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Hempseed Oil

Jace C. Callaway[1,2] and David W. Pate[3]
[1]Finola ky, PL 236, Kuopio, Finland FI-70101, www.finola.com; [2]Departments of Pharmaceutical Chemistry and Neurobiology, University of Kuopio, FI-70211 Kuopio, Finland; [3]Centre for Phytochemistry and Pharmacology Southern Cross University, Lismore, NSW 2480 Australia

Introduction

Nondrug varieties of *Cannabis sativa* L., collectively known as "hemp," provide an important source of industrial fiber. Hemp fiber is used in the production of specialty paper (e.g., cigarette papers, bank notes, and tea bags), in addition to ropes, woven and nonwoven fabrics, automotive and building insulation, construction materials, and many other durable goods. Fiber varieties of hemp can be over four meters tall, and require over 150 days for seed maturation. In contrast, oilseed varieties are usually less than two meters tall at the time of harvest (110 to 150 days after sowing), which allows them to be efficiently harvested by conventional grain combines. Hemp contains very low amounts of δ-9-tetrahydrocannabinol (THC), the main psychoactive component in drug varieties of *Cannabis*. The amount of THC in the mature hemp plant is typically less than 0.5% of the plant's dry weight, which is not sufficient for drug purposes. In addition, THC is not a toxic compound in humans, even at high dosages and over long periods of time.

Hempseed oil is a highly unsaturated product that is pressed or extracted from the achenes of *Cannabis*, which are also a source of highly digestible protein (Table 6.1); thus, the tiny nut is an exceptionally good source of nutrition (Callaway, 2004; Deferne & Pate, 1996). This fruit of *Cannabis,* which has a relatively hard shell when mature, varies in shape—from almost spherical to somewhat oblong. Its overall size can vary considerably, but most often it approximates a match-head.

Not only does food-quality hempseed oil taste and smell delicious, it is extremely rich in lipid nutrients. The chemical analysis of hemp and other major seed oils was well underway in the late nineteenth century (Von Hazura, 1887) when linoleic acid (LA) was first identified (as "sativinsäure" or "sativic acid") as the main component of hempseed oil. The quantitative analysis of the major fatty-acid components in hempseed oil became of scientific interest in the early twentieth century (Kaufmann & Juschkewitsch, 1930). The essential fatty acids (EFAs) are well represented in hempseed oil. The "ω-6" LA (18:2n-6) component is present at about 55%, and

Table 6.1. Typical Nutritional Composition of Whole Hempseed, Dehulled Seed, and Seed Meal* (modified from Callaway, 2004)

	Whole seed	Dehulled seed	Seed meal
Oil	36%	44%	11%
Protein	25	33	34
Carbohydrates	28	12	43
Moisture	6	5	5
Ash	5	6	7
Energy	2200	2093	1700
Total dietary fiber	28%	7%	43%
Digestible fiber	6	6	16
Nondigestible fiber	22	1	27

*cultivar Finola

"ω-3" α-linolenic acid (ALA, 18:3n-3) occurs at about 20%. In addition, significant amounts of their respective metabolic products are found: the presence of γ-linolenic acid (GLA, 18:3n-6) ranges from 1 to 4%, and stearidonic acid (SDA, 18:4n-3) occurs at about 0.5 to 2%. While most vegetable oils have at least some EFAs, to have such high amounts of both is unusual, and in this proportion, in addition to GLA and SDA (Table 6.2). In fact, no other industrial crop can make this claim.

No great differences exist in the amounts or proportions of EFAs between an oilseed hemp cultivar from Northern Europe and a typical fiber hemp cultivar from Central Europe (Table 6.2). However, a considerable difference in the native abundance of both GLA and SDA was noted between northern and southern varieties of hempseed within the first report on the presence of SDA in hempseed (Callaway et al., 1997). Subsequent investigations confirmed this observation (Anwar et al., 2006; Bagci et al., 2003; Blade et al., 2005; Callaway, 2002, 2004; Matthäus et al., 2005; Mölleken & Theimer, 1997). The highest concentrations of GLA and SDA are found in the seeds of hemp varieties that are derived from extreme northern climes (Blade et al.. 2005; Callaway et al., 1997). Perhaps their higher amounts of super-unsaturated fatty acids protect these seeds from freezing solid during the harsh winter months, conferring the evolutionary advantage of an expanded range. Hempseed oil, for example, does not begin to thicken until it is stored for at least several days below –20°C. In an early study (Ross et al., 1996) on the fatty-acid profile of seed oils from drug-*Cannabis*, a remarkable uniformity was found in profiles of confiscated samples from Mexico, Columbia, Jamaica, and Thailand. These tropical seed samples were missing (ALA, which complements the aforementioned observations of greater seed-oil unsaturation being correlated with more extreme latitudes.

If the nuisance of shell fragments between the teeth is disregarded, one can consume whole hempseed directly from the plant, because it lacks the anti-nutritive

Table 6.2. Typical Fatty-Acid Profiles (%) of Hemp and Other Seed Oils (Callaway, 2004)

Seed	Palmitic acid	Stearic acid	Oleic acid	LA	ALA	GLA	SDA	%PUFA	n-6/n-3 ratio
Oil hemp-seed*	5	2	9	56	22	4	2	84	2.5
Fiber hempseed	8	3	11	55	21	1	<1	77	2.7
Black cur-rant	7	1	11	48	13	17	3	81	4.1
Flax (lin-seed)	6	3	15	15	61	0	0	76	0.2
Evening primrose	6	1	8	76	0	9	0	85	>100.0
Sunflower	5	11	22	63	<1	0	0	63	>100.0
Wheat germ	3	17	24	46	5	5	<1	56	10.2
Rapeseed	4	<1	60	23	13	0	0	36	1.8
Soy	10	4	23	55	8	0	0	63	6.9
Borage	12	5	17	42	0	24	0	66	>100.0
Corn	12	2	25	60	1	0	0	60	60.0
Olive	15	0	76	8	<1	0	0	8	>100.0

*cultivar Finola. LA = Linoleic Acid (18:2n-6), ALA = α-Linolenic Acid (18:3n-3), GLA = γ-Linolenic Acid (18:4n-6), SDA = Stearidonic Acid (18:4n-3), PUFA = Polyunsaturated Fatty Acid, n-6/n-3 Ratio = Percentages of ω-6 Fatty Acids Divided by ω-3 Fatty Acids
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properties that are commonly found in so many other raw foods and oilseeds (Mattäus, 1997). One can also feed the seed-press meal to pets and livestock. Hempseed also does not contain gluten, which makes it an important source of vegetable protein for people who suffer from coeliac disease (also written as "celiac" disease), an autoimmune-based gluten intolerance disorder of the small bowel that affects approximately 1% of Indo–European populations, and a disease which is significantly underdiagnosed (Collin, 1999). In addition to its value for oil and protein, hempseed and the seed meal by-product of oil pressing also contain respectable amounts of vitamins and minerals (Table 6.3).

