



Hempseed as a nutritional resource: An overview

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Summary

The seed of *Cannabis sativa* L. has been an important source of nutrition for thousands of years in Old World cultures. Non-drug varieties of *Cannabis*, commonly referred to as hemp, have not been studied extensively for their nutritional potential in recent years, nor has hempseed been utilized to any great extent by the industrial processes and food markets that have developed during the 20th century. Technically a nut, hempseed typically contains over 30% oil and about 25% protein, with considerable amounts of dietary fiber, vitamins and minerals. Hempseed oil is over 80% in polyunsaturated fatty acids (PUFAs), and is an exceptionally rich source of the two essential fatty acids (EFAs) linoleic acid (18:2 *omega*-6) and *alpha*-linolenic acid (18:3 *omega*-3). The *omega*-6 to *omega*-3 ratio (n6/n3) in hempseed oil is normally between 2:1 and 3:1, which is considered to be optimal for human health. In addition, the biological metabolites of the two EFAs, *gamma*-linolenic acid (18:3 *omega*-6; 'GLA') and stearidonic acid (18:4 *omega*-3; 'SDA'), are also present in hempseed oil. The two main proteins in hempseed are edestin and albumin. Both of these high-quality storage proteins are easily digested and contain nutritionally significant amounts of all essential amino acids. In addition, hempseed has exceptionally high levels of the amino acid arginine. Hempseed has been used to treat various disorders for thousands of years in traditional oriental medicine. Recent clinical trials have identified hempseed oil as a functional food, and animal feeding studies demonstrate the long-standing utility of hempseed as an important food resource.

Abbreviations: AL: *alpha*-Linolenic acid (18:3 *omega*-3); GLA: *gamma*-Linolenic acid (18:3 *omega*-6); EFA: Essential fatty acid; LDL: Low density lipoprotein; n6/n3: Ratio of *omega*-6/*omega*-3 fatty acids; PUFAs: Polyunsaturated fatty acids; SDA: Stearidonic acid (18:4 *omega*-3); THC: *delta*-9-Tetrahydrocannabinol

Introduction

Cannabis sativa L. has been an important source of food, fiber and medicine for thousands of years in the Old World (Zias et al., 1993; Xiaozhai & Clarke, 1995; de Padua et al., 1999; Pringle, 1997). The bast fiber from the stalk is still used in the modern production of durable fabrics and specialty papers in some countries; e.g., as canvas, linen, tea bags, paper money, cigarette papers and other strong, thin papers that are used to make thick books, such as the Holy Bible. Both the ripened seed of hemp and seed meal are excellent sources of dietary oil, fiber and protein (Table 1). Seed-eating migratory birds and rodents are especially

attracted to hemp fields at harvest time, which in turn attract raptors and other predatory animals. Eaten raw, or after long-term storage, this common seed was certainly used by prehistoric humans (Weiss et al., 2004), and probably earlier hominids as well (McPartland & Geoffrey, 2004). This is both logical and in line with the prehistoric use of *Cannabis* as an important source of economic plant fiber in the fabrication of nets, for catching birds and other small animals (Pringle, 1997), in addition to the medical potential of useful cannabinoids in the leaves and flowers of the plant itself (Zias et al., 1993). Hempseed has been documented as a source of food throughout recorded history – raw, cooked or roasted, and hempseed oil has been used as

Table 1. Typical nutritional content (%) of hempseed^a

	Whole seed	Seed meal
Oil (%)	35.5	11.1
Protein	24.8	33.5
Carbohydrates	27.6	42.6
Moisture	6.5	5.6
Ash	5.6	7.2
Energy (kJ/100 g)	2200	1700
Total dietary fiber (%)	27.6	42.6
Digestible fiber	5.4	16.4
Non-digestible fiber	22.2	26.2

^acv Finola.

a food/medicine in China for at least 3000 years (de Padua et al., 1999). The seed, both crushed and whole, remains an important grain in traditional Asiatic foods and medicines. In North America, hempseed has been used in the paint and varnish industries and imported as bird food. Within the last 10 years, hempseed has been legally used as food for humans in both Canada and the United States, while the cultivation of hemp remains illegal in the latter.

