–24% total fat. Oleic acid was the primary fatty acid in the date seed oil and had a concentration of 43.5–45% of total fatty acids. This was followed by lauric (12:0), myristic (14:0), palmitic (16:0), linoleic (18:2n6), capric (10:0), and stearic (18:0) acids along with trace amounts of other fatty acids (Table 4). Date seed oil may serve as an excellent dietary source of oleic acid with a minor amount of linoleic acid.

5. Summary

There is an increasing demand for edible oils with special fatty acid profiles and other beneficial components for improving nutritional status. A number of studies have been conducted to screen for and evaluate the chemical composition and potential nutraceutical applications of fruit, spice, and herb seed oils. Among the discussed edible seed oils, some have unique fatty acid compositions, such as black raspberry and hemp seed oils rich in α-linolenic acid and date and naked seed squash seed oils rich in oleic acid, whereas blackcurrant seed oil is rich in γ -linolenic acid. The oils of selected fruit, spice, and herb seeds may also contain significant levels of phytosterols, tocopherols, carotenoids, and natural antioxidants.

The chemical composition of edible seed oil determines the potential health benefit and applications for the oil. Individual edible seed oils may be preferred by special groups of consumers for preventing and treating a selected health problem or for general health promotion. Great opportunities are available in the research and development of specialty seed oils and the oil-based nutraceutical products from fruit, spice, and herb seeds for improving human health. More research is required to screen and characterize the fatty acids and bioactive components in the fruit, spice, and herb seeds to develop novel edible seed oils for optimum human nutrition.

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