bitter almond (*P. dulcis variety amara*) and sweet almond (*P. dulcis variety dulcis*). Bitter almond contains amygdalin, which is a poisonous compound and breaks down to prussic acid. Oils intended for human use is prepared from sweet almonds. Unrefined oils, especially oils produced by pressing, usually contain peptides and proteins that may cause allergenic reactions.

Nut oils are used as salad oil, cooking oil and in other food applications. Non-edible applications of nut oils include massage oils, lubricant, emollients in pharmaceuticals, cosmetics, soaps, shampoos, hair conditioning/repair products and skin lotions.

Sesame Seed Oil

The sesame plant, *Sesamum* ssp., grows in tropical and subtropical climates. According to the literature, sesame oil was one of the first oils known and consumed by humans. It was referred to as "queen of oilseeds." Sesame seeds contain about 50 percent oil and 20 to 25 percent protein.

Physical, chemical and organoleptic attributes of sesame oil vary depending on the processing conditions. Hexane extracted crude oil is refined to produce different grades of oil. Final products usually have light color and bland flavor and taste. Mechanically cold pressed oil is considered superior to hexane extracted oil. Sometimes, sesame seeds are roasted at 180-220 degrees Celsius prior to oil extraction. Oil extracted from roasted seeds is red colored and has very high oxidative stability, which is attributed to the Maillard reaction (occurs between sugar and protein molecules) products formed during heat treatment. Palmitic (7 to 12 percent), stearic (3 to 6 percent), oleic (35 to 50 percent) and linoleic (35 to 50 percent) acids are the major fatty acids in sesame seed oil.

Sesame oil is unique because it contains lignans, sesamin and sesamolin. There are a number of scientific studies indicating that sesame oil and sesame lignans may inhibit cholesterol biosynthesis exerting significant health benefits.

Sesame oil is used in a number of applications including edible and non-edible product formulations including solvents for intramuscular injection, drugs, perfumes, cosmetics, creams, lubricants, insecticides and fungicides.

Wheat Germ Oil

Wheat germ oil (WGO) is a specialty product with very high nutritional value. It is rich in health beneficial bioactive compounds such as phytosterols, tocopherols, carotenoids and omega-3 fatty acids.

Hexane-extracted WGO consists of about 56 percent linoleic acid. Total unsaturated and PUFA contents of WGO are about 81 and 64 percent, respectively. It has been well documented that unsaturated fatty acids, especially PUFA intake reduces coronary heart disease (CHD). Several scientific studies have shown that omega-3 fatty acids have health benefits such as lowering CHD risk (see fact sheet FAPC-135). It has been suggested an omega-6/omega-3 ratio of 10 or less results in a reduction in fatal CHD risk. The omega-6/omega-3 recommendations of the World Health Organization, Sweden and Japan are 5-10/1, 5/1 and 2/1, respectively. WGO has very high unsaturated and polyunsaturated fatty acid content and an excellent omega-6/omega-3 fatty acid ratio (9/1). A high concentration of PUFA is a positive attribute in the functional foods and nutraceutical market. However, a high content of linolenic acid makes the oil susceptible to oxidative rancidity.

Wheat germ oil is one of the richest natural sources of alpha-tocopherols, natural vitamin E, which is a fat-soluble vitamin. Natural vitamin E has about two times higher bioavailability than synthetic vitamin E. Policosanol are a group of high molecular weight primary fatty alcohols present in many plants. WGO contains a significantly higher amount of phytosterols (plant sterols) and policosanols than the other common commercial oils. Both policosanols and phytosterols are reported to have cholesterol lowering properties.

Applications of WGO range from cosmetics, toiletries, pharmaceuticals, health foods to dietary supplements. WGO is marketed as a dietary supplement in bottles or in capsules. WGO is also used as an antioxidant in various fats and oils. There have been reports that many trainers recommend WGO as a dietary supplement for athletes to enhance endurance and physical fitness. This effect has been attributed to WGO components called policosanols. Feed applications of WGO include diet supplements for farm animals, racehorses, pets and mink.

WGO is also a potent insect attractant and used for insect control. It has been shown that the volatile components of WGO are responsible for aggregation activity of Trogoderma glabrum larvae, which is a stored product pest. Medium-chain (C13-C16) saturated and unsaturated hydrocarbons, branched hexylbenzene, octanoic acid, gamma-nonalactone, substituted naphthalenes and cyclic branched ketones are the WGO components, which function as insect attractants.

Various health benefits of WGO have been reported. For example, according to the literature, certain neuromuscular disorders could be alleviated with WGO treatment. The most responsive conditions to WGO therapy were collagen-related diseases such as dermatomyositis and menopausal muscular dystrophy. The healing effect of WGO was attributed to its high vitamin E content. WGO is also effective in inhibiting inflammation.

