

Review

# Hemp: An Alternative Source for Various Industries and an Emerging Tool for Functional Food and Pharmaceutical Sectors

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**Abstract:** Hemp is a high-value crop that originated in Central Asia and is a historic but emerging cultivated plant. It may be grown for fiber, food, paper making, textiles, and therapeutic reasons. In the 21st century, market interest in hemp and its products has notably increased because seed portions can be utilized in the agri-food business, the woody component of the stem can be used in green buildings, the outer layer of the stems can be used in the textile industry, and the extraction of bioactive components from roots can play a vital role in the pharmacological industries. Hemp has recently been demonstrated to be a viable alternative for economies built on synthetic materials by the food, pharmaceutical, textiles, paper, building, and energy industries, among others. As a result, the goal of this study is to assemble the significant advancements in hemp, as well as to identify research gaps and research direction opportunities. The hemp plant will be provided more encouragement to be grown and be used. Many applications of hemp may be pushed to the next level for both producing a green environment and profit. A strong vision and a well-defined plan will pave the path for the discovery of new technologies and concepts.

**Keywords:** hemp; health potential; textile industry; pharmacological; food



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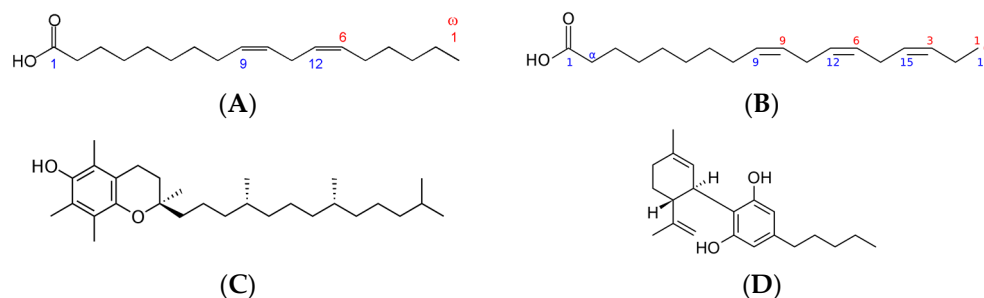
## 1. Introduction

Hemp (*Cannabis sativa* L.) has been one of the most valuable host species to mankind for millennia [1,2]. *Cannabis* is a genus that arose in Central Asia and subsequently spread to other parts of the globe. The plant's rapid growth in both temperate and tropical climates, as well as its enriching of the soil after each yield on cultivation, has enticed numerous people to it [3]. It has been with people for a long time, serving a lot of functions. The wooden core, seeds, and fiber of this species have historically been used to make a wide range of goods. The oldest indication of its production dates to the Neolithic period (about 4000 BC) when pollen grain traces were discovered in a Chinese town called Pani-p'ò. In Taiwan, the plant cannabis was identified in pots dating back ten thousand years for its fiber production. It has been grown as an important crop in China from prehistoric days for the creation of clothes, ropes, papers, oils, and sails, among many other things, and was formerly one of the five most widely used kinds of cereal [4]. Hemp utilization in medieval Ellora cave murals from the 6th to 11th centuries CE, as well as in the huge Daulatabad fort for lime plasterwork, shows that the inhabitants of the period had a thorough understanding of hemp and its applications in building [3]. In addition, hemp was among the earliest crops used for nutritional and medicinal purposes as a multi-purpose plant. Hemp seeds have now been extensively established as a primordial origin of dietary fiber, proteins, and fat with significant nutritive content, whether raw, roasted, or squeezed into oil [5]. Moreover, hemp's qualities have been utilized for millennia in eastern folk medication to help treat and prevent illnesses. Hemp fiber's composition mainly consists of cellulose (70–74%), hemicellulose (17–22%), and lignin (3–5%); among the most common vegetable-based fibers,

only cotton (82–93%) and flax (71–78%) contain more cellulose, while hemicellulose is more present in areca (35–64%), rice (23–28%), wheat (26–32%), and oats (27–38%). Regarding lignin, only flax has a lower percentage (2.2%). Finally, it is worth noting that hemp contains small percentages of ash (2.6%), pectin (0.9%), and wax (0.8%) [6,7].

Most scientists believe that cannabis has only one species, *Cannabis sativa* L. Small and Cronquist [8] classified this into two sub-species in the 1970s: (i) sub-species indica, which has maximum levels of the psychotropic component delta-9-tetrahydrocannabinol (THC) and (ii) sub-species sativa, which contains comparatively minimum levels of THC. Under the sub-species sativa, var. spontanea is wild while var. sativa is cultivated, and under the sub-species indica, var. indica is cultivated and var. kafiristanica is wild [8]. The modern industrial hemp types would be classified as subsp. sativa, whereas most medicinal cannabis cultivars would be classified as subsp. indica, according to this system. Numerous hybrids also blur the distinction. Researchers have demonstrated that medicinal cannabis is more closely related to *Cannabis indica* than *Cannabis sativa* [9].

