

Review Article

Reinventing Hemp as Bio Fiber Material for Paper Applications – Past, Present and the Future

ABSTRACT

This review paper gives an overview Hemp known as *Cannabis Sativa*, which has been cultivated and used as an agricultural crop centuries before the Common Era. Hemp has been described as the billion-dollar plant in 1938 but has lost its value in the U.S. and the World due to regulatory and legislature issues since then.

Hemp has seen a new push in the U.S. and other parts of the world with the introduction of legislature in the late 20th century in Europe and other parts of the world and recently in the U.S with the 2018 Farm Bill which allows on a federal level to grow Hemp, pending on individual state regulations, allowing Hemp to become a new sustainable crop for many future applications. However, Hemp research in these areas has stalled due to the complexity of law.

Hemp is used in many countries today that do not have as strict regulations as the U.S. and Europe in a variety of applications such as beauty products, pharmaceuticals, carpets, industrial insulation materials, paper products, cooking oil, personal care products, and textiles as well as biofuel application to replace petroleum-based fuels and gases due to its low lignin and high cellulose level.

In most European countries, and the U.S. cultivars with a level below 0.3% THC are allowed. But cultivation is generally subject to reporting. The use of Hemp plants with higher levels is strictly forbidden in most countries.

Usage of Hemp fibers as sustainable environmentally friendly fiber source for energy and industrial applications are slowly moving forwards at present time, due to the fact that there is barely practical large-scale research and pilot installations available about its industrial application potential.

Keywords: Biofiber, biofuel, fiber material, Hemp, papermaking, packaging, sustainability

1. INTRODUCTION

Hemp was used centuries before the Before the Common Era (BCE) and is one of the oldest fibers materials that has been cultivated [1] 5,000 year old pottery from ancient China show images of Hemp rope which also suggest it use dates back even longer. [2]. The birthplace of common Hemp is believed to be in central Asia. The earliest known evidence of Hemp fiber use to about 8,000 BCE in Taiwan [3,4].

Native Americans knew Hemp as the indigenous species (*Apocynumcannabinum*), however the cultivated Hemp species in the colonies was imported and most often the species (*Cannabissativa*) [2].

The Hemp plants have not only long and sturdy fibers, but Hemp plant have also separate male and female plants. The female plants contain a high level of a chemical called delta

nine tetra hydro cannabinol (Δ^9 -THC), chemical formula shown in Figure 1, which is found in a resin produced from unfertilized female flowers, and called today marihuana. Marihuana can also be collected in cakes and is then called hashish. [1,2].

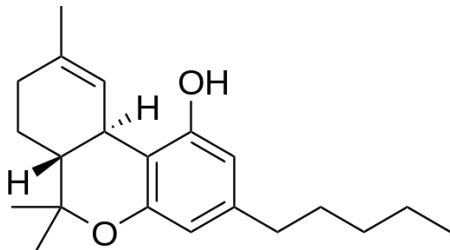


Fig. 1. Δ^9 -tetrahydrocannabinol (Δ^9 -THC), [5].

However, marijuana's hallucinogenic properties if eaten or smoked were known in the 18th century, but no evidence shows that colonial Americans may have taken advantage of this [2]. Farmers at that time during the pre-industrial area had to focus on making a decent living and therefore had to focus on their cash crop that could be transformed into ropes, sacks, and cloth instead on its psychoactive side effects [2].

Historically, Hemp has been applied preferably in the manufacture of heavy-duty materials such as sailcloth, canvas cloth, sackcloth, and cordage. Finer textile materials have been preferably produced from flax material. From flax material generally, it is easier to produce finer yarns as from flax and therefore Hemp was often preferred for technical applications [6]. However, both flax and Hemp are fiber materials that have been used since centuries BCE [7]. The application of Hemp in paper products dates back eventually even before the nominal invention of papermaking in ancient China during the Han Dynasty (105 CE) by Cai Lun [6,8,9].

Hemp has been a crucial material in the history of the United States and European and continues to be a useful material today, because of the strength and durability of its fibers as well as its variety of applications as well as today as a rediscovered sustainable fiber material [1].