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Gourmet and Specialty Oils

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The term "Gourmet" usually refers to the "highest quality, perfectly prepared and artfully presented food." Gourmet vegetable oils are characterized by their high quality, specifically their aroma and taste.

Specialty oils are produced in very small quantities (about 1 to 2 million tons per year global production). Some of these oils have unique properties that are desirable in industrial and non-edible applications. Many specialty oils are marketed for their health promoting properties. This fact sheet summarizes chemical, physical and organoleptic properties of economically important specialty and gourmet oils in alphabetical order.

Algae Oil

Algae are diverse group of organisms or simple plants (See fact sheets FAPC-191, 192 and 193). Algae live in water or soil and may be single or multi-cellular organisms. There are many strains of microalgae (unicellular organisms), macroalgae (seaweeds) and cyanobacteria (also known as blue-green algae) that are commercially important.

Chemical composition of algal biomass varies depending on the algae strain and growth conditions. Algae cells mainly comprise of proteins, lipids and carbohydrates. Some algae strains accumulate significant amounts of oil within the cells (possibly more than 50 percent of their ash-free cell dry weight). Many microalgae strains accumulate large amounts of oil rich in omega-3 fatty acids (see fact sheet FAPC-135). In general, commercial algae oils are rich in docosahexaenoic (DHA), docosapentaenoic (DPA) and/or eicosapentaenoic (EPA) omega-3 fatty acids. Palmitic acid is the most abundant saturated fatty acid in algae oil. Due to the reported health benefits of omega-3 rich oils for infants and adults, algae oil has been used in infant formulas, dietary supplements and functional foods. Algae oil is also utilized as animal feed to incorporate omega-3 fatty acid in eggs and chicken and pork meat.

Omega-3 rich oils (polyunsaturated fatty acids) are prone to oxidation, hence, need to be handled and stored carefully and kept away from light, at low temperature and in an inert atmosphere (i.e. low oxygen and high nitrogen).

Avocado Oil

Avocado, *Persea Americana* Mil., is a subtropical tree. Both seeds and flesh of avocado fruit can be used to extract oil. The use of avocado seed oil for treating scars and rashes dates back to 16th century. Commercial availability of oil from fruit flesh is relatively new. Global avocado oil production volume is quite low, 2000 tons/year. Cosmetics industry is the major user of avocado oil in skincare products due to fast skin absorption and sunscreen properties of the oil. Massage and muscle creams, preparations for psoriasis and dandruff treatment and soaps are some of the products formulated using avocado oil. Mild buttery flavor of avocado oil makes it an attractive ingredient for culinary applications. Avocado oil is used for shallow pan frying because of its high smoke point (more than 250 degrees Celsius or 482 degrees Fahrenheit). The majority of the fatty acids (see fact sheet FAPC-196) in avocado oil are unsaturated (70 to 90 percent of the total fatty acids). Oleic (50 to 70 percent), linoleic (10 to 20 percent) and palmitoleic (3 to 10 percent) are the major fatty acids present in oil extracted from the avocado fruit flesh. Scientific studies on the health benefits of avocado oil are limited. However, there are claims avocado oil can be a healthy addition to the Mediterranean diet because of its lipid composition similar to olive oil, rich in oleic acid, tocopherols and phytosterols.

Butter Oil

Butter oil is obtained from butter or cream by removing the water and nonfat solids. The terms milk fat, anhydrous milk fat, dry butter fat and dehydrated butter fat are synonymous with butter oil. Butter oil has a longer shelf life than butter due to its lower moisture content. Saturated fatty acid content of butter oil is quite high, 6 to 15 percent myristic, 25 to 40 percent palmitic and 6 to 12 percent stearic acid. Oleic acid is the major unsaturated fatty acid in butter oil, 19 to 35

percent. Flavor profile of butter fat depends on the original milk used in the production. Digestibility of milk fat is higher than vegetable oils because milk fat globules are naturally emulsified in milk, while vegetable oils are emulsified by bile, pancreatic enzymes and intestinal enzymes before they can pass through the intestinal wall. Milk fat is rich in short- and medium-chain fatty acids, i.e. myristic acid, which are easily absorbed in the body. Milk fat carries fat soluble vitamins. Butter oil contains about 2 to 5 percent lauric acid, which is reported to have antiviral and antibacterial properties. It also has been reported myristic acid may help body to fight infections.

Coconut Oil

The coconut palm (*Cocos nucifera* L.) produces fruits that weigh about 1 kg (about 2 pounds). The meat or kernel inside the hard fruit shell is about 1 to 2 centimeters thick. Dried kernel or meat of coconut fruit is called copra. Coconut oil, which is extracted from copra, has a colorless to pale brownish yellow color, bland flavor and pleasant aroma. Either dry or wet processing can be used to obtain coconut oil. Dry processing is the most widely used oil extraction technique. Cleaned, dried, ground and steamed copra is pressed by wedge press, screw press or hydraulic press to obtain crude coconut oil. Then, oil goes through a refining process that involves bleaching and deodorization (see fact sheets FAPC-158, 159 and 160).