The use of *Cannabis* as a source of food, fiber, and medicine is widespread in the Old World, and the whole seed continues to be used as a food and condiment by people in Asia (Xiaozhai & Clarke, 1995). After considering the historical accounts that demonstrate an intimate human relationship with this plant, imagining that this seed was overlooked by ancient humans in its transition from food gathering to the development of agriculture is difficult (Weiss et al., 2004). The oldest existing documents that describe the use of hempseed as both food and medicine are from China (de Padua et al., 1999), where *Cannabis* stalks, leaves, and seeds were found in tombs that are over 4500 years old (Jiang et al., 2006). Good evidence suggests that

Table 6.3. Typical Nutritional Values for Vitamins and Minerals in Hempseed* (Callaway, 2004)

Vitamins and minerals	Nutritional values
Vitamin E (total)	90 mg/100 g
α-tocopherol	5 mg/100 g
γ-tocopherol	85 mg/100 g
Thiamine (B1)	0.4 mg/100 g
Riboflavin (B2)	0.1 mg/100 g
Phophorus (P)	1,160 mg/100 g
Potassium (K)	859 mg/100 g
Magnesium (Mg)	483 mg/100 g
Calcium (Ca)	145 mg/100 g
Iron (Fe)	14 mg/100 g
Sodium (Na)	12 mg/100 g
Manganese (Mn)	7 mg/100 g
Zinc (Zn)	7 mg/100 g
Copper (Cu)	2 mg/100 g

*cultivar Finola
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Cannabis was used as a source of fiber and as a medicament in Ancient Egypt (Russo, 2007). Other tangible evidence suggests that *Cannabis* was used as a source of fiber for at least 6000 years (Schultes, 1970), and possibly up to 12,000 years (Abel, 1980). Patterns of woven material, possibly *Cannabis* fibers in the form of nets for trapping small animals, were preserved as fossilized remains that are over 20,000 years old (Pringle, 1997). By providing a nutritious food from its seed, a durable fiber from its stalk, and an efficacious medicine from its flower and leaves, *Cannabis* has assisted in human development like no other plant species. A more intimate relationship for the co-evolution of *Cannabis* with humans was advanced (McPartland & Guy, 2004).

Hempseed Oil Composition

Good-quality, cold-pressed hempseed oil has a clear green to olive color, and ideally possesses a fresh nutty taste and smell (Table 6.4). It is an exceptionally rich source of polyunsaturated fatty acids (PUFAs), ranging from 75 to 85% (Table 6.2) of the total oil content (Blade et al., 2005; Callaway et al., 1997; Kriese et al., 2004; Matthäus et al., 2005). The absolute amounts of GLA and SDA in hempseed oil seem to be genetically determined, and their relative ratio is highly consistent, showing a range from 0.67 to4.08% and 0.4 to1.6%, respectively, of the total seed oil (Matthäus et al., 2005).

The ratio of n-6/n-3 EFAs in hempseed oil (i.e., the percentages of LA divided by ALA) is typically near an ideal value for their efficient and simultaneous metabolic conversion. Due to the metabolic competition between the two EFAs for access to the rate-limiting enzyme δ-6 desaturase (Gerster, 1988), the significance of an appropriate dietary ratio of these fatty acids is important to consider in any discussion of general health (Okuyama et al., 1997) and within the interpretation of results from clinical studies that contain significant amounts of these oils (Simopoulos, 1999), especially in chronic-disease states. Only a decade ago, an optimal LA to ALA (n-6/n-3) ratio was considered to be somewhere between 5:1 and 10:1 (WHO & FAO, 1995). Soybean oil was popular and promoted as a healthy oil by the food industry and the agricultural community at the time, apparently because its ratio (about 7:1) is within that range. More recent considerations suggest an optimal n-6/n-3 ratio to be somewhere between 2:1 and 3:1 (Simopoulos et al., 2000), which reflects the ratio found in the traditional Japanese and Mediterranean diets, where the incidence of coronary heart disease was historically low. Fortuitously, the n-6/n-3 ratio in most commercial hempseed oils is typically near 2.5:1 (Table 6.2; Callaway et al., 1997; Kriese et al., 2004).

Flaxseed (*Linum usitatissimum*) oil typically contains about 60% of ALA, but lacks both GLA and SDA, while hempseed oils tend to have just over 20% of ALA (Table 6-B). An excess of ALA can disturb the human metabolic balance of fatty-acid metabolism by leaving a net deficit in "ω-6" metabolites, which are derived from dietary LA. In fact, the daily use of only two tablespoons of flaxseed oil per day can sig-

Table 6.4. Technical Characteristics of Cold-pressed Hempseed Oil

Solidification point	–20°C
Flash point	141°C
Smoke point	165°C
Specific gravity	0.9295 g/mL at 20°C
Saponification value	193
Iodine value	160
Chlorophyll content	5–80 ppm
Color:	
fresh cold-pressed oil	clear bright to dark green; fresh, nutty smell
old cold-pressed oil	clear olive green to yellow; fishy, paint smell
refined oil	clear colorless to light yellow; odorless to paint smell
Peroxide value:	
food-grade	< 2 meq/kg
cosmetic-grade	<10 meq/kg
industrial-grade	>10 meq/kg
Free fatty acid value:	
food-grade	<0.1%
other grades	>1.0%

nificantly decrease the competitive metabolic production of GLA from LA (Schwab et al., 2006). The presence of both GLA and SDA in hempseed oil allows this competition for δ-6-desaturase to be efficiently bypassed (Callaway et al., 2005; Okuyama et al., 1997; Schwab et al., 2006), while the favorable n-6/n-3 ratio in hempseed oil allows for the efficient metabolism of both EFAs to proceed in concert.

Protein By-products of Hempseed

Hempseed and hempseed meal are excellent sources of digestible protein. Figure 6.1 compares the amino acid profile for the total protein in hempseed, soy bean and egg white. Protein concentrations vary between whole hempseed (ca. 25%), de-hulled hempseed (ca. 45%) soy bean (ca. 32%) and egg white (ca. 11%). Figure 6.1 illustrates individual amino acid values per 100 g of protein to provide a direct comparison between these products. Another important fact to keep in mind is that hempseed and egg white lack the anti-nutritional trypsin-inhibiting factors that are found in

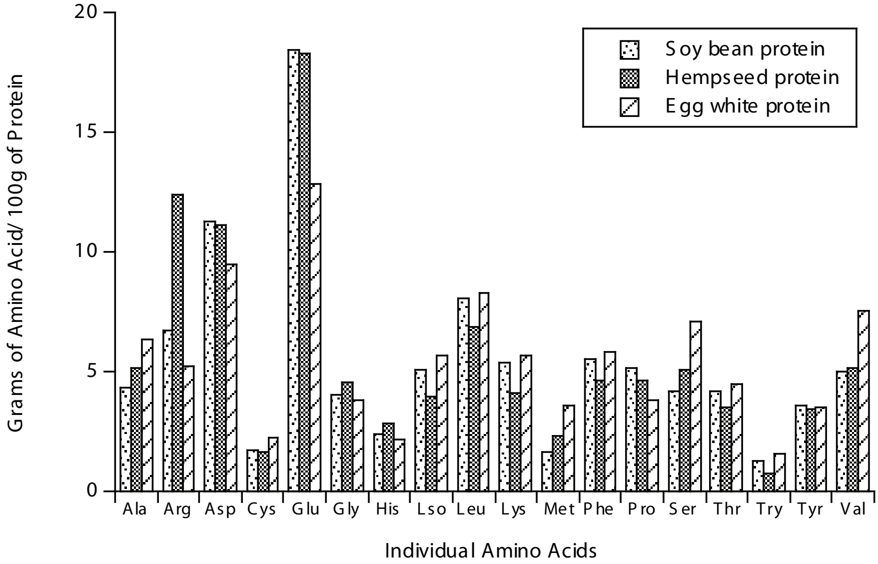

Fig. 6.1. Amino acid profiles of soy bean, hempseed, and egg white proteins, as represented by their IUPAC abbreviations (Callaway 2004). Reprinted with the kind permission of Springer Science and Business Media.

soy and most other vegetable products. This means that, like egg white, a greater proportion of the protein found in hempseed is digested and available for absorption. Recent interest in hempseed protein has increased due to its exceptional content of sulfur-containing amino acids (Callaway 2004, Tang et al. 2006), i.e., methionine and cystine (Odani & Odani 1998), and its surprisingly high amount of arginine (Fig. 6.1). As with most vegetable proteins, hempseed is considered to be lacking in the essential amino acid lysine, and is therefore not sufficient as the sole source of dietary protein for children under 10 years of age, according to FAO/WHO essential amino acid requirements (WHO & FAO 1995).