Industrial Hemp (*Cannabis sativa* L.) has a long history of utilization in Europe. The easily sown seeds, strong bast fibers, and edible seeds made the plant a valuable cash crop during early plant domestication [10]. The multifaceted plant has provided good fibers for a variety of different applications throughout history, particularly since its rise in production during the 1700s. Hemp has had many applications in a variety of different industries throughout the history of Europe. It has played no small part in the making of empires and armadas. Even today, with the issue of sustainability and environmental awareness, Hemp's potential as a biodegradable material has brought it back to the forefront of research and innovation.

Between the 17th and 20th centuries, Hemp played a significant role in European mercantilism and imperialism [11]. The durability of the Hemp fibers made it a prime resource for making the sails and rope needed for ships, making it a crucial material for shipping and trading, as well as naval warfare. Ship's charts, maps, and logs were made from Hemp paper, too [12]. Therefore, English farmers and their colonial counterparts had to devote a share of their acreage to produce Hemp [Swenson]. In fact, much of the paper used before the 20th century was made with Hemp fibers. Hemp textiles were used in sacking, tarpaulins, and upholstery, and traded to overseas colonies and other markets [13]. Hemp was such an important material for shipping that in 1800 a governmental committee was set up in Britain to find new sources of Hemp after the supply from Russia was cut off [14]. Spain, too, attempted to find or create other sources of Hemp fibers by promoting

Hemp cultivation in its American colonies [15]. However, even after attempting to find alternative fibers to use in sails and cordage, the Spanish empire relied on Russian Hemp because the demand for Hemp fibers was still too great to be fulfilled by colonial production. Despite attempts by multiple countries to supplant Russian Hemp, the need for fiber was too high to be self-sufficient, implying that Hemp was an important resource that could not be substituted at the time.

Hemp has been cultivated in the British Colonies in the Americas before 1619 [16] for commercial use to supplement the ever-growing demand of Hemp fibers for the British industry. Hemp yields at least twice as much fiber than flax per acre [2]. This advantage made Hemp the main agricultural export product of the British colonies. Hemp fiber was used to manufacture textile products, ropes, paper, uniform, tents, Canastota wagon covers, sails and currency [17,18].

Because Hemp fibers are resistant to natural decay, they are a ideal fiber material for maritime applications [19].

Most of the Hemp fiber production in the British colonies was meant to be sent back to England. However, some settlers want to keep the Hemp fibers in the Americas [20].

The two main fibers that were used in the colony's era were flax and Hemp. Flax fibers are short and fine, which is better suitable for manufacturing clothing rather than paper. Hemp fibers on the other hand have double the yield than flax fibers under ideal conditions [21].

The process and breaking down Hemp fibers was very hard and an extremely labor intensive and long process.

The Hemp and cotton fibers would grow a lot better in the Americas than in Europe, so the British had most of their plantation's in the Americas. The British colonies compelled the settlers to grow Hemp as a main crop [2,21].

During the Revolutionary war the price of Hemp increased significantly due to the demand to make sails, rope and cordage for the colonies' ships. The Hemp fibers were used to produce uniforms, tents and canvas during the Revolutionary war. Hemp had a huge impact on the colonial America economy and was one of biggest exports of colonial Americas.[2], and over 8000 Hemp plantations existed mostly in the south during the colonial times [2,16,19,22].

As the cultivation of Hemp travels westward toward Kentucky and Illinois due to the increased demand for sailcloth's and cordage in the mid-1800s. At the same time the cultivation of Hemp stopped mostly in the south due to the demand of tobacco and cotton production in the (colonies) southern states.

With the invention of steam ships, the demand of Hemp fibers in the Midwest of United States started to decline. The end of the sailing navies, and the ships being powered by steam engines decrease the need for sailcloth's and cordage, in the 19th century [23].

Majority of the states in United States stopped the production of Hemp right before the start of the civil war besides Kentucky and some of Midwest states. The stages of growing and processing Hemp were still relying on hand labor until 1920s. The International Harvester Company made a steam power machine that can process Hemp fibers to the desired quality that customers want the Hemp fibers. The Hemp-processing would turn the location of stalks in the field during the retting process. The retting process soaks the fibers into water, which breaks down the fiber faster than having no moisture on the fibers [24]. The turn of the location of fibers will cause the Hemp fibers to break down faster. The Hemp's fibers were still used for paper, cordage, rope, textiles, and clothes between the end of the 19th century and the 1930's till World War II. During that time Hemp products were replaced by other fibers from cotton and wood [25]. New technology such as the cotton made cotton a cheaper, less labor-intensive source of fiber than Hemp [2].

In 1937, the United States Congress passed the Marijuana Tax Act [22]. The Marijuana Tax Act requires registration and licensing of all Hemp growing and processing to restrict the production of marijuana. The law led to a decrease of Hemp processing mills since the regulations added more cost to the production of Hemp. Most of the agricultural Hemp

growers decide to produce other products like tobacco, cotton, and food crops to save cost and stay in business.

The production of Hemp kept declining until World War 2, where the United States federal government instituted an emergency program to increase the production of Hemp. The needs of cordage, soldier's uniform, and other materials for World War 2 [26]. After the war ended, the Marijuana Tax Act was put back in place and Hemp production went rapidly declining again.

Then in the 1990s Hemp production was reauthorized throughout the European Union and demand was revitalized because of a new interest in natural resources and energy conservation [27,28,29].

In 2014, the Section 7606 of the Agricultural Act (the Farm Bill) changed the legal status of Hemp, allowing the growth by researchers at an institute of higher education, by state Departments of Agriculture, or by farmers participating in a research program [30]. All growth operations needed to be permitted and overseen by a state Department of Agriculture [31].

Pennsylvania allowed the cultivation of Hemp in 2017 for research purposes, but only under the supervision of the Pennsylvania Department of Agriculture. In the US the interest of commercial production of Hemp has increased since then and Hemp is produced today in 38 U.S. states for the use of its fibers or for research purposes [32]. Nevertheless, there are also some Hemp growths for dual purposes. But this requires not only specialized harvesting machinery but also management.

The restriction on Hemp production in the USA lasted till 2018 with the passage of the 2019 Farm Bill, which allows on a federal level to grow Hemp, pending on state regulations [30].

In the US the Farm bill is guiding industrial Hemp production of *Cannabis sativa L.* and any derivate thereof with a THC level of not more than 0.3% on a dry weight basis. This removes industrial Hemp from the Controlled Substance Act (CSA) and allows the growing and cultivation of Hemp for research, agricultural use, and pilot program in wee state law permits the production of industrial Hemp. However, the legal assessment for growing and cultivating Hemp under a pilot and research program is very complicated and strictly enforced [32, 33].

At present time the cultivation of industrial Hemp is not legalized in the State of Idaho, South Dakota, Mississippi, District of Columbia, as well las the 5 US territories American Samoa, Guam, Northern Mariana Islands, Puerto Ricco and the U.S. Virgin Islands [1,32].

Currently industrial Hemp production is allowed in at least 38 US States but requires the grower to be register under a program that requires testing and inspection with the state and/or federal government [34].

This created a new opportunity for many states in the United States in which the selling of CBD oils and the recreational marijuana uses is allowed, creating a resurged the usage of Hemp into products [35].

Today CBD containing products are available in in a large variety in almost every grocery store. Products range from CBD oil itself and CBD oil containing products such as tinctures, masks and gels or medical products such as transdermal delivery systems [1,36].

The cosmetic industry benefits a lot from the rising demand on CBD containing crèmes, tinctures, and other alike products.

For instance, in most European countries, cultivars with a level below 0.3% THC are allowed for fiber, seed and cannabidiol production [37]. Italy however only allows cultivars with an THC level under 0.2% [38].

For that reason, modern Hemp is selectively bred and currently 51 Hemp cultivars have been approved for industrial purposes by the European Union [39].

All this has led in recent years, that Hemp production increasing as the demand for new and old applications of Hemp fiber increases.

2. HEMP CULTIVATION

Hemp, one of the oldest annual crops [1,40], can be considered a multi-purpose crop plant for many industrial applications such as paper, textile, rope, due to Hemp stem cellulose and fiber, home furnishings, industrial and recreational oils [40], which can be obtained via either cold pressing, water and/or hydrocarbon solvent or through supercritical carbon dioxide fluid extraction, and microwave assisted extraction [41,42,43]. Hemp has applications for the food and cosmetics industry [44], and the pharmaceutical industry, due to its many medicinal and therapeutic properties such as analgesic, antibacterial, antidiabetic, antiinflammatory, antispasm effects [1].

To supply Hemp for today's potential industrial applications large scale agricultural cultivation is required.

2.1 Agricultural Cultivation

According to the Textile Exchange the USA produced in 2021 approximately 15,113,000 short tons of Hemp on 12,690 acres, whereas global production reached approximately 302,451,000 short tons on 195,985 acres [40]

Since 2015 land use for Hemp cultivation has increased from 19,970 hectares to 32,000 in 2021 [40,45]. The total production of Hemp increased from 94,120 tons in 2015 to 152,820 tons in 2019.

According to the Textile Exchange, Hemp grown in the U.S. represents only 5% of the annual production with Poland and North Korea at the same level. France and China represent 47% and 24% [40].

Cultivating Hemp requires well-drained soil with pH between 6.0 and 7.0. Hemp does not grow well on wet soils, or soils with a high clay content. In addition, Hemp is sensitive to soil crusting and soil compaction. Hemp is also considered a short-day plant, meaning, it requires less than twelve hours of sunlight.

Recommendation for soil fertilization of Hemp plants have been developed by the Penn state Agricultural Analytical Services for a crop with a 1,500-pound yield potential would be 150 pounds of nitrogen (N), 30 pounds of phosphate (P_2O_5), and 20 pounds of potash (K_2O) [31]. Just like forage crops, Hemp can be grown in a tilled seedbed, which is firm, level and relatively fine. Even though they have not been volubly in trials, Hemp is sensitive to be affected by diseases like gray mold (*Botrytis cinerea*), white mold (*Sclerotinia sclerotiorum*), bacterial leaf spots, viruses, and Pythium root rot and blight during establishment. Additionally, insect like cutworm, grubs, flea beetles, grasshoppers, and aphids, Japanese beetle (only attracted to male plants as current trials show) or other animals such as Mourning doves or Slugs, are likely to destroy Hemp plants, especially when harvesting is delayed. However, the destruction through woodchucks or deer contrasts with other crops, slightly uncommon and not as fatal [1].

There are both long and short seasoned plants. The long-seasoned plants should be planted in May to early June. Short seasoned Canadian growths can also just be planted from mid to late June [1].

Industrial Hemp should be planted in a depth of $\frac{1}{2}$ to $\frac{3}{4}$ inch. Depending on the variety, general planting rates from 25 to 35 pounds per acre are recommended for industrial Hemp. Further depending on the variety is the sort of planting. It can be planted in rows, like corn. Then the cultivation requires some mechanical weed control, since there are no herbicides established on Hemp so far. Further control offers no-till methods, which use burndown herbicides. It can also be planted like small grain, with a grain. "For fiber production, planting is best done in drilled stands at seeding rates of 35–50 pounds per acre, which should result in stands of around 15 plants per square foot [1,46].

2.2 Harvesting

The plants are still green, Hemp is harvested for Hempseeds when it begins to shatter. Nevertheless, about 70 percent of seeds will be ripe at this time, and the moisture is about 22-30 percent [1].

When Hemp is cultivated for its fiber, the harvesting usually takes part between early bloom and seed set, depending on the quality of the fiber.

Due to the strength of the fibers in the stems harvesting with combine might cause problems as the fibers wrapping in the combine can cause damage.

After the Hemp is cut, it must undergo a process called retting. The bonds between the two different types of fibers in the Hemp plant, the bast (the outer long fibers) and the hurds (inner short fibers) are being severed [1].

The most common process for that matter of fact is called field retting and involves leaving the crop in the field for up to five weeks to allow a field decomposition process to occur. Windrows are raked two or three times before harvest to dry and remove leaf materials. Afterwards, the crop is dried and baled in round or square bales and 'hauled to a storage facility [1].

Before the plant material is manufactured into the final product, the bast and hurds are separated [1].

Cultivating Cannabis can have environmental impacts. Soil pollution, pollution of surface or ground water or any other contaminations are possible, due to the handling of pesticides and other chemicals. Yet, Cannabis is an ecofriendly plant, and can even be utilized for soil regeneration in highly contaminated areas [47,48].

2.2 Hemp Processing

The Hemp plant is one of the oldest plant used in the history of mankind. Agricultural and industrial use of Hemp utilizes the whole plant.

Hemp seeds can be pressed to Hemp oil which is used as dietary supplement due to the above-described ingredients. Leftovers after pressing are used as feed for life stock applications.

Hemp leaves are used in tea and tea mixtures and the production of etheric oils together with Hemp flowers, used as food flavoring fragrance in perfumes and laundry detergents.

Hemp fibers from the Hemp stem are utilized as fiber material in textile, paper, as isolation materials, ropes, concrete, and other building applications.

The remaining Hemp fiber material can be used as bedding material and composite fiber board [48,49].

Since drugs can be obtained from the leaves and female flowers of some Hemp varieties, there was a ban on cultivation. And the legislature is moving forward to reintroduce Hemp as sustainable bio fiber material [50,51]. In Germany from 1982. Low-intoxicant varieties with a THC (tetrahydrocannabinol) content of less than 0.2% have been approved since 1996 in Germany for example. However, cultivation is generally subject to reporting [50].

In the U.S. the USDA released in 2021 the final rule for regulating the domestic production of Hemp [51]. In the U.S. a THC level of less than 0.3% in industrial Hemp is required and requires permitting [30].

After harvesting the Hemp plant fibers go through a variety of processing steps that include post-harvest processing stages before Hemp fiber can be utilized for various industrial applications.

Hemp seed harvesting is mostly done manually at smaller farms for the production of seeds and oil products by farm workers which collect the seeds for further processing into products. to collect. Larger farms might utilize harvesting machines such as modified combines and specialized Hemp harvesting equipment which adds obstacles to economical hemp farming operations [52]. Therefore, research and development are still needed to optimize equipment and harvesting operations.

Hemp plants can reach a height of approximately 3.5 meters. Before Hemp fibers can be used in a finished product various process steps that may include: a) retting, b) decorticating, c) scutching (for long fiber), d) degumming, e) cottonizing/mechanical softening (if not degummed), f) hackling, g) carding, h) drawing, i) roving, j) spinning, k) knitting/ weaving, l) finishing (including bleaching and dyeing), and m) cutting and sewing. are

necessary to turn the Hemp material into usable fibers and or textile products. For non-wovens, there are far fewer stages such as retting, decortication, cleaning, carding [40]. Harvesting machines cut the Hemp plant close to the ground, feed the long stalks through the machine and shorten them to approx. 60 cm long pieces to make further processing easier. The shortened Hemp straw remains in the field for two to four weeks for so-called field retting and is turned once or twice during this time.

During the retting process, which is a biological process utilizing microorganisms such as bacteria or fungi produce enzymes, that dissolve the cementing substances (pectin, lignin) between the fibers and the remaining stem and expose the fibers. Roasting significantly simplifies the subsequent mechanical pulping of the fibers and increases the yield and fineness of the fibers. After roasting, the Hemp straw is pressed into bales on dry days and stored in a dry place until the fibers are digested. Hemp fibers can be stored over several years without any loss of quality.

The fiber bales can then be processed in fiber pulping plants. The wood core of the stem (the latter "shives") is broken, and the fibers separate from the wood. Depending on further processing, fiber bundles of varying fineness and length distribution remain [53]

Cellulose production from Hemp fibers material for paper making can then be processed with a pulping process. However, these processes are still in the development / laboratory stage. In the recent past and present laboratory trials on processing hem material cut into 25 mm long pieces have been done using the Kraft pulping process, the paper industries most common pulping method, developed by a German scientist named Carl Friedrich Dahl in 1879, which received a US. Patent with number 229,935 in 1884 [6a]. by substituting sodium sulphate with sodium carbonate, a less expensive material. This allowed replacing the alkali lost in the pulping and chemical recovery process. In 1884 C.F. Dahl obtained US. Patent 229,935 [54,55,56,58].

No large-scale trials have been performed because not enough hem is available in the US. According to the 2023 Textile Exchange in the U.S. 15,111 short tons of Hemp are grown on 12,690 acres. Pulping Hemp, depending on the pulping process conditions can yield 46% and 77% of cellulose [57,59]. Assuming all Hemp biomasses in the U.S. can be used for paper production a medium paper machine producing 500 t/d of paper can only be operated for 15 days and a yearly operation producing Hemp packaging paper would require a raw Hemp biomass supply of approximately 367,700 short tons grown on 308,748 acres in the U.S., which is approximately 65,000 tons and over the total Hemp grown worldwide. Therefore, Hemp at present time and in the near future can only be used for small specialty paper and packaging application yielding a few tons of specialty paper products, because the needed agricultural area, producing the Hemp biomass, processing facilities, pulping facilities and needed infrastructure are not existent and have not been developed to sustain a full-grown paper production on large industrial scale. In addition, most of the currently produced hem is used for other industrial applications and would not be available for paper production.

3. HEMP AS A FUTURE FIBER RESOURCE FOR INDUSTRY

Hemp is one of the most versatile plants and one of the oldest annual crops with multi-purpose cultivation for a large array of products for food, cosmetics, medical and pharmaceutical, and industrial applications. On the one hand, Paper and textile production is possible due to Hemp stem cellulose and fiber, on the other hand Hemp seed oil, which is obtained via either cold pressing, hydrocarbon solvent or through supercritical carbon dioxide fluid extraction. It is suited not only for the pharmaceutical industry, due to its many medicinal and therapeutic properties such as analgesic, antibacterial, antidiabetic, anti-inflammatory, antispasm, but also for the food and cosmetic industry [44].

3.1 Food Industry

Many products today contain at least traces of Hemp and Hemp as food ingredient has become more and more popular over the years. Hemp seeds are healthy and rich on unsaturated acids and contains a rare ratio of Omega-6 linoleic and Omega-3 α -linolenic acid with a ratio of 3:1, which makes it an ideal product for vegetarian diets [39].

Omega-3 fatty acids prevent aging, are rich on protein, enzymes, terpenes, Vitamin E, Magnesium, Iron, and Vitamin B1 and B2, and insoluble fibers. Hemp seeds are use in baking goods, organic muesli, and a variety of food applications. Hemp seeds can be pressed to Hemp oil which is used as dietary supplement due to the above-described ingredients [39,48,49] Hemp seeds and its oil improv immunity and cardiovascular health and is beneficial for hair, nails and skin tissues.

This makes it beneficial for diabetic diets, metabolic process, and low cholesterol and for hormonal balance, due to its rare oil containing g-linolenic acid [39]. Hemp seeds are used in bakery goods, protein flour [1].

3.2 Consumables

Considering the different effects of Cannabis depending on the sort of plant, chemical composition, strength, and homogeneity based on the raw plant material, containing either high or low levels of Δ^9 -THC, you must differ between the consumables. Incidentally, there are products, which are only Cannabis related or just have a placebo effect, such as chewing gums. Nonetheless, there are also cannabis products made for consumption, which have therapeutic or intoxic effects on the human body. For that matter, the cannabinoids must be decarboxylated to their natural form via high temperature. This is not a problem when the food products are baked or heated at high temperature. Popsicles, soft drinks, and any other product that is not subjected to high heat, must contain plant material which has either been aged or heated before.

Nevertheless, a variety of different products entered the food market in the last decades. Primary food products such as chewing gum, mints, chocolate etc., containing lower levels of CBD are gaining interest on the international market, but also, teas for medical treatment are more and more in use and gaining in popularity. In addition, Hemp oil can be purchased as a nutty tasting salad dressing [1,38,48,60-66].

3.3. Cosmetic Industry

Not only the food and the medical industry benefits from the therapeutic properties Hemp offers. Hemp is applied in cosmetics. for hair, nails, and skin tissues [6]. Since not only teenagers, but also grown-up men and women are fighting against acne, CBD oils, masks and other therapeutic products are a possible solution. Due to their antibacterial, anti-inflammatory, fumigating and scouring ability CBD products are ideally suited for cosmetic products, concerning skin issues. Further, cannabinoids are a group of active chemical compounds, which stimulate the viral balance in our body. They are both antiviral and antibacterial and studies already efficacy in the cure of chronic skin conditions such as eczema, acne and psoriasis. The antioxidants contained in the plant can also minimize premature signs of aging [39]. CBD oils or cold pressed Hemp seed oils can be mixed with a variety of other products such as olive oil or grape seed oil for producing a functional and therapeutic cr me. [67]. Shampoos, lip balsam, tinctures, masks, cr mes etc. are the most common beauty products.

Hemp oil is used as personal care products such as soaps, beauty products and moisturizer. Hemp seeds are used in bakery goods, protein flour.

3.4 Medical and Pharmaceutical industry

Utilization of Hemp or more precisely `medical marihuana`, was already cultivated and used in the ancient times, due to its pharmaceutical properties and intoxicating effects [68,69,70]. Medical marihuana, known for its high amounts of tetra hydro cannabinol, which is

responsible for the intoxicating effect and the so called “high-feeling”, was prohibited by the Us Comprehensive Drug Abuse Prevention and Control Act of 1970 in the United States of America [68]. The ban included cannabis of any sort, respectively. Nonetheless, the discovery of a system of endogenous cannabinoid receptors and ligands has created interest for the therapeutic potential of Cannabis once more. Nowadays, almost 30 states in the Us [68] and countries all over the world allow at least the research or use of cannabis for medical or industrial purposes [71, 72,73].

3.5 Technical Applications

Hemp has been used as a fiber for multiple industries in America since the 1700s and has been a great impact to the American’s economy in pre- and past industrial times.

The Popular Mechanics Magazine described Hemp as the new billion-dollar plant in 1938 [74]. Even Today Hemp is still one of the most controversial plants [1,75,76].

Legislature changes as already described, in the recent past allowed Hemp to be rediscovered as a new sustainable fiber source for products like cordage, clothes and paper [3,4,5,25,27], making Hemp fiber material being viewed as a sustainable environmentally friendly fiber material that has beside the recreational marijuana and CBD oil production many applications which include usage of the remaining Hemp fibers as biomass to make paper, insulation, biofuels and cordage.

This increase of Hemp fibers is most likely due to new applications of Hemp fiber in the automobile industry, construction, composition materials, bioenergy sector, and future applications in paper making. Today, Hemp fiber is used in a variety of different new applications fields that were not possible before.

Another promising Hemp fiber application might be the textiles industry. The strength of the fibers makes Hemp textiles hold their shape better and improves durability, but the strength of the Hemp fibers material represents a challenge in the manufacturing process [45]. Hemp clothing also exhibits a variety of desirable properties like being breathable, absorbent, and heat resistant, and more durable [60]. However, Hemp textiles face a variety of obstacles due to Hemp’s history and image as being the same as Cannabis. The prohibition of Hemp production in Europe and the U.S. led to the industry falling behind competitors like cotton because of the lack of research and innovation into less labor-intensive methods and machines for processing Hemp. Besides Hemp fabric, Hemp leather is also a promising future industry, A study of imitation leather made from Hemp fiber found that Hemp leather is more environmentally friendly than bovine leather [77].

While the fibers for textile processing must be as long, fine, and free of shives as possible, technical applications and in particular NFK have only low requirements, which are also reflected in lower fiber prices.

Fine and short Hemp fibers can be processed using injection molding. For fleeces and felts for later molded parts, however, 6 to 10 cm long “technical fibers” are required. In both cases, the lowest possible hive content of less than two percent is desired, as the hives can disrupt further processing - even causing visible surface defects in the finished product [53].

New applications of Hemp fiber, like bio composites for automobiles and insulation, make up a large percentage of the use of Hemp fibers but are still eclipsed using Hemp fibers in pulp and paper [50]. Hemp plastics and composites in the automobile industry are currently used in trunks, headliners, door panels, dashboards, and many other vehicle parts [53]. Research has also been conducted on making Hemp-based bioplastics to replace synthetic plastics because they are 100% biodegradable [78,79].

With the goal of achieving zero-emission and fully decarbonized building stock by 2050, the European Commission may increase the demand for Hemp concrete and Hemp construction materials in the future. Hemp concrete can store more carbon than the emissions generated in its production, making it an excellent material for reducing carbon emissions in the construction industry [80,81].

Hemp's richness of cellulose makes Hemp ideal for biofuel production [73,82], dense flowering varieties offer abundant seed or high CBD to THC ratios, its fibers are used for pulping and as fine fibers for textile products [82,83,84,85].

A rising global energy demand makes energy one of the most important commodities of modern life. Socio-economic development calls for implementing sustainable energy operations for the replacement of fossil-based fuels with economically viable sources [86].

Implementing a sustainable bio energy supply to the already existing fuel system is one potential solution and approach currently undertaken and biomass conversion into biofuels has gained a lot of interest [1,83].

Biomass in general can contain different organic waste like wood, sewage sludge from water treatment plants, household organic waste, industrial oil and greases, manure, and certain crops [1]. Biomass conversion to bioenergy can either occur through Gasification, digestion, or combustion. Bioethanol, biodiesel, solid biofuel, biohydrogen and solid biogas are possible bio energies, that can be produced from lignocellulosic biomass. However, Hemp appears to have suitable abilities to be considered for biomass production [1,88,89].

Biofuels production is based traditionally on crops that contain starch or sugar such as corn, wheat, sugar beets, and sugar cane. Industrial Hemp can become one of the top feedstocks and has great potential to become again a commodity crop for producing biofuels and other value -added products. From an economical stand of point, industrial Hemp could produce higher per hectare gross profit than other crops. [82, 90]

Biofuels, as an alternative for petroleum-based fuels, are more sustainable, have positive ecological impact, because they reduce greenhouse gases, and their production can have considerable economic benefits. Hemp biomass has emerged as the newest possibility. Hemp contains higher cellulose and lower lignin levels. Hemp also has a 96% glucose recovery from Hemp hurds. [47,83, 91, 92,93,94]. However, in the U.S. Hemp research in these areas has stalled due to the complexity of law [30, 32, 33].

Hemp contains nearly the same Glucan and Xylan levels in comparison with kenaf, and sorghum, as shown in current research, which can be certainly of use for biofuel production [82].

Today Biofuel is already made from a wide variety of resources used in the anaerobic digestion process, such as animal waste, sewage sludge, crop residue or household organic waste [88,89].

The time of harvesting can influence biogas yield of industrial Hemp. Late harvesting times during September to October shown biomass yield of 14.4 t/ha [96]. Biogas yield from hem digestion and co-digestion show up to 231 to 290 l/kg [96,97]. Additional treatment after mechanical processing to remove some of the structural resistance can increase the biogas yield by up to 21% [96].

At present time, there is barely practical large-scale research available about the actual potential of industrial Hemp as a biogas feedstock [95]. Still, there is a lot of theoretical research about its potential.

10. CONCLUSION

This review paper gives an overview Hemp known as *Cannabis Sativa*, which has been cultivated and used as an agricultural crop centuries before the Common Era.

Hemp has been used extensively in the colonial times as a cash crop in Europe and the America between the 17th and 20th centuries and played a significant role in European mercantilism and imperialism manufacture.

Due to its durability, Hemp has had many applications in a variety of different industries throughout history. Hemp fibers made it a prime resource for making the sails and rope needed for ships, making it a crucial material for shipping and trading, as well as naval warfare including ship's charts, maps, and Hemp paper.

With industrialization Hemp usage declined as sailing ships disappeared and agricultural production declined significantly before the U.S. civil war. Hemp was still produced on a small scale for textile and other applications and relied heavily on hand labor until 1920s. With the

In 1937, the Marijuana Tax Act required registration and licensing of all Hemp growing and processing to restrict the production of marijuana, and Hemp production nearly came to an end with a short production increase during World War II.

In the 1990s Hemp production was reauthorized throughout the European Union and demand was revitalized because of a new interest in natural resources and energy conservation. The U.S. followed in 2014 with the Farm Bill, that changed the legal status of Hemp, allowing the growth by researchers at an institute of higher education, by state Departments of Agriculture, or by farmers participating in a research program.

As of today In most European countries, and the U.S. cultivars with a level below 0.3% THC are allowed, but cultivation is generally subject to reporting. The use of Hemp plants with higher levels is strictly forbidden in most countries.

Hemp has been used as a fiber for multiple industries since the 1700s and has been a great impact to the European and American economy in pre- and past industrial times.

The Popular Mechanics Magazine described Hemp as the new billion-dollar plant in 1938.

With legislature changes Hemp has been rediscovered as a new sustainable environmentally friendly fiber source for products like cordage, clothes, automobile industry, construction, composition materials, bioenergy sector, and future applications in paper making, beside the recreational marijuana and CBD oil production many applications which include usage of the remaining Hemp fibers as biomass for energy and industrial applications are slowly moving forwards at present time, due to the fact that there is barely practical large-scale research and pilot installations available about its industrial application potential.

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