Virgin coconut oil is obtained from fresh, mature kernel of the coconut by mechanical pressing with little or no heat. Virgin oil does not go through a refining process. Hence, it retains most of its health beneficial component.

Its high resistance to rancidity, a narrow range of melting temperature, easy digestibility and absorbability and excellent foam retention capacity make coconut oil a desirable ingredient for a wide range of edible and non-edible applications. The majority of fatty acids in coconut oil are short- or medium-chain saturated fatty acids such as myristic, lauric and caprylic acids.

There are some concerns coconut oil elevates blood cholesterol level because of its high saturated fatty acid content. Prior to oil extraction, copra is dried usually by exposing it to very high temperatures and/or sunlight for several days. The latter drying conditions may inactivate the health beneficial oil components such as tocopherols, tocotrienols and polyphenols. There are studies indicating virgin coconut oil with high polyphenol content was capable of maintaining the normal levels of cholesterol and other lipid parameters in tissues and serum and also increased the concentration of high density lipoprotein (HDL) (good cholesterol) levels in rats.

Fish Oil

Fish oil is a byproduct of fish meal production process. Fish meal is used as animal feed. Fish oil is usually obtained from the open ocean fatty fish species (i.e. Menhaden) using relatively simple processes involving grinding, cooking and pressing to separate the oil from the meal. The oil fraction is dried and refined to the specifications required by the final application. In the modern human diet, fish oil provides the long chain polyunsaturated fatty acids, especially omega-3 fatty acids.

Fatty acid composition of fish oil varies depending on the origin and the species of fish used, and the harvest season. EPA and DHA are very important components of fish oil. In general, palmitic and lauric acids and EPA (omega-3), DHA (omega-3), palmitoleic and oleic acids are the most abundant saturated and unsaturated fatty acids in fish oil, respectively. For example, Menhaden oil produced in U.S. contains about 9, 11, 13 and 19 percent DHA, EPA, oleic and palmitic acids, respectively.

Originally, fish oil was used as lightning oil for street lamps in Europe. Later, fish oil became very popular as an animal feed component, especially for poultry and swine feed. Today, fish oil is widely used in functional foods, dietary supplements, baby foods and infant formula due to their broad range of health benefits (see fact sheet FAPC-135). It is very important to note that fish oil is prone to rapid oxidation and quality deterioration due to its high content of polyunsaturated fatty acids. Strong odor, dark color, off-flavor and texture are indications of oil quality degradation in the products.

Flax Oil

Flax or linseed (*Linum usitatissimum*, L.) has been used for food and fiber for centuries. Oil content of flax seed varies between 29 and 45 percent depending on the cultivar. There are dark brown or yellow seed coated flax varieties. The color of the oil depends on the variety. Flax seed oil is rich in alpha-linolenic acid (ALA) (about 60 percent), which is an omega-3 fatty acid with shorter carbon chain length (18 carbons) and less unsaturation (3 double bonds) than DHA (22 carbons and 6 double bond) and EPA (20 carbons and 5 double bonds). Linoleic acid (about 15 percent) and oleic acid (about 18 percent) are the other abundant fatty acids in flax seed oil. Very high total polyunsaturated fatty acid content of flax oil, about 73 percent, makes it extremely susceptible to oxidation and quality degradation.

Oil to be used for edible applications is usually extracted by mechanical pressing. Flaxseed contains cyclic peptides formed of hydrophobic amino acids. These peptides are co-extracted with oil. Mechanically pressed oil may contain trace amount of allergenic proteins. Fresh oil has a nutty flavor due to the presence of these cyclic peptides. A lingering bitter off-flavor develops during oil storage at room temperature. Although, these peptides adversely affect the flavor profile of the oil, they are reported to have several health benefits including immunosuppressive activity. Cold pressed flax seed oil flavor is usually described as herbaceous, green, woody and sweet. Sour, pungent and fruity are the less pronounced notes used to describe flax seed oil flavor. There are studies indicating the consumption of ALA may provide protection against cardiovascular and other inflammatory diseases.

Flax seed oil is mostly marketed as a dietary supplement in the form of soft gel capsules. It also is used in lipid infusions for patients with certain types of disorders and as an ingredient in cosmetics and skin cream formulations. It has also been suggested that incorporation of flax seed oil to ice cream and frozen desserts would improve their nutritional profile. Industrial applications of solvent extracted and refined flax seed oil include oil-based paints, varnishes, linoleum, printing inks, lacquers, waterproof coatings on cloth and wood treatment products.