The major protein found in hempseed is edestin, which accounts for about 60-80% of the total protein content, with albumin making up the balance (Odani & Odani 1998, Tang et al. 2006). Edestin is a well-characterized protein, with a rich and detailed past (Osborn 1892) that has been nearly forgotten today. As with the soy protein glycinin, edestin is a hexamer, being composed of six identical AB protein subunits with molecular weights of about 33.0 and 20.0 kDa (Patel et al. 1994). An interesting non-food application for hempseed protein isolate derives from its ability to form cast films, which can be used in the production of biodegradable and even edible food packaging (Yin et al. 2007). In this study, the physical properties of cast films from hempseed protein isolate were investigated and compared to those of soy protein isolate. Their results suggest that hempseed protein isolates had good potential for the preparation of protein films and demonstrated some superior characteristics over soy isolates, such as low aqueous solubility and high surface hydrophobicity. Both of these properties are extremely important characteristics for durable food packaging of products having high moisture content.

Economy of Hempseed and Hempseed Oil

Neither hempseed nor hempseed oil are among the 200 primary commodities that are tracked by the FAO. However, some limited amount of information is available for both. Hempseed oil production data from the FAO is important to consider (FAOSTAT 2007), and clearly shows China to be in the lead (Fig. 6.2). Figure 6.2 shows worldwide reported data for hempseed oil production from 1994 to 2004, with individual contributions from the major participants, Western Europe and China. It is important to note that the hempseed oil production reported to FAO is probably almost entirely for non-food, industrial purposes; e.g., in the production of paints, varnishes, resins and some bio-plastics such as linoleum. The main reason for presenting this information in this context is to give some idea of the recent scale of reported industrial hempseed oil production worldwide. Unfortunately, the FAO does not have more extensive information on hempseed oil production, and nothing at all on products made from hempseed oil at this time.

The FAO began to report worldwide values for hempseed production in 1961. From 1961 to 1975, Turkey led all countries in reported world exports of hempseed until Lebanon dominated the reported market from 1977 to 1985 (data not shown). France, Germany and Chile were also significant hempseed producers from 1961 to 1985, with the Netherlands, Spain, Italy and Yugoslavia also making considerable contributions from Europe during this time. China's reported hempseed exports accounted for almost 77% of the total world exports reported in 1986, with 12,200 metric tons (MT). FAO data for China's hempseed exports, primarily for bird feed, are only available from 1986-1991, with a maximum reported value of 17,777 MT in 1991, and then again from 1998-2005, with an average value of just over 10,300 MT/year during this period of time. Unfortunately, there are no FAO data from the Soviet Union or Russia for hempseed or hempseed oil. This omission is unfortunate because of the long history of hemp production in Russia. Although production of hemp in this region of the world was primarily for bast fiber, which was used to produce durable fabrics, the production dietary hempseed oil was also important side product for "peasants" who could not afford butter (Grigoryev 2005). In Russia, hempseed oil is still referred to as 'black' oil because of its dark green color and, from 1925 to 1929, hempseed production was reported to be just over 500,000 MT/year (Kaufmann & Juschkewitsch 1930).

As a commodity, hempseed and hempseed oil occupy markets similar to flaxseed and flaxseed oil, with the latter production being about 70 times more than that of hempseed from 1999 to 2004, according to FAO data. Like hempseed, only a rela-

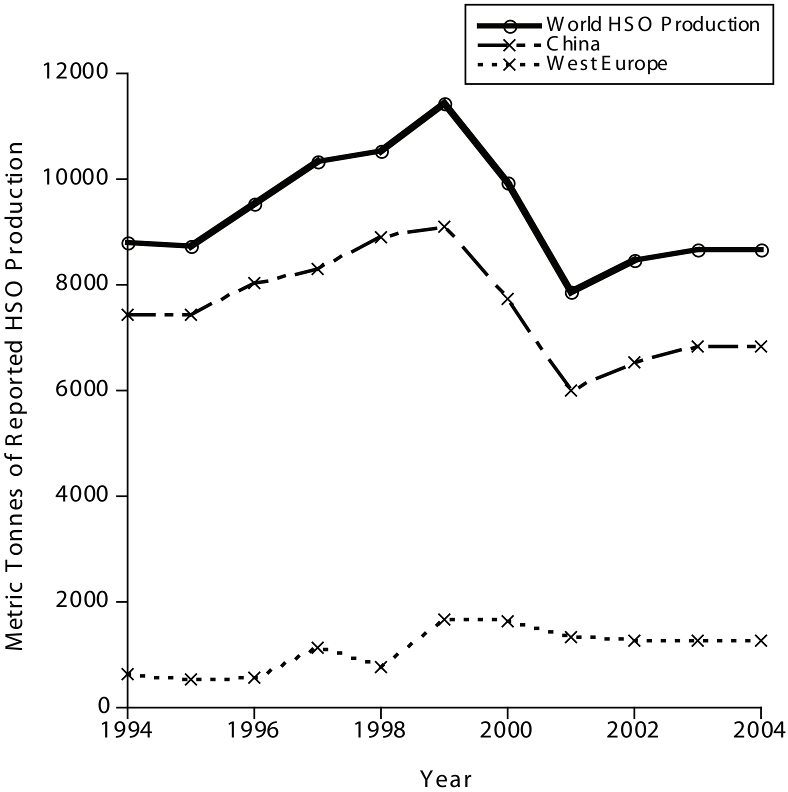

Fig. 6.2. Hempseed oil (HSO) production from 1994 to 2004, according to the United Nations Food and Agriculture Organization (http://faostat.fao.org/).

tively small amount of flaxseed is cultivated for the production of human foods, while most flaxseed oil goes for industrial purposes, such as the production of paints, with the seed meal being used as a vegetable protein additive in animal feed.

Bulk quantities of food-grade hempseed and hempseed oil from Canada and Europe are still relatively expensive, as the cultivated area has not yet reached the levels of other grain commodities, and production costs are still high. Most hempseed for human food is produced in temperate climes throughout the world, although one early-maturing oilseed variety (i.e., Finola) grows well in the arable regions of subarctic Canada and northern Europe (Callaway, 2002). So far, Canada seems to be the largest producer of food-grade hempseed and hempseed oil. From Canada, food-grade hempseed in lots of 1 MT or more costs about € 0.90/kg for conventional grain and about € 1.50/kg for certified organic grain. Bulk hempseed oil from Canada, in

1000-L bladders, may cost about € 5.00/L for conventional and € 9.50/L for certified organic. Retail unit prices vary considerably, along with quality; however, a direct correlation may not necessarily exist between price and quality, in most cases. Hempseed oil is typically sold in retail units of 250–500 mL, with conventional oil currently retailing at about € 6–7 for the smaller size and € 10–11 for the larger size. One can find certified organic hempseed oil for about € 9–10/250 mL and € 14–15/500 mL. European production of dietary hempseed and hempseed oil has lagged behind that of Canada, plus the costs of food production are higher in Europe, with the areas of cultivation being considerably smaller. For these reasons, retail prices for hempseed oil in Europe are currently about 20–30% higher than prices in Canada.

In Canada, 256 MTs of food-grade hempseed were exported in 2006, and 306 MTs were reported to have been exported by May of 2007, according to Agriculture and Agri-Food Canada. If 600 MTs were exported from Canada in 2007, then this would amount to about 3% of the world's exported hempseed. Over 90% of Canadian hempseed export is sterilized and sent to the United States for the production of human foods, where one is still forbidden to cultivate industrial hemp crops for any purpose, and viable hempseed in the United States is indiscriminately lumped into the same legal category as drug-*Cannabis*.

According to the FAO, most varieties of hemp are cultivated for fiber. However, a harvest must produce a sufficient amount of seed to allow for cultivation in subsequent years, and some of this is inevitably utilized for food. Only a few varieties of hemp (e.g., Finola, Craig, and USO-31) are designated specifically as oilseed varieties.

Hempseed Oil Processing

Hempseed oil that is used for human consumption is ideally produced from fresh, well-cleaned seeds that were air-dried at low temperatures (<25°C) over several days or weeks. At the time of harvest, the hempseed moisture content is typically 15–20%. The final moisture content of hempseed for storage and pressing should be just below 10%, and one must take special care to insure that the seed does not support mold growth between the time of harvest and the time of drying. If special care is not immediately taken at harvest, the aesthetic qualities of the product will suffer greatly, and the resulting oil will have a relatively short shelf life of only a few months, at best. Bulk oil stored in glazed-metal, ceramic, or glass containers is preferred after pressing; then the oil is either filtered for immediate bottling into glass or allowed to settle before it is bottled for retail distribution. The fine sediment from freshly pressed hempseed oil has a high nutritive value, and one can use it directly as a nut-butter spread or in other human-food products, or in high-end pet foods.

As oxidation was noted as the main problem for the long-term storage of any polyunsaturated oil, one should take special care to insure that the seed is already under an inert atmosphere before it reaches the press head, and one must maintain this inert atmosphere throughout the processing until the oil is bottled and capped. After bottling, one should protect the product from light and store it at the coldest temperature possible. No worry exists of oil expansion and subsequent container damage when it has solidified at low temperatures (<–20°C), in contrast to frozen aqueous products.

In reality, the ideal scenario is seldom the case. Most contemporary producers of hempseed oil are either individual operators with a small press or small start-up enterprises with one or two presses. Unfortunately, hempseed is rarely pressed under an inert atmosphere, but most reputable processors and distributors will at least state a "best before" date on their products. However, these dates are often quite arbitrary and typically stated to meet some economic objective. Most distributors, and especially retailers, are very reluctant to accept products with short "best before" dates, and too many processors are willing to provide a date that is acceptable to the retailer, with little or no regard for the actual quality of the oil that eventually reaches the consumer. Most retailers that carry hempseed oil are small shops that specialize in "biological/ecological/health/organic" foods, and often have little experience with, or appreciation for, the storage requirements of such a highly unsaturated oil. Moreover, many retailers have little or no spare refrigerated space for "yet another" product and so, unfortunately, often leave highly unsaturated oils to more rapidly age on room-temperature shelves. In the past few years, hempseed oil has begun to appear on the shelves of main-stream food stores in the United Kingdom.

Currently, food-grade hempseed oil for human consumption is cold-pressed from hempseed (i.e., small-scale screw presses operating at 40–50°C). The oil is allowed to settle for at least one to two weeks, and is then decanted directly into smaller containers for retail sales. Larger screw presses are used for "industrial" production, and the more successful operations filter the fine sediment directly into bulk 1000 L containers, rather than wait for gravity sedimentation.

Bulk hydraulic pressing offers a viable economic alternative to cold-pressing for food grade hempseed oil, providing that subsequent processing is under inert atmosphere, but such facilities are usually not set up for the production of high-quality hempseed oil. More importantly, the current market for food grade hempseed oil is not nearly at the level required to take advantage of this processing method. In addition, industrial refining or bleaching of hempseed oil to remove chlorophyll and other components will also remove the characteristic taste, antioxidants and other useful components from the oil.

Supercritical carbon dioxide can also be utilized for the extraction of food oils under low temperature and inert atmosphere. However, the main drawback of this technology is cost. Solvent extraction is used for the inexpensive industrial processing of many vegetable oils, although it is not suitable for the production of human food or animal feed because residual solvents (typically hexanes) contaminate the final product.

Current Applications of Hempseed Components

As mentioned in the Introduction, and presented in Tables 6.1, 6.2 and 6.3, hempseed is an incredibly rich source of beneficial dietary components. The demonstrated health benefits of hempseed and hempseed meal, primarily as animal food, is discussed in the following section. It is worth mentioning that a protein powder from sieved hempseed meal is currently the major human food product made from hempseed in Canada today. This is sold as a protein supplement that is added to baked goods, such as bread, and added by consumers to beverages such as smoothies. Pure edestin, a white protein powder isolated from hempseed meal, is commercially available from China, but the price of this material is currently more than twice that of whey protein. The health benefits of hempseed oil are also discussed in a later section of this chapter.

Nonedible Applications

The primary non-food industrial use for hempseed oil originates from its high level (approximately 80%) of PUFAs (Table 6.2), which readily polymerize upon exposure to atmospheric oxygen. Such 'drying oils' are useful for the production of paints, varnishes, sealants and such durable goods as floor coverings (e.g., linoleum, a floor covering made from flaxseed oil, that was invented in 1860) and other bio-plastics. Highly unsaturated vegetable oils from hemp and flax seeds could serve as hydrocarbon feed stocks for the production of plastics, glues and resins, in much the same way as plastics that are presently derived from petroleum. However, it is unreasonable to expect that seed oils can replace the enormous world requirements for petroleum fuels in the future. Because polymerization occurs more thoroughly with an increasing number of double bonds, the greater amount of unsaturated fatty acids in flaxseed oil results in a harder, more brittle quality in the dried product. This is also why flaxseed based paints, coatings and sealants tend to eventually crack after a few years, while similar products from hempseed oil remain pliable for longer periods of time.

Aside from this, hempseed oil has also found some limited use in body care products, particularly soaps and shampoos. However, most products seek to gain more value by simply stating the presence of hemp on the label, rather than having much of it as a physical component. The idea of using hempseed oil in a soap or shampoo does have appeal, but without adequate precautions taken in the formulation and packaging, these highly unsaturated hydrocarbons will oxidize faster than vegetable soaps made from palm or olive oils. Such an oxidized product, containing oil polymers, may leave a residual greasy feeling on the skin, which can be difficult to completely rinse away. On the other hand, EFAs and especially GLA and SDA, do find a demonstrated utility in skin creams and moisturizers, provided that these PUFAs are not oxidized before they are applied. Although triglycerides do not penetrate healthy skin to any significant extent, they do promote healing of dry and damaged skin, where blood vessels are closer to the contact surface and PUFAs can act directly on locally damaged epidermal tissues.

Applications of Hempseed and Hempseed Meal

Most of the world's hempseed is consumed by small birds, primarily as commercial birdseed, which is the major use of exported hempseed from China. Wild birds also take their share of seed in the field and after storage. The flocking of migratory birds in a field of mature hempseed is a very good indication for the time of harvest. Birds fare well on a diet of hempseed, either as whole seed for migratory songbirds, or as feed made from hempseed or hempseed meal for domestic poultry. Hemp is also an excellent game crop that also provides cover for a wide variety of birds and other animals, with the short oilseed hemp varieties providing a safer environment for hunters to more easily see each other. It is not uncommon to observe geese trampling hemp crops at high northern latitudes, to gain access to the nutrient-rich seed (unpublished observations). Moreover, the flocking migratory birds and small mammals that inhabit oilseed hemp fields throughout summer, and especially near harvest time in the late autumn, attract raptors such as hawks and falcons, offering dynamic displays of predator versus prey action.

The main advantage of hempseed meal over rapeseed and flaxseed meals in animal feed is the lack of anti-nutritional components and toxic glycosides (Matthäus 1997). Linamarin, lotaustralin, and other cyanogenic glycosides are present in flaxseed and flaxseed meal at about 0.2% each (Palmer et al. 1980). Raw, whole flaxseed and flaxseed meal that has been heated only to 'cold-pressing' temperatures (e.g., 40–50°C) can be toxic to animals, especially if the seed or the cake is wetted before processing into feed. Under moist and acidic conditions, the seed enzyme linease will release prussic acid (i.e., hydrogen cyanide gas, HCN) from the glycoside. Some naïve flaxseed oil producers even unknowingly advertise the 'delightful almond flavor' of HCN in their product! Bioactive, and especially toxic, levels of HCN limit the amount of flaxseed meal that may safely be fed to poultry and other animals (Wanasundara & Shahidi 1998). Under high-temperature treatment, such as boiling for 10 minutes or steaming under pressure, linease is destroyed and the immediate release of HCN from flaxseed meal can be significantly reduced, although these cyanogenic compounds also spontaneously release HCN over time (Frehner et al. 1990). Extraction with chloroform, dichloromethane, trichloroethylene or carbon tetrachloride removes the glucoside, but subsequent residues of these halogenated solvents will always remain in the meal. Using hempseed, which lacks these toxic factors, avoids the additional costs of high-temperature treatment or solvent extraction to remove or reduce the risk of HCN in flaxseed products.

According to the FAO, the primary use of hempseed meal is for fattening cattle (supplements to 3 kg per day) and sheep (supplements to 0.5 kg per day). The utility of hempseed meal in feed for ruminants and laying hens has more recently been investigated in Canada. For example, Mustafa et al. (1999) described hempseed meal as an excellent source of rumen undegraded protein. Silversides et al. (2005) found that increasing the amount of hempseed meal to 20% of the feed in the diet of laying hens led to significant increases in levels of EFAs and decreased levels of palmitic acid in their eggs.

Flavor and Aroma Components of Hempseed Oil

Fresh, cold-pressed hempseed oil from good quality seed typically offers a delicious combination of citrus, mint and pepper flavors from the oil. These organoleptic components can vary according to seed variety and growing conditions, but is particularly dependent upon the way the seed is dried and stored. The delicate flavors in hempseed oil result primarily from volatile terpenes (Mediavilla & Steinemann 1997, 1998, ElSohly 2002). Thus, it is extremely important to dry hempseed slowly, and at low temperatures (<25°C), to its target moisture content of just under 10%. Fast drying, especially at elevated temperatures, not only makes control of seed moisture difficult, but also results in a subsequent loss of the delicate flavors. The seed also acquires unwanted tastes and smells that are reminiscent of jute rope or burlap sacks (Fig. 6.3) due to oxidation. For these reasons, hempseed oil should ideally be pressed from seed that is not over one year old.

The taste and smell of paint in hempseed oil is the inevitable result of liberated free fatty acids from the triglyceride, and fatty acid oxidation. Fungal infection of seed that is not properly dried can leave sharp odors of fish or ammonia. A fruity smell can eventually develop in hempseed oil through the gradual production of aliphatic esters from oxidized fatty acids (deMan 2000).

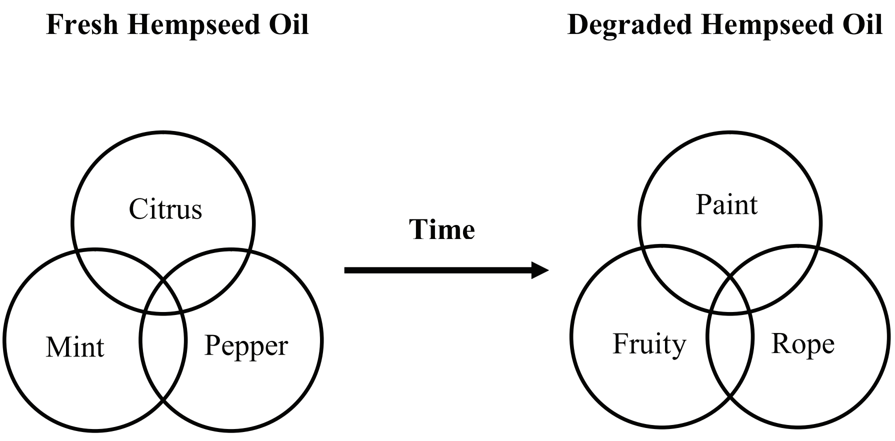

Fig. 6.3. Major organoleptic properties in fresh (left) and degraded (right) cold-pressed hempseed oil.

Possible Allergic Reactions

To date, no reports exist of allergic reactions to hempseed oil. However, importantly, note that hempseed is technically a nut, and one of the proteins in hempseed is albumin, so people with nut and/or egg allergies should certainly be careful when trying hempseed foods, as with any new food. However, in light of this information and the wider availability of hempseed foods over the last decade, surprisingly, only one published medical report exists of an allergy that a hempseed food product could have reasonably precipitated. In 2003, an allergic reaction was reported after an individual consumed part of a restaurant meal that contained dehulled hempseed (Stadtmauer, 2003).

Before hempseed foods became widely available, allergy reports were limited to medical studies on respiratory problems in workers who processed hemp fiber (also common with other natural fibers) under the very dusty industrial conditions which existed until the early decades of the 20th century. Similarly, one other report on a possible allergic reaction to hempseed, as birdseed, merits a mention. The reported context was vague, yet it seems as if the allergy was precipitated by dust from unclean birdseed (i.e., hempseed), which the person possibly inhaled while feeding a pet bird (Vidal et al. 1991).

From the evidence thus far, it seems safe to say that hempseed foods, and particularly hempseed oil, are no more allergenic that other common foods, and probably much less so.

Health Benefits of Hempseed Oil

Although there are numerous articles on the health benefits of polyunsaturated oils (PUFAs), there are very few published studies, to date, on the nutritional effects of dietary hempseed oil, and fewer still that can be considered to be well-controlled clinical investigations into its putative health benefits. Aside from the inherent merits of the fatty acid profile for explaining the beneficial effects of hempseed oil (Table 6.2), the molecular distribution of individual fatty acids on the glycerol molecule of dietary triglycerides offers another important piece of evidence to consider (Table 6.5).