Recent historical considerations

At over 90% in unsaturated fatty acids (Table 2), hempseed oil once rivaled linseed (*Linum usitatissi-*

mum L.) as a drying oil in paints, varnishes and other technical coatings. Hempseed was eventually replaced by linseed in the late 1930s, after a prohibition of the cultivation of all *Cannabis* varieties was affected in North America. Subsequently, the potential use and development of hempseed as a food for humans and domesticated animals was interrupted, and available seed in the west was restricted to the propagation of a few fiber varieties for the production of specialty papers in some European countries for the remainder of the 20th century, notably France. This is an important historical note, for without hemp fiber and pulp from a western source, the United States would have been dependent on Chinese or Russian sources for hemp pulp during the Cold War to make strategically important papers.

Onset of the Second World War quickly brought hemp production back to North America, but only until it could be replaced by other durable natural fibers, such as Manila hemp (i.e., ‘abaca’, *Musa textiles*). By the 1950s, petroleum-based fibers had captured most of the hemp fiber market in North America. By the 1960s, long bast fibers were no longer in great demand for the production of ropes, textiles and related products in Europe and other parts of the world as cheaper petroleum products began to capture a majority of the market share for such durable goods. Thus, with its limited availability, hempseed was not exposed to 20th century farming, food processing or marketing.

Table 2. Typical fatty acid profiles (%) of hemp and other seed oils

Seed	Palmitic acid	Stearic acid	Oleic acid	Linoleic acid	AL ^b acid	GLA	SDA	%PUFA	n6/n3 ratio
Oil hempseed ^a	5	2	9	56	22	4	2	84	2.5
Fiber hempseed	8	3	11	55	21	1	<1	77	2.7
Black currant	7	1	11	48	13	17	3	81	4.1
Flax (linseed)	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
Rape seed	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

^acv. Finola.^bAL: *alpha*-Linolenic acid.

Hempseed as food

For various reasons, hemp has been reconsidered as a valuable industrial crop for both food and fiber in Canada and European countries during the last decade. As a result, hempseed and hempseed food products have become available to the general public in these countries. While the human food potential for hempseed has not yet entered mass markets in the west, its nutritional properties have long been recognized and valued as food for both humans and domesticated animals throughout Asia, India, Russia and Eastern Europe. In China, roasted hempseed is still sold as snacks by street vendors. In Russia, 'black' oil has been pressed from hempseed and used as a substitute for more expensive (and less healthy) sources of dietary fat, such as butter and hydrogenated margarines. The natural dark color of hempseed oil is from chlorophyll within the mature seed, which can hasten auto-oxidation of oil that is exposed to light. Some traditional hempseed foods can still be found in the Baltic states, particularly Latvia, and in other east European countries. Such a long history and a variety of uses over a large geographic area, and throughout so many dif-

ferent cultures, are all strong reminders of hempseed's utility as a useful source of nutrition. Over the past few years, modern science has finally begun to catch up with this ancient knowledge through its own methodologies (Callaway, 2002; Callaway et al. 1997a, 2004; Kriese et al., 2004).

Materials and methods

The data presented in Table 1 were derived experimentally from whole seed of the Finola hemp variety and its seed meal after 'cold' (45 °C) oil pressing. These analytical results were obtained by accredited methods from the Regional Environmental Laboratory of Kuopio, Finland. The data in Table 2 were derived experimentally from commercial oil samples or crushed whole seed as previously described (Callaway, 1997a; Ngeh-Ngwainbi et al., 1997). Amino acid values for hempseed (cv Finola) and rapeseed in Table 3 were derived experimentally at MTT (the National Agricultural Laboratories in Jokionen, Finland). Other amino acid values in Table 3 were obtained from an authoritative literary source (Scherz et al., 1986). The nutritional

Table 3. Typical protein content (%) of each food is given directly below the name

Amino acid	Potato (2%)	Wheat (14%)	Maize (11%)	Rice (9%)	Soy bean (32%)	Hempseed (25%)	Rapeseed (23%)	Egg white (13%)	Whey powder (13%)
Alanine	0.09	0.50	0.72	0.56	1.39	1.28	1.05	0.83	0.61
Arginine	0.10	0.61	0.40	0.62	2.14	3.10	1.49	0.68	0.39
Aspartic acid	0.34	0.69	0.60	0.86	3.62	2.78	1.82	1.23	1.49
Cystine	0.02	0.28	0.15	0.10	0.54	0.41	0.39	0.29	0.17
Glutamic acid	0.37	4.00	1.80	1.68	5.89	4.57	4.41	1.67	2.40
Glycine	0.10	0.71	0.35	0.47	1.29	1.14	1.28	0.50	0.29
Histidine*	0.03	0.27	0.26	0.19	0.76	0.71	0.72	0.28	0.29
Isoleucine*	0.08	0.53	0.35	0.35	1.62	0.98	1.00	0.74	0.85
Leucine*	0.11	0.90	1.19	0.71	2.58	1.72	1.80	1.08	1.40
Lysine*	0.10	0.37	0.33	0.31	1.73	1.03	1.49	0.74	1.15
Methionine*	0.02	0.22	0.18	0.17	0.53	0.58	0.46	0.47	0.23
Phenylalanine*	0.08	0.63	0.46	0.43	1.78	1.17	1.05	0.76	0.49
Proline	0.09	1.53	0.85	0.40	1.65	1.15	1.59	0.50	0.43
Serine	0.08	0.70	0.47	0.48	1.54	1.27	1.10	0.92	0.64
Threonine*	0.07	0.42	0.34	0.34	1.35	0.88	1.13	0.58	1.02
Tryptophan*	0.02	0.51	0.04	0.09	0.41	0.20	0.31	0.20	0.25
Tyrosine	0.06	0.40	0.36	0.33	1.14	0.86	0.69	0.46	0.47
Valine*	0.10	0.61	0.46	0.51	1.60	1.28	1.26	0.98	0.91

Individual amino acid values for each food is given in grams per 100 g. Essential amino acids are indicated by an asterisk (*).

Table 4. Typical nutritional values (mg/100 g) for vitamins and minerals in hempseed^a

Vitamin E	90.0
Thiamine (B1)	0.4
Riboflavin (B2)	0.1
Phosphorous (P)	1160
Potassium (K)	859
Magnesium (Mg)	483
Calcium (Ca)	145
Iron (Fe)	14
Sodium (Na)	12
Manganese (Mn)	7
Zinc (Zn)	7
Copper (Cu)	2

^acv Finola.

values in Table 4 were also derived experimentally from the Finola variety of hempseed at MTT in Jokioinen, Finland. The histogram in Figure 1 was compiled from relevant data in Table 3, after normalizing all protein values to 100% for direct comparison. Individual amino acids in Figure 1 are represented by their IUPAC abbreviations.

The Finola variety of hemp

Finola is the official denomination for a Finnish variety of hemp that was finally accepted as an EU cultivar in 2004, and was already accepted in Canada by 1998. It is especially well adapted for seed production in northern climes. The origins and other useful aspects of this new variety have already been described elsewhere (Callaway & Laakkonen, 1996; Callaway et al., 1997a; Callaway, 2002; Laakkonen & Callaway, 1998).

Compared to other varieties of hemp, Finola is relatively short (ca. 1.5 m at maturity), frost tolerant at all stages of growth (down to -5°C), drought tolerant and early maturing (typically within 115 days). The short stature of Finola allows for harvest with modern agricultural machines, like other grains. Finola is an open pollinated dioecious crop, with an even balance of male and female plants, and demonstrates little to no branching under normal conditions. Unlike other varieties of hemp, the bast fiber of Finola is almost entirely composed of long, primary fibers, and similar to flax in finesse. Finola produces more seed than any other hemp variety to date, and does not require herbicides or pesticides. Independent agricultural trials have

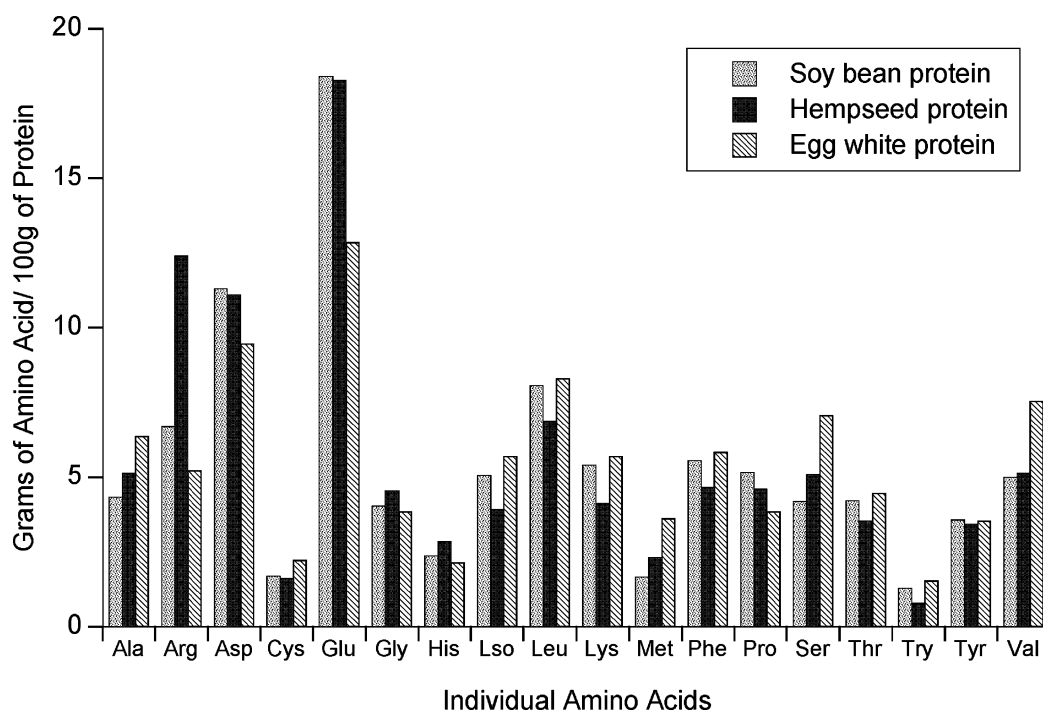


Figure 1. Graphical representation of protein amino acid profiles for soy bean, hempseed (cv Finola) and egg white. Individual amino acids are represented by their IUPAC abbreviations.

measured yields to be over 2000 kg of seed per hectare under good agronomic conditions. The protein content and amino acid profile of Finola is not significantly different from other varieties of hemp, but the fatty acid profile has considerably more GLA and SDA than other varieties (Callaway et al., 1997a; Kriese et al., 2004). The level of *delta*-9-tetrahydrocannabinoid (THC) for Finola is well below the EU level of 0.2%, with average values between 0.10–0.15% dry weight of mature plants (Small & Marcus, 2003). The ratio of cannabidiol (CBD) to THC is well over 2 for Finola, which is another requirement for all approved varieties of hemp in the EU.

Results

Hempseed oil

The recent availability and use of hempseed oil in Europe and North America has fostered anecdotal stories on improvements in health, over a wide range of acute and chronic conditions; e.g., from the rapid healing of simple cuts and burns to influenza, various skin problems, other allergic symptoms and inflammatory diseases. Most, if not all, of these claims can be understood by considering the unique fatty acid profile of hempseed oil (Deferne & Pate, 1996; Kriese et al., 2004), and its direct impact on the subsequent metabolism of dietary essential fatty acids (EFAs) to eicosanoids, which include prostaglandins and other important metabolites (Table 2). Eicosanoids have been implicated in chronic disease states of the human immune system (Darshan & Rudolph, 2000). The difference in the fatty acid profiles between oil hempseed and fiber hempseed has already been reported (Callaway et al., 1997a).

The EFAs are fatty acids that cannot be made by humans and must be obtained through the diet. Their fundamental importance in the human diet was already recognized by the 1930s (Burr & Burr, 1929, 1930). Thus, dietary supplementation with oils that contain high levels of EFAs and other polyunsaturated fatty acids (PUFAs) certainly can be used to enhance human health and development (Simopoulos, 1991), especially when they are lacking in the diet. PUFAs are also incorporated more directly as phospholipids in cellular and organelle membranes (Manku et al., 1984; Oliwiecki et al., 1991). The incorporation of PUFAs in the formation of membrane phospholipid bilayers is essential for maintaining vital characteristics of

cell membrane fluidity, especially in the construction of neuronal membranes within the central nervous system.

Dietary PUFAs and their biologic metabolites can favorably influence the fatty acid profile in low-density lipoproteins (LDL) when compared to saturated fats in the diet, which are strongly associated with coronary heart disease (Callow et al., 2002). Thus, a diet that has sufficient levels of PUFAs can lower both arterial levels of LDL-cholesterol and blood pressure in humans. PUFAs also increase bleeding times by decreasing platelet aggregation, which results in decreased peripheral blood pressure and clot formation.

Hempseed protein and other nutrients

Albumin, a globular protein, and edestin, a legumin, are the two main proteins in hempseed and both are rich in the amino acids that are essential to human health (Table 3). A direct comparison of protein amino acid profiles from egg white, hempseed and soy bean shows that hempseed protein is comparable to these other high quality proteins (Figure 1). Hempseed protein has good amounts of the sulfur-containing amino acids methionine and cystine (Odani & Odani, 1998), in addition to very high levels of arginine and glutamic acid (Table 3). As an industrial source of vegetable nutrition, both hempseed and hempseed meals are rich sources of protein and polyunsaturated oils, in addition to considerable amounts of vitamins and useful minerals (Table 4). The individual tocopherols in hempseed (cv Finola), presented as vitamin E in Table 4, are *alpha*-tocopherol (5 mg/100 g) and *gamma*-tocopherol (85 mg/100 g), for a total of 90 mg/100 g of vitamin E. These levels are considerably higher than those reported for any other varieties of hemp (Kriese et al., 2004).

Discussion

Hempseed oil

The seed oil of *Cannabis sativa* L. is typically over 90% in unsaturated fats. Hempseed oil, pressed from non-drug varieties of the *Cannabis* seed, is an especially rich source of the two EFAs, linoleic acid (18:2 *omega*-6) and *alpha*-linolenic acid (18:3 *omega*-3), in addition to their respective biologic metabolites, *gamma*-linolenic acid (18:3 *omega*-6, 'GLA') and stearidonic acid (18:4 *omega*-3, 'SDA').

Metabolism of dietary fatty acids

Due to metabolic competition between the two EFAs for access to the enzyme *delta*-6 desaturase (Gerster, 1988), the significance of a dietary ratio for the intakes of *omega*-6 and *omega*-3 fatty acids is important to consider in health (Okuyama et al., 1997) and in the interpretation of results from clinical studies (Simopoulos, 1999). Earlier, an optimal *omega*-6/*omega*-3 (n6/n3) ratio was considered to be somewhere between 5:1 and 10:1 (WHO & FAO, 1995), which is similar to the ratio found in soy bean oil (about 7:1). More recent considerations suggest an optimal n6/n3 balance 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 has been historically low. The n6/n3 ratio in most commercial hempseed oils is typically near 2.5:1 (Table 2; Callaway et al., 1997a; Kriese et al., 2004).

An excess of dietary *alpha*-linolenic acid (*omega*-3), for example, can disturb the metabolic balance by leaving a net deficit of *omega*-6 metabolites. The presence of both GLA and SDA in hempseed oil, typically at a favorable n6/n3 ratio of 2:1 (Table 2) allows this enzymatic step with *delta*-6-desaturase to be efficiently bypassed (Okuyama et al., 1997). The same rationale has been applied to rapeseed oil (*Brassica napus*), which has a n6/n3 ratio of about 2:1.

Empirical and clinical studies on hempseed oil

The system of traditional Chinese medicine maintains the oldest recorded source of information on hempseed, both as a traditional food and medicine (Xiaozhai & Clarke, 1995; de Padua et al., 1999). In recent times, a porridge of oats and hempseed was used as an important source of nutrition in the Czech Republic, and at least one published report has described the application of hempseed porridge, from folk medicine, in the treatment of tuberculosis without antibiotics (Sirek, 1955). More recent evidence has described how dietary fatty acids can be used in the treatment of this particular disease (Russell, 2003; Coghlan, 2003; Anes et al., 2003).

During the last decade, hempseed oil has become available in specialty food shops throughout Europe and North America (Leson et al., 1999, 2001). Anecdotal reports attribute improvements in skin quality, stronger finger nails and thicker hair to modest daily usage (ca. 15–30 ml/day) over time; e.g., improvements in skin quality: 2–4 weeks, nails: 2–4 months

and hair: 6–8 months. In both allopathic and traditional forms of medicine, such improvements are considered as good indications of general health. A recent clinical study with topically applied hempseed oil has already demonstrated its usefulness in healing mucosal skin wounds after eye, nose and throat surgery (Grigoriev, 2002). This finding is in line with numerous other clinical studies that have demonstrated the utility of EFAs and other PUFAs in healing and immune response (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). The fatty acid profile of hempseed oil is remarkably similar to that of black currant seed oil, which also seems to have a beneficial impact on immunologic vigor (Wu et al., 1999; Barre, 2001). Borage, which is rich in GLA, but totally lacking in *omega*-3 PUFAs, 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). In a randomized, crossover study that compared hempseed oil and olive oil, improvements were seen in a population of patients with atopic dermatitis (eczema) within eight weeks after the ingestion of hempseed oil at 30 ml (2 tbs)/day (Callaway et al., 2004). In this preliminary study, statistically significant improvements were seen in both skin quality and in plasma fatty acid profiles.

Animal feeding trials

Recent feeding trials with chickens have confirmed that hempseed is an excellent source of nutrition for laying hens, where the *omega* fatty acid profile in egg was favorably influenced after feeding hempseed meal (Silversides et al., 2002). This is in agreement with empirical observations over thousands of years in China and other Asiatic nations. Another study on hempseed found it to be an excellent source of rumen undegraded protein in cows and sheep (Mustafa et al., 1999), and unpublished results from recently completed trials in Finland have demonstrated hempseed meal to be at least as good as soy meal in farmed fish feed.

THC and other Cannabinoids

Most scientific research on *Cannabis* over the last 40 years has focused on the putative toxicity of

tetrahydrocannabinol (THC) and, to a lesser extent, other cannabinoids. Ironically, this effort has resulted in the identification of new medicines (Mechoulam, 1986; Mechoulam & Hanu, 2001; Mechoulam et al., 2002; Kassirer, 1997). THC and other cannabinoids are potent lipophilic antioxidants, which may explain some of the historic therapeutic potential associated with *Cannabis* (Hampson et al., 2000). Trace amounts of THC and other cannabinoids can be detected in foods that are made from hempseed, just as trace amounts of morphine are found in poppy seed. When oil is pressed from the poorly cleaned seed of hemp varieties that have >1% THC (e.g., Chinese hempseed), such trace amounts can have a significant impact on human drug testing (Callaway et al., 1997b). However, there is no significant effect of intoxication with such low levels of THC, and the hemp food industry has worked to reduce this potential in recent years. Such low levels of THC cannot be expected to have any significant negative impact on human health or drug testing with properly cleaned seed hempseed (Leson et al., 2001).

Conclusions

Hempseed is an excellent source of nutrition. Indications from traditional Chinese medicine, recent anecdotal reports and modern human clinical trials agree that hempseed has health promoting properties that are supported by results from nutritional analyses of the seed, oil and seed meal. In particular, the healing properties of hempseed can be attributed to high levels of EFAs and other PUFAs in the oil, in addition to a rich source of important amino acids in an easily digested protein. Recent feeding trials with fish, hens and ruminants, in addition to empirical observations over thousands of years, have effectively demonstrated that hempseed and its derivatives are useful in animal feed as well. Subjective concerns over THC in hemp foods are not supported by scientific evidence.

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