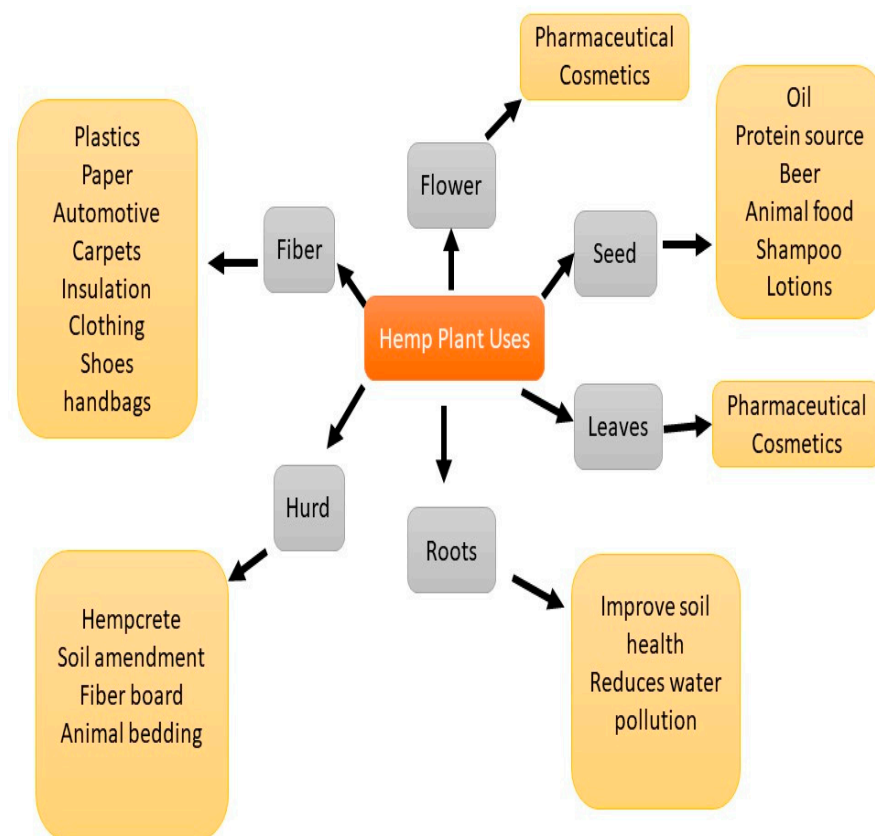
*Cannabis sativa* L., like every plant, has cellulose polymeric chains linked by microfibrils in its fundamental plant structure [10]. The primary metabolites' structure and quantities are comparable to those of any other plant. Hemp relies heavily on secondary metabolites (Figure 1).



**Figure 1.** Chemical make-up of a few hemp compounds which are biologically active. (A) linoleic acid, (B) alpha-linolenic acid, (C) tocopherol, (D) cannabidiol.

Hemp terpeno-phenolic components are known as cannabinoids; they are made by glandular trichomes, which can be mainly found on the majority of the plant's aerial surfaces. Cannabinoids make up the majority of the 450 natural supplementary compounds generated [11]. So far, more than 90 cannabinoids have been identified. The most common are cannabinodiolic acid, cannabinolic acid, and cannabidiolic acid, followed by cannabidgerolic acid, cannabichromic acid, and tetra-hydro-cannabinolic acid [10,11]. Cannabinoids are typically found as carboxylic acids, which are decarboxylated by dehydrating or scorching the collected plant over the period. Plant psychoactive properties are attributed to a chemical known as delta-9-tetrahydrocannabinol or THC. The growth of hemp plants is prohibited beyond a THC threshold of 0.3%, as this causes toxification [12].

Because of its readily adaptable climatic ability to thrive in both temperate and tropical conditions, the hemp plant has been disseminated internationally since ancient times. Development and growth do not need a great deal of work. Whereas the plant is currently classified as a powerful hallucinogenic that can only be grown illegally, it was formerly a well-known plant that was collected for a variety of applications including rope, clothes, and sails. Seeds, flowering heads, and leaves, among other plant components, are utilized for a variety of purposes. Seeds were crushed to make oil used in lamps or cooking [4,13]. Hemp may be used to make a variety of industrial or commercial items (Figure 2). Fiber and oilseed hemp are both types of industrial hemp.

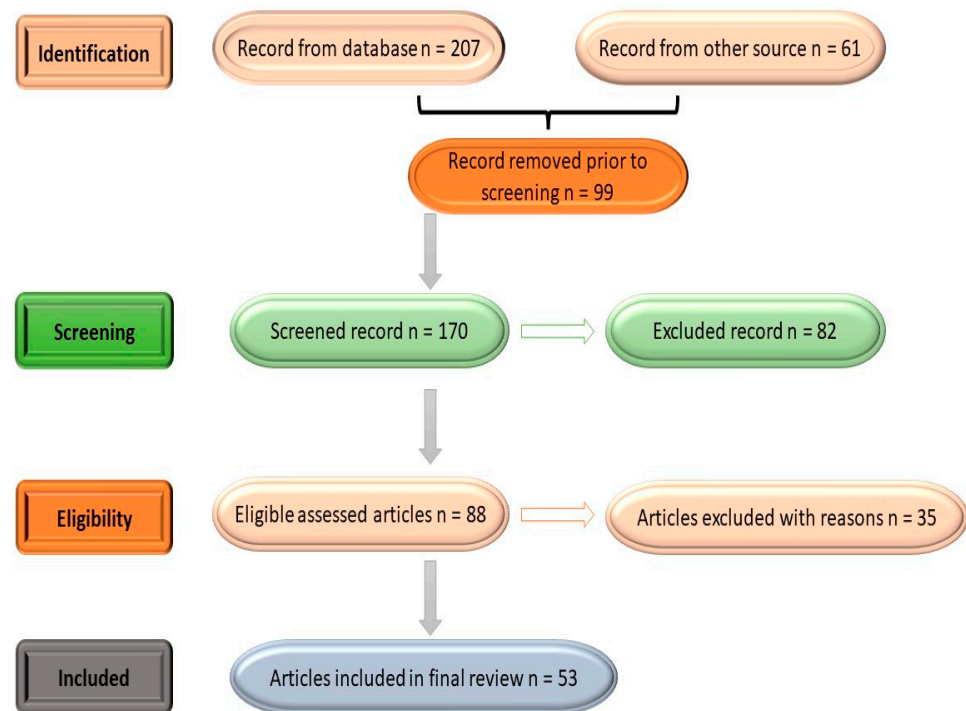


**Figure 2.** Summary of hemp plant applications [13].

The stalk-based fiber content in hemp varies from 10–15% in the phloem to 46–49% in dry straw [14]. Hemp filament is a specialty crop only cultivated in tropical climates. Users have been more interested in hemp seeds and byproducts, and these have a wide range of applications. The hemp industry is projected to include over 25,000 items, including textiles, garments, ropes, household goods, industrial oils, cosmetics, food, and medicines. Products made from hemp seeds have grown to encompass a variety of foods and drinks, alternative protein sources, dietary products, and medicines in the past decade [12]. Hemp seeds used as a nutraceutical component are seeing a resurgence of their traditional medical roles, thanks to their metabolites' strong biological activity [14].

## 2. Consideration of Work

The pertinent items that should be included were selected based on strict guidelines. For instance, publications published in languages other than English or for which just an abstract was available were disregarded. The final 53 publications, covering the years 2003–2021, were included in this systematic review as shown in the PRISMA flow diagram (Figure 3).



**Figure 3.** Preferred reporting items for systematic reviews and meta-analyses (PRISMA). Flow diagram of the screening process.

### 3. Hemp as a New Biocomposite

Biocomposites are composite materials generated from biological sources. They are made up of one or more stages of natural fiber reinforced with organic matrices or biopolymers [15]. Plant fibers such as flax, cotton, and hemp, as well as fibers generated with discarded papers or byproducts of food crops, are examples of biological components and reinforcements. Because of their numerous superior characteristics and uses, these materials are gaining a lot of attention. Hemp has been used as a raw material in manufacturing for over 2000 years [16]. As its relevance waned, it was relegated to the status of a significant mind-altering substance, and its industrial worth dwindled. It was rediscovered in the 1990s as a major raw resource in a viable green economy for bio-based items; the most significant application is as a bio-composite (natural fiber-reinforced plastic) [17].

Hemp fiber reinforcement to make hemp biocomposites can be a highly important alternative for producing sustainable bio-products [16,18]. These biomaterials may be found in a variety of forms; coatings, membranes, polymer-loaded particle fibers, and polymers are all examples. This makes up 14% of all applications [19]. Among all biocomposites, press-molding biocomposites are the most popular and have several increased uses. Hemp fiber may be strengthened to make insulating mats and automobile panels for the inner surface [18]. Fiber hemp is among the oldest and most frequently grown hemp types. In the late nineteenth and early twentieth centuries, several natural and synthetic fabrics battled with hemp for use as a textile material [20]. Hemp has recently been rediscovered as a low-cost, maximum-yielding commercial fiber crop that can assist in meeting the world's expanding fiber need. Mowing (typically with a sickle-bar mower), retting on the field, and baling are all part of the fiber harvesting process [21]. Hemp fiber is used in textiles, clothes, biomaterials for vehicles, paper, construction materials (hempcrete), and animal bedding, and it has the potential to be a biofuel crop. Hemp is made up of two types of fibers: (1) long outer fibers known as bast and (2) inner small fibers known as hurd [22]. For thousands of years, hemp was farmed for its bast fiber, and hurd was considered a waste by-product of bast manufacturing. Fibers can account for 20–30% of the stalk, and better-grade bast fiber is obtained from intensively cultivated hemp fields. Hurd fibers, on the other hand, account for 70–80% of the stalk and generally contain 20–30% lignin.

To separate the fibers from the non-fiber components, or the more valuable bast from the hurds, microbial, chemical, or mechanical methods are utilized [21,22].

Until recently, the only truly recognized application of hemp biocomposites was in car interior parts. Automotive bio-composite consumption is increasing, in door frames, trunk covers, spare tire covers, luggage boxes, headlining, and a range of additional products. Hemp biocomposites have high strength and durability, lightweight properties, and excellent accident behavior. Hemp-fiber-reinforced composites could be employed as mechanically resistant components in a few applications, as recycling and CO<sub>2</sub> emissions are becoming more and more essential. Improved mechanical testing, including compression, interlaminar, and in-plane shear tests, must be carried out to better define the proposed biocomposites. The findings of Madhu et al.'s [23] analysis of bending stiffness show a clear distinction between bio-epoxy and conventional epoxy resins.

#### 4. Hemp Grown for Hemp Extract Cannabidiol

Cannabidiol (CBD) hemp cultivars differ from seed or fiber-producing hemp varieties. Because CBD is contained mostly in female flowers, plants are frequently grown in greenhouses from propagated female clones and transferred two to four weeks after establishment. Since hemp was legalized in the United States, CBD has been a growing topic of interest, and most states have begun to enact regulations that will allow more farmers to produce CBD. Apart from its numerous health advantages, it is a great crop, particularly for small-scale farmers with limited resources who want to cultivate hemp for CBD. CBD is thought to be far more cost-effective than all other hemp byproducts, and its sales are expected to outpace all other hemp-based goods by 2022 [24,25]. Cannabinoids are a subclass of terpenophenolic chemicals found in cannabis. One of these chemicals is CBD, the main cannabinoid in hemp and a non-psychoactive component derived from the hemp plant. CBD was isolated from cannabis for the first time in the late 1930s [24] and has since been discovered to offer therapeutic potential for diseases such as inflammation and anxiety, as well as being a possible neuroprotective agent and antioxidant [24].

#### 5. Hempcrete Technology








Hempcrete is made by combining hemp hurds/shiv using a lime binder and H<sub>2</sub>O to create a reinforced material. Over 1500 years ago (sixth century), the ancient Indians mixed hemp using lime/clay mortar. This demonstrates that early people were cognizant of the use of hemp in buildings [3,26].

Furthermore, hempcrete constructions created in ancient times are still surviving in France, demonstrating its good endurance [3]. As a result, there is a demand for reliable substitutes which will help to reduce construction's ecological footprint and save our natural environment. These solutions may encourage the creation of long-term building goods and the replacement of artificial products. Many present environmental concerns might be resolved if hemp was used in buildings [26]. The main advantage of using aqueous leaf extract in homes and structures is that it sequesters CO<sub>2</sub> from building sites and provides a greenhouse-negative living environment [27]. Another significant benefit of utilizing cannabis is as an effective pesticide and repellent for insects, ensuring that the timber is minimally susceptible to harm and seems to have a high life expectancy. Hemp walls have high insulating power, which reduces energy demand costs by 50%, as hempcrete has an R-value of 30 for a 12-inch-wide wall, which is approximately double that of standard walls. The R-value of a material is a measurement of its ability to endure thermal flow [27,28]. Hempcrete, Canobiote, Canosmose, and other brands of hemp plaster are currently available from a variety of building companies [29]; for instance, hempcrete has been used to construct a residential building in Asheville, North Carolina [30].

Floor pavers and roof insulation are made of hempcrete, and it is used as an interior covering for repairing ancient stone walls. The proportion of hemp epitome and lime mix varies depending on the application. Considering the impact of the environmental benefits, such as the possibility of the sequestration of carbon, as well as financial advantages to the

agriculture and infrastructure industries, more research and investigation of hemp lime as a building material is needed. Globally, the industrial hemp industry is still dominated by China, which produces over half of the world's hemp fiber supply. The resurgence of interest in hemp crops can be related to the need for environmentally friendly farming techniques, as well as the awareness of hemp's excellent fiber content and nutritional profile. In 2011, 340 production permits were given to farmers who planted more than 39,000 acres of industrial hemp, primarily in central and western Canada [18,31]. The mechanical properties of the hemp plant compared with other vegetable-based natural fibers are shown in Table 1.

**Table 1.** Mechanical properties of vegetable-based natural fibers modified from Ahmed et al. [7].

Fiber Source	Density (g/cm <sup>3</sup> )	Length (mm)	Tensile Strength (Mpa)	Specific Tensile Strength (Mpa/g.cm <sup>-3</sup> )	Diameter (μm)	Elongation at Break (%)
 Abaca	1.5	-	691	13.35	-	6.5
 Cotton	1.55	35	543.5	360	32.5	22.5
 Bamboo	3.2	-	575	383	32.5	3.1
 Pineapple	1.2	6	1020	708	-	3
 Banana	-	2.5	721	534	-	2
 Jute	1.4	60.75	562.5	230	110	2
 Hemp	1.5	30	820	550	262.5	2.3

Leadership and authorities around the globe are working to avert the drastic consequences of climate change and global warming because of mounting worries about escalating carbon emissions. As a result, awareness of sustainable construction will sky-

rocket in coming years. However, the following problems need the attention of researchers for study and investigation.

The impact of compression on the hydraulicity of hemp concrete mixtures made with lime–pozzolana. Physical treatment has yet to be investigated in terms of its influence on the sensitivity of hemp and lime–pozzolana combinations. There has been very little research focusing on enhancing the mechanical characteristics of hemp concrete. At the moment, only the mechanical characterization of hemp concrete is being investigated. Regarding the microbiological component of hemp concrete’s endurance, there is considerable uncertainty.

## 6. Hemp Uses in Various Industries

### 6.1. Hemp Uses in Textiles

Hemp has long been regarded as a top fiber. Because of its distinctiveness and endurance, the fiber is well liked and has been in high demand since antiquity. Sailors relied on hemp’s strength to keep their boats and canvas in position. As per evidence, Christopher Columbus traveled to the USA on a hemp-rigged ship. Archaeologists’ fieldwork discoveries of 8000 BC graves indicate that hemp textile material was utilized in tombs. Besty Ross fashioned the first American flag out of hemp [1]. The main benefit of utilizing hemp cloth is its remarkable sustainability. Microfibers are discharged into the water every time synthetic fabrics are cleaned, harming marine animals. Even when disposed of, fabricated materials remain in dumps for approximately three centuries. Cotton fabric, although biodegradable, contaminates breakdown sites due to the many chemicals employed across the manufacturing procedure. In contrast, hemp is an organic polymer that decomposes easily. Unlike any other material, it delivers softness, warmth, a cool sensation, and remarkable unmatched durability. Hemp’s major characteristic is its comfort as well as its durability. With usage, the cloth softens progressively. Molds and UV light are inherently resistant to it [32].

It is worth noting that the growth of the hemp fiber industry has encountered several obstacles, since hemp is a specialized fiber. The biggest shortcoming is the absence of contemporary, specialized machinery needed to complete the technical chain. The polymers obtained from hemp should be studied for the results of their interaction with human skin. Making hemp textile fibers economically competitive with other natural fibers requires the acquisition of information from research facilities to industry regarding fiber processing, the development of a hemp-machine-rich market allowing for the creation of innovative technological lines, and the development of new business models [30].

### 6.2. Hemp Uses in Papermaking

In the 12th and 13th centuries, the notion of manufacturing hemp-based paper went from China to Europe, then the rest of the globe. This indicates that hemp used as paper or in the manufacturing of paper is not novel. Hemp-based paper was originally manufactured from discarded ropes, sails, clothing, tatters, and fish traps. Prior to the nineteenth century, hemp fiber processing accounted for 75–80% of total global paper output. Hemp-based paper was popular and frequently utilized. The Declaration of Independence and the United States Constitution were written on hemp paper and then copied on parchment because it was so popular. Hemp is a special kind of plant that may be used to make paper due to its high content of cellulose (Table 1) [33,34]; hemp paper has three times more cellulose than conventional paper, and a triple amount of paper can be generated from one hectare of hemp field [35]. Hemp paper has a number of characteristics that distinguish it from other types of paper: it is extremely long-lasting and does not yellow with age [4], does not have to be bleached, and may be whitened with hydrogen peroxide if it becomes yellow. As a result, unlike paper manufactured from wood, hemp paper does not contain harmful elements such as chlorine or dioxin. When compared with regular wood pulp paper, the chemical processing used throughout the manufacturing process is less hazardous.

Moreover, the greatest benefit of hemp-based paper is its ability to be recycled. Paper manufactured from hemp may be reused 7–8 times, compared with pulpwood paper, which can only be recycled three times [33]. In the existing situation, hemp in paper production really has a great history to build on since wood pulp remains the primary material used in papermaking. Because of the high demand for paper, trees are being chopped down at a rate three times faster than they are growing. As a result, paper manufacturing will become more expensive, and reforestation will attract greater attention [33,34]. Therefore, high-quality hemp will be used as a raw resource much more following the development as well as deployment of a unique technology for the manufacturing of this mash.

### 6.3. Hemp Uses in the Automotive Industry

Plastics, fibers, foam, glass, and rubber remnants account for 25% of vehicle trash by weight, making their disposal a serious challenge in the handling of vehicle disposal. Humanity has planned to take the proper procedures to minimize the environmental impact of combustion engines and to properly manage waste [35]. The fibrous hemp that inspired the use of hemp in the automotive business dates to approximately 1940, when Henry Ford, founder of Ford Motor Co., designed a hemp-based automobile industry [35].

James Meredith, a researcher at Warwick University in the United Kingdom, released a study in 2012 in which he investigated three natural polymers that were tested for specific energy absorption (SEA): untangled hemp, wove flax, and jute. He determined that hemp survived the most SEA, demonstrating that it can bear enormous pressure despite its low bulk. Hemp appears to be a suitable alternative to fiberglass in automobile paneling, according to this research. Today, BMW and Mercedes employ hemp composite in high-end vehicles, and BMW has shown off automobiles like the i3 electric vehicle and the i8 hybrid supercar as prototype cars which are partially made of hemp polymers [36]. Figure 3 shows various vehicles made from hemp fiber and their parts. Canadian company Motive Industries used hemp to create the Kestrel vehicle. It is around 2500 pounds in weight and comes at a very reasonable price. The vehicle's structure is built entirely of hemp and totally withstands impact. The bodyshell's impact resistance was demonstrated because of clearing a safety inspection; unlike steel, the team reshaped it themselves [37]. The automobile sector has a lot of capacity for "green composites," as they strive to maximize components' recyclability and biodegradability. The mechanical strength and the safety of the passengers still need to be researched. The use of modern machines is required to process hemp fibers for the automobile industry.

### 6.4. Hemp Uses in Cosmetic Products

The primary component in hemp, CBD, offers antioxidant and anti-aging effects, which are essential in the beauty business. CBD aids skin healing and regeneration by interacting with the human endocannabinoid system. Anandamide, an endocannabinoid produced by the body, stimulates sebum production. Sebum causes the skin to become oilier and clogs pores, creating a favorable environment for bacterial development and, ultimately, acne [38]. Hemp-based cosmetics, according to experts, provide excellent pollutant protection for the skin, as well as muscular relaxation. Because of such characteristics, it is a great addition to skincare products. Moreover, CBD oil, among the top ten most popular hemp-based cosmetics, is now gaining great traction [38,39]. Because of its standards and principles, another product called CBD skin salve has also received positive feedback. Hemp-based products are organic and suitable for even the most sensitive skin types [39]. Hemp chemicals used as ingredients in conditioners, hair-care products, soaps, moisturizers, lip glosses, body lotions, cosmetics, and antiperspirants contain hemp [25].

### 6.5. Hemp Uses in Plastics

According to data released in 2017, just 9% of all plastic produced gets recycled, with the remaining 79% ending in dumps and organic surroundings [40]. If the current trend of toxic waste continues to build up, the environment will be polluted by nearly 12 billion



metric tons of plastic by 2050 [40]. Plastics, which are petroleum-based chemicals, have extremely negative and destructive impacts on the environment. The trash generated as a by-product of the plastic manufacturing process is detrimental to our land, water, and animals. Because of their numerous negative consequences, environmentally friendly methods for plastics are required to slow the rate of climate change and mitigate environmental concerns. These attempts to develop hygienic and ecological alternatives will someday be available to help to decrease the undesirable impact on the planet [40].

Hemp-based plastics offer a viable alternative for preserving polymers' usability by reducing our environmental impact. Such bioplastics are natural-fiber-reinforced biomaterials with low costs that might be utilized to replace petroleum goods. Biopolymer made from hemp is produced from the stems of the plant, which contain a high cellulose content. In comparison to wood (40% wood), flax (75% flax), and cotton (70% cotton), hemp has the greatest cellulose content (65–70%) [40]. Currently, melding hemp fibers produces many types of hemp biocomposites. Ordinary hemp-fiber-reinforced plastics (comprising 30–40% hemp fibers) and hemp-fiber-reinforced plastics (comprising 100% hemp fibers) are currently available. Hemp biopolymers are multiple times firmer than polypropylene. They are less polluting, better lasting, and recyclable due to the fiber infusion. Organizations like Kanesis and Zoeform push for using hemp in the production of composites [25].

In addition, hemp seems to have a great ability to handle and collect heavy metals such as lead (Pb), nickel (Ni), and cadmium (Cd) and afterward preserve it in its root, allowing the hemp plant to be harvested with dangerous chemicals. A broad variety of hemp cultivars are suitable for phytoremediation, and they are very resistant to Cd stress [25]. Similar research has discovered that the largest amounts of heavy metal accumulation were detected in the leaves, even though they were dispersed throughout the plant. Heavy metals, such as Cu ( $1530 \text{ mg kg}^{-1}$ ), Cd ( $151 \text{ mg kg}^{-1}$ ), and Ni ( $123 \text{ mg kg}^{-1}$ ), were found in hemp plant leaves taken from a polluted heavy metal location in Pakistan [41]. Compared with conventional plastics, hemp polymers are not as robust. They might not be able to withstand misuse or abuse, which might cause them to be thrown away rather than recycled. The availability of hemp polymers is still limited. This will require time for people to grow accustomed to them and for businesses to learn how to build them. Products made with hemp plastic may only be rarely available from retailers up until that point.

## 7. Hemp's Contribution to Carbon Sequestration

Because of its rapid expansion and innovation, hemp is one of the quickest CO<sub>2</sub>-to-biomass conversion mechanisms. Hemp has been demonstrated to be an efficient carbon sink, absorbing more CO<sub>2</sub> per hectare than other commercial crops or even forests. One hectare of hemp, for example, can absorb 22 tons of CO<sub>2</sub> [42]. High-biomass crops, such as hemp, can sequester carbon through photosynthesis and then store it in the plant's body and roots through bio-sequestration. The harvested hemp stem stores most of the carbon, with little retained in the roots and leaves. Hemp has the potential to create at least 13 tons of biochar per acre per year [42].

Because of its high biomass and energy concentration per hectare, hemp has been identified as one of the energy plants [43]. Hemp plants' weed-suppressing powers, minimal pesticide requirements, and soil health improvement capabilities make them, even more, energy-efficient. Hemp's fuel characteristics are comparable to or better than those of other solid biofuels such as cereal straw and wood [43]. Hemp, for example, has a heat of combustion equivalent to maize ( $18 \text{ MJ kg}^{-1}$ ), somewhat larger than Jerusalem artichoke ( $16.5 \text{ MJ kg}^{-1}$ ), and significantly less than *Miscanthus sp.* ( $19.8 \text{ MJ kg}^{-1}$ ) [44].

## 8. Significant Health Advantages

Hemp seed has been linked to a slew of health benefits and possible treatments. Hemp seed has a favorable omega-6 to omega-3 PUFA ratio, which would enhance cardiovascular fitness, alleviate osteoporosis symptoms, and alleviate eczema problems [45]. Hemp seed has been studied as a dietary intervention for cardiovascular health. For four weeks,

30 mL of hemp seed oil was added to the human diet on a regular basis causing beneficial improvements in the blood lipid profile by increasing linoleic acid (LA) and alpha-linolenic acid (ALA) levels [46]. According to another study, rats who were fed a diet enriched with either 5% or 10% hemp seed for 12 weeks had increased plasma levels of LA and ALA [47].

Following the meal, post-ischemic heart function was evaluated; the ability of the heart to recuperate from ischemia-reperfusion injury appears to be closely related to the PUFA contents of hemp seed [48].

Since Munson et al. [49] published the first research demonstrating the anti-cancer benefits of cannabis phytochemicals, there have been significant advancements in comprehending the processes and targeted cannabinoids' activity. Findings demonstrate that phyto-cannabinoids, endo-cannabinoids, and synthetic cannabinoids have characteristics that can cure brain, prostate, breast, skin, pancreatic, and colon cancer. Cannabinoids appear to have a part in determining cellular processes that cause anti-proliferative, anti-metastatic, anti-angiogenic, and pro-apoptotic responses in both in vitro and in vivo models [50]. CBD has also been studied for its potential use in prostatic and carcinoma therapy; Sarfaraz et al. [51] discovered that CBD treatment of androgen-responsive human prostate cancer cells causes a pro-apoptotic reaction, inhibits the growth of cells, and decreases production of antigens, particularly to the prostate, which is normally increased in malignant cells. Among various organic cannabinoids studied on breast cancer cell lines, CBD extracts demonstrated the most potent antitumor effect, while causing considerably less harm to cells that are functional [51]. In a carcinoma cell, CBD induced apoptosis by activating the CB2 receptor, which was overexpressed [52].

CBD has also been shown to help with the most common neurological condition, epilepsy. Perucca [53] investigated epileptic occurrence and discovered that CBD possesses therapeutic effects; it was used in temporal lobe seizures in an intensive pilocarpine type and a penicillin model to corroborate those results. Both investigations showed a reduction in the intensity and fatality of seizures. CBD therapy is even helpful for patients with treatment-resistant epilepsy; with lengthy treatment, side events, intensity, and the number of convulsions were dramatically and sustainably decreased [54]. Numerous medical researchers have described the use of cannabinoids to alleviate stiffness, discomfort, and impaired bladder control in multiple sclerosis (MS) patients. THC/CBD oromucosal spray (Sativex), a new cannabis treatment, has been offered to individuals experiencing nerve problems, which may be problematic to control with standard medicines. Placebo-controlled research discovered that the spray might reduce MS-induced neuropathic discomfort [55]. An identical spray is being tried out for symptom relief and has been shown to reduce spasticity incidence and severity while having little deleterious impact on cognition. This might be related to the important role CBD plays in reducing THC's intoxicating effects. A spray identical to this one given to properly treated MS individuals decreased sleep and pain disruption. In the active therapy group, THC/CBD extracted supplements were administered to MS sufferers, and daily self-reports of contraction frequency, motion, and capacity to fall asleep were enhanced [56].

Hemp oil has been utilized in the past in traditional Chinese folk medicine to alleviate chronic knee pain and enhance blood circulation in individuals with rheumatoid arthritis (RA) [57]. RA is a kind of autoimmune inflammatory illness characterized largely by irritation and hypertrophy of the synovial membrane. According to Jeong et al. [58], hemp seed oil promotes the production of reactive oxygen species (ROS), lipid storage, the production of endoplasmic reticulum stress markers, which act as anti-rheumatoid factors in downstream processes, and improved blood circulation, providing additional relief to RA patients. Hammell et al. [59] discovered that CBD can help with arthritic discomfort. Topical CBD administration was studied using a rat model; inflammation of the knees, pain evaluations, synovial tissue stiffness, immune cell invasion, and inflammatory biomarkers were all dramatically decreased in proportion to the drug response [59]. Another kind of arthritis was treated with a CBD-based oil: osteoarthritis in dogs. Canines who received

therapy experienced much less discomfort than those who did not, enabling such dogs to become more energetic and relaxed [60].

The therapeutic potential of hemp has been widely recognized since the beginning, even before solid evidence. For over 6000 years, people have been writing about their experiences with hemp. These documents have been extremely helpful in disseminating information about its therapeutic usage. Cannabis usage was originally documented about 1000 BC in medical literature such as ‘Sushrita.’ Furthermore, hemp has been alluded to in Indian literature such as in the Tajnighuntu and Rajbulubha for its usage in the cure of multiple ailments linked to phlegm clearing and flatulence expulsion [61]. Several fields of therapy with hemp compounds have received less attention than those mentioned above. Hemp seed oil has been shown to be effective in treating stultification [62]. Furthermore, mouse studies have demonstrated that consuming hemp seeds improves memory and learning produced by chemical treatments [63].

CBD has immune-suppressive effects, such as reducing inflammatory responses, suppressing cellular and humoral resistance, and inducing death in certain lymphocytes; such activities are beneficial in the treatment of inflammatory diseases [64]. Diabetes type 1 is an instance of an inflammatory disease that may benefit from CBD preventive therapy; non-obese diabetic mice given CBD had delayed diabetes onset and considerably reduced leukocyte activation compared with mice given a control [65]. Using an experimental mouse model, hemp seeds revealed anti-neuroinflammatory effects [66]. Additionally, researchers discovered that pregnant women who used cannabis had worse mental health, including depression and anxiety. The fetus and/or newborn child may be affected by cannabis usage during pregnancy, just like using cigarettes or alcohol. In fact, research indicates that using cannabis while pregnant raises placental vascular resistance, which reduces the amount of oxygen reaching the placenta and slows the fetus’ development [67,68]. The absence of protracted research is the primary restriction for treating all of the previously listed health problems. There is almost no study on the protracted consequences, particularly of CBD-derived hemp-based medicines. Short-term studies suggest that it is well-accepted and has few negative side effects. In addition to the flavonoids found, the cannabinoids and terpenes in cannabis interact constantly to give the mentioned health advantages [69]. The terpenes obtained from hemp and their healing properties are mentioned in Table 2.

**Table 2.** Biodynamic effects of the main terpenes found in *Cannabis sativa* L. [69].

Terpene	Biodynamic Effect
$\beta$ -caryophyllene	Anti-viral, antioxidant, anti-inflammatory, anticancerogenic, analgesic, anxiolytic, antibacterial, and antifungal.
$\beta$ -myrcene	Antioxidant, anti-inflammatory, anticancerogenic, analgesic, sedative, muscle relaxant, and antipsychotic.
$\alpha$ -pinene	Anti-inflammatory, antibacterial, bronchodilator, antiseptic, and gastroprotective.
$\alpha$ -humulene	Anti-inflammatory, anticancerogenic, antifungal, and analgesic.
limonene	Antibacterial, antifungal, antimicrobial, antiproliferative, anxiolytic, antidepressant, antispasmodic, and gastroprotective.
linalool	Antineoplastic, antiepileptic, anticonvulsant, sedative, anxiolytic, antipsychotic, analgesic, antidepressant, and anesthetic.

Due to hemp’s medicinal capabilities, new avenues of study into hemp as a pharmaceutical have been opened. Many formulations were created as pharmaceutical businesses became aware of the characteristics of hemp and its unique components. Hemp joined the pharmaceutical industry in 2003, and several global conglomerates have turned their emphasis to hemp medicinal goods. GW Pharmaceutical collaborated and signed unique promotion arrangements. Several medications are now FDA (Food and Drug Administration) authorized and available in drugstores. In the future, the use of such medications will become further widespread, and they could be widely accessible in the marketplace [66]. Most of the research is focused on the relationships between CBD and neurologic medicines.

It must be highlighted that interactions between other medications and CBD, due to shared metabolic pathways, would influence CBD kinetics. CBD's kinetic behavior in humans after long-term exposure is not entirely known [65]. The idea that the long-term buildup seen in rats may also develop in people is concerning and constitutes a knowledge gap [65]. There is an indication that CBD can cause human diarrhea, which can disrupt digestive health. Experience and understanding of this diarrhea-inducing impact after immediate and long-term exposure to CBD in groups of healthy humans is lacking. Additionally, the mechanism through which CBD may have this diarrhea-inducing action is not well understood [65]. There are significant gaps in the literature regarding the possible long-term effects of CBD in healthy persons as well as the interaction of CBD with several molecular targets that are also involved in the control of neurophysiological processes; a significant information gap exists in research conducted on animals about the possible teratogenic and reprotoxic consequences of CBD exposure, particularly in females and in connection to lower dosages [69].

### 9. Applications of Hemp in Food and Nutraceuticals

Hemp has been utilized as a food source for about 3000 centuries; once it was an important food item for the Chinese and Nepalese [28]. The value of hemp as a food source faded as its hallucinogenic effects gained prominence and its production became outlawed. As dietitians examined hemp, it was resurrected as a highly nutritious dietary source very rich in vitamins, namely vitamin E (90 mg 100 g<sup>-1</sup>), thiamine (0.4 mg 100 g<sup>-1</sup>), and riboflavin (0.1 mg 100 g<sup>-1</sup>), and minerals, particularly P (1160 mg 100 g<sup>-1</sup>), K (859 mg 100 g<sup>-1</sup>), Mg (483 mg 100 g<sup>-1</sup>), and Ca (145 mg 100 g<sup>-1</sup>) [70]. The inclusion of hemp seed protein, termed edestin, contributes to its distinctive nutritional quality; hemp contains the largest quantity of this protein in the seeds of any plant in the world. Hemp is the main source of ALA and an excellent fat component of a balanced diet, especially for individuals who do not eat eggs or seafood [26]. Hemp seeds contain phytosterols, which help to lower cholesterol levels in the body by removing fat build-up inside the vessels. As the nutritional benefits of hemp seed were understood, a slew of new products hit the market. Just a few examples are hemp seed margarine, hemp seed oils, hemp dairy, and hemp flour [28].

Consumers are increasingly fascinated by how their food may help them to solve health deficiencies and improve their overall well-being. Over a decade ago, two-thirds of supermarket consumers stated their purchases were heavily affected by the desire to avoid, manage, or treat a specific health problem [70,71]. Food experts have been focusing on these consumers' needs by researching and publicizing the extra health advantages and bio-active characteristics that functional foods bring. Recently, several unusual oils obtained from plants, including hemp seed oil, have gained recognition for providing more than simply culinary use and providing goods, but also have therapeutic use and the possibility for pharmaceutical use [72]. Moreover, hemp seeds have also been milled to obtain functional food ingredients and vegetable proteins, which can be included in drink mixes, sweetened yogurt, bakery items, and other foods [72]. Metz and Selg-Mann [73] created a flavoring sauce from fermented hemp seeds.

Because of the macro- and micronutrients as well as the phytochemicals, industrial hemp seed production has recently sparked attention. Cannabis seeds are a completely healthy choice that contain bioactive compounds that can help with health issues beyond simple nutrition. Hemp seed contains readily digested proteins (20–25%), polyunsaturated fatty acids (PUFA), substantial lipids (25–35%), and carbohydrates (20–30%) rich in insoluble fiber. Hemp seed proteins are suitable for human and animal consumption since they are composed mostly of high-quality proteins, i.e., edestin and albumin, both of which are high in essential amino acids [74]. The high concentrations of PUFA, LA (omega-6), and ALA (omega-3) are beneficial and considered balanced for human nutrition [74]. LA values vary from 64% to 72% of total fatty acid makeup [71]. This variance can be attributed to differences in hemp cultivars, farming practices, and processing and storage conditions. According to nutritional guidelines, fats should account for 15–20% of daily calorie intake,

with essential fatty acids accounting for one-third of this amount. This nutritional goal is thought to be achievable with three tablespoons of hemp seed oil [75].

Hemp seeds are rich in tocopherol isomers, including beta-tocopherol, gamma-tocopherol, alpha-tocopherol, and delta-tocopherol, with gamma-tocopherol being the most abundant [76]. Tocopherols are natural antioxidants that have been shown to lower the risk of oxidative-degeneration-related diseases [77]. Terpenes and polyphenols have also been discovered; they contribute to the aroma as well as the innate antioxidant properties. Flavonoids, such as flavanones, flavanols, and isoflavones, were the most prevalent phenolic chemicals, as shown in Table 3 [78].

**Table 3.** Different flavonoids extracted from the hemp plant and their health benefits.

S/No	Compounds	Functions	References
1	Apigenin	Anti-inflammatory, antioxidant, promotes or reduces the carbohydrate exposure of membrane glycolipids	[79,80]
2	Luteolin	Antioxidant, promotes or reduces the carbohydrate exposure of membrane glycolipids	[79,80]
3	Kaempferol	Antioxidant, promotes or reduces the carbohydrate exposure of membrane glycolipids	[79,80]
4	Quercetin	Antioxidant, promotes or reduces the carbohydrate exposure of membrane glycolipids	[79–81]
5	Orientin	Antifungal	[79–81]
6	Silymarin	Anti-cancer potential	[79,81]
7	Quercetin 3-O-rutinoside	Used in the treatment of heart diseases	[79–81]
9	Cannflavin A	Anti-inflammatory agent; anti-cancer agent	[79–81]
10	Cannflavin B	Anti-inflammatory agent; anti-cancer agent	[79–81]
11	Cannflavin C	Anti-inflammatory agent; anti-cancer agent	[80,81]

As demand rises, it is anticipated that hemp use in the food and supplement industries will increase over the next several years, with significant social, economic, and hygienic ramifications. Legal and administrative actions must encourage sufficient clinical research to confirm or refute the product safety derived from hemp, as industry and the research community have not yet done this unilaterally. There is a need for well-conducted, randomized, placebo-controlled, double-blind clinical research on the benefits of hemp-derived functional food components and products, dietary supplements, and nutraceuticals on human health promotion. Additional research must concentrate on examining industrial hemp's various bioactive phytochemicals, like polyphenols and isoprenoids [72]. It is yet unclear how hemp's polyphenols and isoprenoids affect the sensory appeal, shelf life, and health advantages of the finished goods. Consequently, the hemp market is beginning to thrive all over the world. To fulfill industrial hemp's commercial viability as a continuous source of high-value functional food components and nutraceutical goods, regulatory bodies must separate it from medicinal cannabis (marijuana) [72,75,78,81].

## 10. Conclusions

Hemp has been grown since prehistoric times to provide nutritional and therapeutic advantages. Nowadays, hemp has also proved to have practical, value-added food and nutraceutical uses. As hemp has been shown to be a blessing to humanity, its economy has a very bright future ahead of it. Because of the numerous uses indicated in terms of its possibility for industrial, economic, and agricultural use, the hemp plant should be provided more encouragement to be grown and used. Many applications of hemp may be pushed to the next level for producing both a green environment and profit, with sufficient strategies for future expansion activities and a clear sense of responsibility. A strong vision and a well-defined plan will pave the path for the discovery of new technologies and concepts. Hemp innovations will enhance the lowering of environmental and health concerns via the manufacturing and utilization of such renewable substances.

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