In dietary oils, the fatty acids on the outer positions of the triacylglycerol (TAG) backbone (i.e., the sn-1 and sn-3 positions), are readily hydrolyzed during digestion by pancreatic and lipoprotein lipases, primarily in the duodenum (for a recent review, see Karupaiah & Sundram 2007). The remaining fatty acid at the sn-2 (center) position of the newly formed monoacylglyceride is substantially preserved in chylomicrons, where a new triglyceride may then be reconstructed with other fatty acids in the body. Alternatively, this monoacylglyceride may serve as a precursor in either gut or liver phospholipid syntheses. Thus, preservation of the native fatty acid in the sn-2 position has a prolonging effect in subsequent metabolic processes, such as construction of the phospholipid bilayers of all living cells. Clearly, there is considerable benefit in having the EFAs (i.e., LA and ALA) at the center of the TAG structure, the sn-2 position, for long-term health effects from dietary oils. From the information in Table 6.5, it seems that hempseed oil is the only commercial food oil that can deliver both EFAs at the sn-2 position in significant amounts, as the triacylglycerols LnLLn, LLL and LLnLn make up about 45% of the total found in hempseed oil.

The motivation to investigate possible improvements in health from dietary intake of hempseed oil has come from folklore, traditional medicine, and modern anecdotes derived from the introduction of hempseed foods to modern consumers in Europe and North America. Such contemporary stories began to circulate during the 1990s, particularly concerning the ability of dietary hempseed oil to improve skin quality and certain skin conditions, within a couple of weeks, when taken in modest daily amounts as a dietary supplement. Due to the lipophilic character of the oil, and exceptionally high content of PUFAs, it is readily absorbed for metabolism and immediate use, or stored in adipose tissues for later use. For example, hempseed oil is not an effective laxative, even in relatively large amounts (100-200 ml), due to its rapid absorption and low content of saturated fats. Another consistent anecdotal report from consumers over the last decade is that dietary hempseed oil results in thicker hair and harder nails. These later effects are noticed only after several months, due to the slower growth of these dermal tissues, when compared with the rate of squamous cell turnover in normal skin. Not surprisingly, skin, hair, and nails develop from the same dermal stem cell line, and it seems that the PUFAs in hempseed oil are critical to the appropriate construction and subsequent function of these similar tissues.

Brittle hair and nails are certainly not life-threatening maladies, and it is quite possible to go through life with skin that does not retain water very well. However, these superficial imperfections are symptomatic of other cellular processes that are less easily observed, as all cells in the body require a sufficient amount of EFAs in a balance that supports the optimal metabolism of omega-6 and omega-3 fatty acids.

Table 6.5. Stereospecificity (*sn*-1, *sn*-2, *sn*-3) of the Predominant Triacylglycerol (TAG) Species Found in HSO, Compared to Other Vegetable Oils

[1]Hempseed oil	LnLLn	LLL	LLnLn
[2]Flaxseed oil	LnLnLn	LnLnL	LnLnO
[3]Rapeseed oil	OOO	LOO	OOLn
[3]Olive oil	OOO	OOP	OLO
[3]Corn oil	LLL	LOL	LLP
[3]Soybean oil	LLL	LLO	LLP
[3]Sunflower oil	LLL	OLL	LOO

Ln = α-linolenate (18:3n-3), L = linoleate (18:2n-6), O = oleate (18:1n-9), P = palmitate (16:0). Sources: [1]Larson & Graham, 2007; [2]Krist et al., 2006; [3]Karupaiah & Sundram, 2007.

Immunity and autoimmune disease are also linked to diet and EFA deficiencies or imbalances (Harbige 1998). So far, only two well-controlled, human clinical trials have been performed with hempseed oil, and both studies resulted in beneficial results (Callaway et al., 2005; Schwab et al., 2006).

In the first of these published studies (Callaway et al. 2005), hempseed oil versus olive oil were compared in a 20-week randomized crossover study of 20 patients with eczema, which is also known as atopic dermatitis. Eczema is a condition of chronic dry skin that is often itchy and painful, and has been linked (e.g., Thijs et al., 2000; Horrobin, 2000) to metabolic disturbances in EFA metabolism. Scratching, typically during sleep, results in abrasions that are slow to heal and easily infected. In the Callaway et al. study, patients were instructed to take two tablespoons of the study oil each day (30 ml/day), and suggestions were given to easily include this amount of oil within their normal diets. Each patient took one of the two study oils for eight weeks, followed by a washout period of four weeks. After the washout period, the patient crossed-over to the other study oil for the remaining eight weeks. Fatty acid profiles were determined from blood triglycerides, cholesteryl esters and the phospholipid fractions. Levels of both EFAs and GLA increased significantly in all fractions after administration of the hempseed oil, with no significant increase in arachidonic acid after the eight-week intervention. No adverse effects were reported by the patients or observed by the clinicians. Skin dryness and itchiness were also measured, and these symptoms improved significantly after hempseed oil, with no corresponding improvements after olive oil treatment. Patient use of topical dermal medications decreased significantly only after hempseed oil consumption. This study concluded that the improvements in atopic symptoms resulted from the balanced and abundant supply of the PUFAs in hempseed oil (Callaway et al. 2005).

In the second published study (Schwab et al. 2006), dietary hempseed oil was compared with flaxseed oil in a group of 14 healthy volunteers. Hempseed oil and flaxseed oil each contain high amounts of both EFAs, but in approximately inverse proportions (Table 6.2). However, flaxseed oil has neither GLA nor SDA. While an excessive intake of one EFA over the other was thought to interfere with their respective metabolisms, through competition for delta-6-desaturase, a controlled clinical study had never been conducted to prove this hypothesis in humans. Again, a randomized crossover design was used, wherein the volunteers consumed 30 ml/day of the study oil, but only for four weeks, with a four week wash-out period between each intervention. The results were striking. Increased levels of both EFAs were again found in blood cholesteryl esters and triglycerides after intervention with both study oils, and considerably more ALA was sequestered after the flaxseed oil intervention. GLA levels increased after ingesting the hempseed oil, but there was a dramatic decrease in GLA after taking flaxseed oil. Thus, it was demonstrated that excessive ALA (the omega-3 EFA) from flaxseed oil does compete for access to Δ-6 desaturase and inhibits the production of GLA from LA (the omega-6 EFA). It was not surprising that GLA increased after hempseed oil, as this fatty acid is a natural component of that oil. The other remarkable finding in this study was a trend towards a lower "total-cholesterol" to "HDL-cholesterol" ratio after hempseed oil, which was not seen after the intervention with flaxseed oil. This effectively means an improvement in the "good cholesterol" over the "bad cholesterol" with dietary hempseed oil, but not with flaxseed oil. Neither any significant differences nor adverse effects were found between the experimental periods for either oil in measured values of fasting serum total lipids or lipoprotein lipids, plasma glucose, insulin or hemostatic factors. It is especially remarkable that these statistically significant findings were obtained from such a small group of volunteers.

SDA, a rare omega-3 biological metabolite of ALA that is present in hempseed oil, was detectable at low levels, but not quantified in either of these two clinical studies, due to its rapid metabolism to longer and more unsaturated omega-3 metabolites. It is a pity that more clinical information is not available for SDA, as it does not compete for delta-6-desaturase (as does its immediate precursor, ALA), and serves as an unrestricted dietary precursor to the biologically active EPA (20:5n3) (James et al., 2003). Moreover, SDA can provide similar metabolic benefits as fish oils, but does not suffer from the organic and inorganic contaminants that are found in fish oils. A recent study with dogs (Harris et al 2007) clearly indicated that SDA supplementation increased levels of EPA in the heart and red blood cells, and concluded that SDA may have utility as a safe, plant-based source of omega-3 fatty acid.

An observational study, with intention to treat, reported on the utility of hempseed oil topically applied to healing mucosal wounds after ear, nose, mouth and throat surgery, and concluded that hempseed oil provided rapid and complete support for wound healing (Grigoriev, 2002). Although triglycerides do not normally pass through intact skin tissues, the oil apparently affected wound healing by direct contact with blood capillaries and deeper tissues of the damaged mucosa. This finding is consistent with numerous other clinical studies that have demonstrated the utility of EFAs and other PUFAs in healing and immune response (e.g., Manku et al., 1982, 1984; Bordoni et al., 1988; Oliwiecki et al., 1991; Sakai et al., 1994; Yu & Björkstén, 1998; Derek & Meckling-Gill, 1999; Harbige et al., 2000; Harbige & Fisher, 2001; Horrobin, 2000; Simopoulos, 2002a & b; Simopoulos, 2006).

The fatty acid profile of hempseed oil (Table 6.2) is remarkably similar to that of black currant seed oil (Laakso & Voutilainen 1996), which also seems to have a beneficial impact on immunologic vigor (Wu et al., 1999; Barre, 2001). Borage, which is rich in GLA, but almost totally lacking in omega-3 PUFAs (Laakso & Voutilainen, 1996), is fairly well tolerated as a source of this fatty acid (Takwale et al., 2003), but perhaps more than just GLA is required in some disease states, such as atopy (Whitaker et al., 1996; van Gool et al., 2003; Callaway et al., 2005).

A porridge made from crushed oats and hempseed is a traditional food in the Czech Republic and other areas of Eastern Europe, much like the Chinese hempseed porridge *hou ma you*. One early published report from the former Czechoslovakia described the use of such porridge in treating children who had tuberculosis (Sirek, 1955). In this interesting report, improvements in the children's health were evaluated by medical diagnosis and confirmed by chest X-rays. Considering what is now known, it seems that a rapid improvement of nutritional input, due to hempseed proteins and PUFAs, was probably responsible for the dramatic results stated in this report. More recent investigations into the role of PUFAs for treating tuberculosis support this suggestion (Anes et al., 2003; Russel, 2003).

In rats, dietary hempseed oil reduced platelet aggregation upon the addition of 5% and 10% hempseed meal, containing residual hempseed oil, to their chow (Richard et al., 2007). These amounts were comparable to relative levels of human consumption. Platelet aggregation and rate of aggregation were significantly inhibited by the presence of both 5% and 10% hempseed meal in the rat chow. These effects were not seen with the control diet that contained a corresponding amount of palm oil. It was concluded that the observed effect of improved platelet function was due to the oil from the added hempseed meal.

Also in rats, an increase in plasma EFA profiles was observed (Al-Khalifa et al., 2007) after feeding them a diet that contained hempseed meal. The results were in line with those already seen in humans with hempseed oil (Callaway et al., 2005; Schwab et al., 2006). Moreover, improved heart function and significant cardio-protective effects were observed during post-ischemic reperfusion after the rats consumed 5 or 10% of their food as hempseed meal (Al-Khalifa et al., 2007). In another study (Karimi & Hayatghaib, 2006), rats were fed whole hempseed for only 20 days, which significantly decreased their mean fasting serum LDL level and significantly increased the mean fasting serum HDL and total protein levels. In that study, the authors concluded that short-term hempseed feeding improved rat blood lipid and protein profiles, and recommended that individuals with high cholesterol and high LDL levels, or those affected with coronary artery and liver diseases, incorporate hempseed into their food preparation. A similar improvement in LDL and HDL levels was also observed as a statistical trend in the aforementioned human clinical trial with hempseed oil (Schwab et al., 2006).

Hempseed Oil Stability

An unfortunate paradox of hempseed oil resides within its unsaturation, as this structural feature makes it both highly nutritious and chemically unstable (deMan, 2000). This vulnerability is not unique to hempseed oil, but is characteristic of any unsaturated oil, and is determined primarily by the degree of unsaturation of each of its component fatty acids, and the percentages of such compounds within the oil. This chemical difference explains why relatively saturated palm and coconut oils are more stable (and also solid at room temperature) than highly unsaturated hemp and flaxseed oils (which are still liquid at very cold temperatures).

Degradative processes in unsaturated oils were originally thought to begin with oxidation of the chemical double bond. Although reactions can occur at this site, the predominant mechanism is now recognized to be a free-radical reaction at the allylic carbon atoms adjacent to the double bond. These methylene carbons are more susceptible to reaction with oxygen due to the low dissociation energy of their hydrogen atoms (Ohloff, 1973). Thus, a predominantly monounsaturated mixture, such as olive oil, has one minor site (i.e., the double bond) and two major sites (i.e., the allylic carbons) of lability on its oleic acid constituent, which makes up over 70% of the fatty acids present.

Multiple bis-allylic carbons are found on fatty acids of greater unsaturation, which makes them proportionately more labile. For example, the additional double-bond of ALA or GLA endows these compounds with twice the instability of LA (Cosgrove et al., 1987). It should be remembered that unsaturated oil is only as stable as the most unstable component molecule, and once oxidative degradation begins, these reactions rapidly proliferate to include previously unaffected molecules. Excellent and detailed reviews of vegetable oil oxidation are available (e.g., deMan, 2000; SRI, 2005).

The potential instability of unsaturated oils is provoked to actually begin the process of oxidation by both intrinsic factors and assorted environmental influences (Sherwin, 1978). The first problem begins when enzymes are released from their proper sequestration within cellular structures of the oil-storage endosperm during the process of extraction. Lipase and lipoxygenase are consequently freed to disrupt triglyceride and fatty acid structures, respectively, immediately upon oil manufacture unless the oil "drip temperature" is hot enough (circa 60°C) to denature these proteins. However, even the relatively low temperatures (> 40°C) of "cold-pressed" oil manufacture promote oxidation when the press screw thoroughly adds atmospheric oxygen, so care must be taken to extract under an inert atmosphere (e.g., nitrogen). In addition, the use of transition metals such as iron, or particularly copper, to manufacture oil-exposed parts of the press is problematic. Trace amounts of these metals (i.e., <1 ppm) can catalyze degradation (Sherwin, 1978), especially if the oil contains significant amounts of the more reactive free fatty acids. Ideally, the working surfaces of press heads should be made from completely inert materials, such as high strength ceramic. Failing that, chelating agents (e.g., citric acid) should be promptly added to the oil, especially if the receiving or bulk-storage vessels are metallic.

Light also accelerates oxidation, and the chlorophyll found in raw, unprocessed oils will accelerate this process through its ability to capture light energy. Therefore, unnecessary exposure to light must be avoided during manufacture, and consumer bottles should be made of dark glass. Opaque plastic is sometimes used, but leaching of plasticizers and other chemical components into the oil may be a health hazard, unless the bottle interior is coated with an acceptable shielding resin.

Differences of stability between any two highly unsaturated oils, such as flaxseed and hempseed, can be observed and are at least partially attributable to the proportions of ancillary components within their respective seeds (Abuzaytoun & Shahidi, 2006), which are co-expressed with the oil. These components include phenolic pigments that act as anti-oxidants, or specific anti-oxidants such as the tocopherols. Tocopherols act as in situ preservatives during natural over-wintering of the seed, or during storage of its unadulterated oil. The various tocopherols differ in their respective anti-oxidant characteristics and biological activities. The alpha isomer of tocopherol (Vitamin E) has a high value in human nutrition, yet is relatively poor as an anti-oxidant (Helm, 2006). In contrast, the beta-, gamma- and delta-tocopherols are not nearly as effective as nutrients, but are 130, 200, or 500 times more powerful, respectively, in their anti-oxidant capacities (Helm, 2006). The primary tocopherol in flaxseed oil is the gamma isomer, with minor amounts of alpha-tocopherol (Abuzaytoun & Shahidi, 2006). Hempseed oil has somewhat more gamma-tocopherol as its major anti-oxidant, with collectively significant amounts of the alpha, beta, and delta isomers (Kriese et al., 2004; Blade et al., 2005; Abuzaytoun & Shahidi, 2006). The addition of ascorbyl palmitate is recommended to synergize the anti-oxidant action of these native tocopherols (Helm, 2006). Minor amounts of other native anti-oxidants, such as plastochromanol-8 (Kriese et al., 2004), cannabidiol (Hampson et al. 1998), or terpenes (Radonic & Milos, 2003), may also contribute to the natural stability of hempseed oil. Overall, differences in anti-oxidant quantity and composition, combined with the much greater amounts of unstable ALA in flaxseed oil, make hempseed oil the more stable of the two (Ramadana & Moersel, 2006). The previously mentioned review of vegetable oil oxidation (SRI, 2005) also contains a comprehensive review of anti-oxidants and oxidation test methods.

Because of the aforementioned oxidative properties, it should be obvious that hempseed oil and other polyunsaturated oils should not be used for frying, and moreover, that frying foods is an inherently unhealthy practice, as even the most saturated natural fats and oils contain some polyunsaturates. In general, the use of hempseed oil in any type of cooking should be limited to the temperature of boiling water. Interestingly, the internal temperature of baking bread does not surpass this threshold (Seiz, 2004). At most, the temperature of hempseed oil should not exceed about 120°C (Oomah et al., 2002), which is approximately the temperature found in pressure-cooking, and then only for relatively short periods of time. Not only are PUFAs vulnerable to high temperatures, but also tocopherols begin to degrade above 50°C, a process which accelerates above 100°C (Kerschbaum & Schweiger, 2007). Observing these use parameters to prevent oil oxidation will easily prevent the formation of the trans isomers (Mjos & Solvang, 2006) formed at higher temperatures (Wolff, 1993, Koletzko & Decsi, 1997), which have been linked to coronary heart disease and other chronic health problems (Woodside & Kromhout, 2005). In general, the best way to use hempseed oil is simply as an ingredient in salad dressings, dips and sandwich spreads, or as a substitute for butter on cooked foods such as bread, pasta, and vegetables.

Whole and De-hulled Hempseed

The tough, fibrous shell of whole hempseed can limit the digestibility of the hempseed meal that is produced as a by-product of oil pressing or extraction. This limitation is dependent on the physical size of the shell particle present in the feed, especially in pig and poultry feeds, according to the FAO. However, whole hemp seed can be fed to poultry and other birds if access to sandy gravel is provided for the avian crop. The hempseed hull is not without value, as it contains considerable amounts of phytosterols such as sitosterol and other nutriceutical components (Jeong et al., 1974; Leizer et al., 2000).

De-hulled hempseed is a new and useful product that was not commercially available before the late 1990s. With the hull removed from hempseed, both oil and protein values increase dramatically (Table 6.1). De-hulled hempseed can be eaten directly or added as an ingredient in the preparation of foods, especially "smoothies." Grinding de-hulled hempseed with water produces a tasty vegetable drink which looks like milk and tastes like walnuts or sunflower seeds. This taste is easily modified by a variety of flavors, ranging from sweet to salty. At a ratio of 1 cup de-hulled hempseed to one cup of water, the resulting 'milk' can be used as a substitute for eggs and dairy products in the production of baked goods. For example, cakes and muffins can be made without milk or eggs, as hempseed proteins will denature in the same manner as egg white to produce the desired texture.

Other Issues

The possibility always exists for the adulteration of vegetable oils, particularly when supplies are limited and unscrupulous individuals try to stretch a limited resource by diluting the more valuable component with something cheaper. Dilution by another vegetable oil will normally maintain the appearance of cold-pressed hempseed oil, due to the high level of chlorophyll in the latter. From our analysis of hundreds of hempseed oil samples, a very few examples of hempseed oil adulteration, presumably with cheaper rapeseed oil, were identified in the mid-1990s by gas chromatography. This was noticed primarily as an unusually high amount of oleic acid (>15%) in these particular samples. Possibly, these samples were adulterated with olive oil, but its higher price and higher level of oleic acid make this choice less likely.

Through carelessness or neglect, dirt and other potentially harmful contaminants can become part of the hempseed oil during the crushing process. Detectable amounts of THC and other cannabinoids can also adhere to the hull of poorly cleaned hempseed. In the past, such poorly crafted oils resulted in a positive urinalysis for *Cannabis* metabolites in some individuals who were subjected to drug-testing procedures that are unable to differentiate between the consumption of illegally smoked drug-*Cannabis* and the legal consumption of hempseed oil (Callaway et al., 1997; Lehmann et al., 1997). A similar dilemma exists with poppy seeds (which contain small amounts of morphine and other opioids), which are popular in many baked goods. In the latter case, drug-testing officials quickly responded by raising the cutoff level for urinary opioid metabolites to a reasonably high level (2000 ng/mL).

Unfortunately, a special form of U.S. hysteria that can only be described as "cannabiphobia" has not allowed for a similarly lucid approach to be applied to hemp foods, apparently in the fear that a few occasional users of drug-*Cannabis* might slip by the detection process. Therefore, the cutoff level for a positive determination of cannabinoid metabolites in the urine remains at the exceptionally low value of 50 ng/mL, which is also the lower limit of quantitation for radioimmunoassay. The nascent hemp food industry in North America was quick to react to the potential negative implications for their customers under the so-called "zero tolerance" policies of the United States. Consequently, industry procedures were instituted to press hempseed oil only from well-cleaned hemp seed of varieties that produce only very low levels of THC (Leson et al., 2000). Such low levels of THC in hemp foods are no longer a cause for regulatory concern in workplace drug testing (Lachenmeier & Walch, 2005).

These onerous conditions originate within a U.S. political landscape that forbids the cultivation of industrial hemp, and intentionally seeks to confuse it with drug-Cannabis, even though hemp is otherwise universally acknowledged as having absolutely no value as a drug substance. Moreover, hemp varieties have been shown to produce more cannabidiol than THC, while drug varieties of Cannabis tend to produce more THC than cannabidiol (Hillig and Mahlberg, 2004; Mechtler et al. 2004). Aside from being a potent, oil-soluble antioxidant and a useful phytochemical marker, cannabidiol can effectively attenuate the putative psychoactive effects of low THC levels by binding to cannabinoid (CB1) receptors in the brain (Pertwee, 2008). Unfortunately, the reasons for this intransigent position towards hemp in the U.S. are essentially doctrinal rather than rational, so it may take a bit more time and public education for hempseed products to become more widely recognized there as uniquely useful functional foods.

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