Hempseed Oil

Cannabis sativa is one of the oldest cultivated crops that provide food, oil, fiber, and even medicine. *Cannabis sativa* L. refers to both industrial hemp and marijuana. Industrial hemp is a class of non-drug *Cannabis sativa* varieties grown for fiber. The ban on hemp production is due to the presence of the psychoactive compound, delta-9-tetrahydrocannabinol (THC) in the plant. Most cultivated hemp crop contains less than 1 percent THC.

Hempseed is a rich source of easily digestible protein, 20-25 percent, and highly unsaturated food oil, 30-35 percent, containing phytosterols, oil-soluble vitamins and minerals. The remainder of the seeds consists of dietary fiber, mostly from the hull.

Hempseed oil is extremely low in saturated fats and rich in polyunsaturated fatty acids (PUFA), 72 to 83 percent. The major fatty acid in hempseed oil is linoleic acid, an omega-6 fatty acid, (50 to 70 percent). ALA, an omega-3 fatty acid, content in the oil is about 15-34 percent. Both linoleic and linolenic acids are essential fatty acids, meaning that human body cannot produce them, hence, they need to be delivered through diet. The health benefits of hemp seed oil are attributed to its desirable omega-6: omega-3 fatty acid ratio, 3:1. Although the topic is still controversial, the ideal omega-6: omega-3 ratio for optimal health benefits is broadly recognized as 3:1 to 5:1.

Hexane extracted hempseed oil has a yellow color, bland taste and a nutty aroma. Depending on the seed growth location, oil extraction conditions and the seed maturity, hempseed oil may have a strong and pungent flavor. The taste of the oil will also be influenced by postharvest management practices (i.e. high drying temperatures), which affect the formation of volatile compounds including oil degradation products. Good-quality cold-pressed hempseed oil has an excellent taste that is similar to walnuts and sunflower seeds. There are reports indicating that toasted seeds impart a savory umami flavor similar to that of bacon and fried prawns.

Applications of hempseed oil in medicine for treatment of glaucoma and cancer, reducing cholesterol level in human blood and controlling high blood pressure have been reported. Anecdotal benefits of daily consumption of hempseed oil are marked improvements in skin, hair and nail quality.

Mechanically pressed hempseed oil is utilized as salad dressing, but it is not suitable for high temperature applications because of its high unsaturated fatty acid content. The shelf life of hempseed oil is rather short because high level of unsaturated fatty acids provides ample opportunity for oxidation with atmospheric oxygen. Hempseed oil has to be handled very carefully and kept away from high heat and light to minimize oxidation. Hempseed oil is the main ingredient in a wide range of cosmetic products including liquid and bar soaps, creams, lotions and lip balm. Industrial applications of hempseed oil include paints, varnishes, and other coating materials. Plastic flooring such as linoleum and similar materials have been made from hempseed oil.

Tree Nut Oils

In many countries tree nuts are cultivated as oil crops. Some nuts may contain over 75 percent oil on weight basis, i.e. about 50, 60, 65 to 75, 65 and 40 percent oil in almonds, hazelnuts, pecans, walnuts and pistachios, respectively. In general, tree nut oils are rich in monounsaturated fatty acids, such as oleic acid, 50-80 percent. Either mechanical pressing or solvent extraction with hexane is used to recover oil from tree nuts. Compared to the commodity vegetable oils (i.e. soybean, canola) tree nut oils show high oxidative stability and longer shelf life. This is due to the presence of high concentrations of monounsaturated fatty acids and lipid soluble antioxidants such as alpha-tocopherol or vitamin E and phenolic acids in the oil. There are numerous studies indicating cardiovascular benefits of nut oils through improvement of blood lipid profile by lowering low density lipoprotein (bad cholesterol) and increasing high density lipoprotein (good cholesterol) levels.

Most of the nut oils are characterized by their specific flavor and aroma. For example, the compound filbertone (5-methyl-E-2-hepen-4-one) is responsible for the characteristic flavor of hazelnut oil. Filbertone can produce hazelnut like aroma at very low concentrations. Oil from unroasted hazelnuts may contain about 6 microgram fibertone/kg oil, whereas oil from roasted nut can have over 300 microgram fibertone/kg oil. Because of their higher price, adulteration of nut oils with commodity oils is an issue in commerce and quite difficult to detect. However, there are some analytical techniques that can detect adulteration. For example, aroma compounds such as filbertone can be used as an index for assessing possible adulteration of other oils with hazelnut oil and the extend of adulteration.

In general, nut oils are colorless to pale yellow due to the lack of chlorophyll in nut kernels. However, allergens and some toxic compounds naturally present in some tree nuts could be an issue for edible products. An example would be almonds. There are two almond varieties grown widely: