



Market Opportunities for Industrial Hemp

Guide to understanding markets and demand for various industrial hemp plant products

Commissioned by the Missouri Hemp Producers Association with funding from the Missouri Agricultural and Small Business Development Authority

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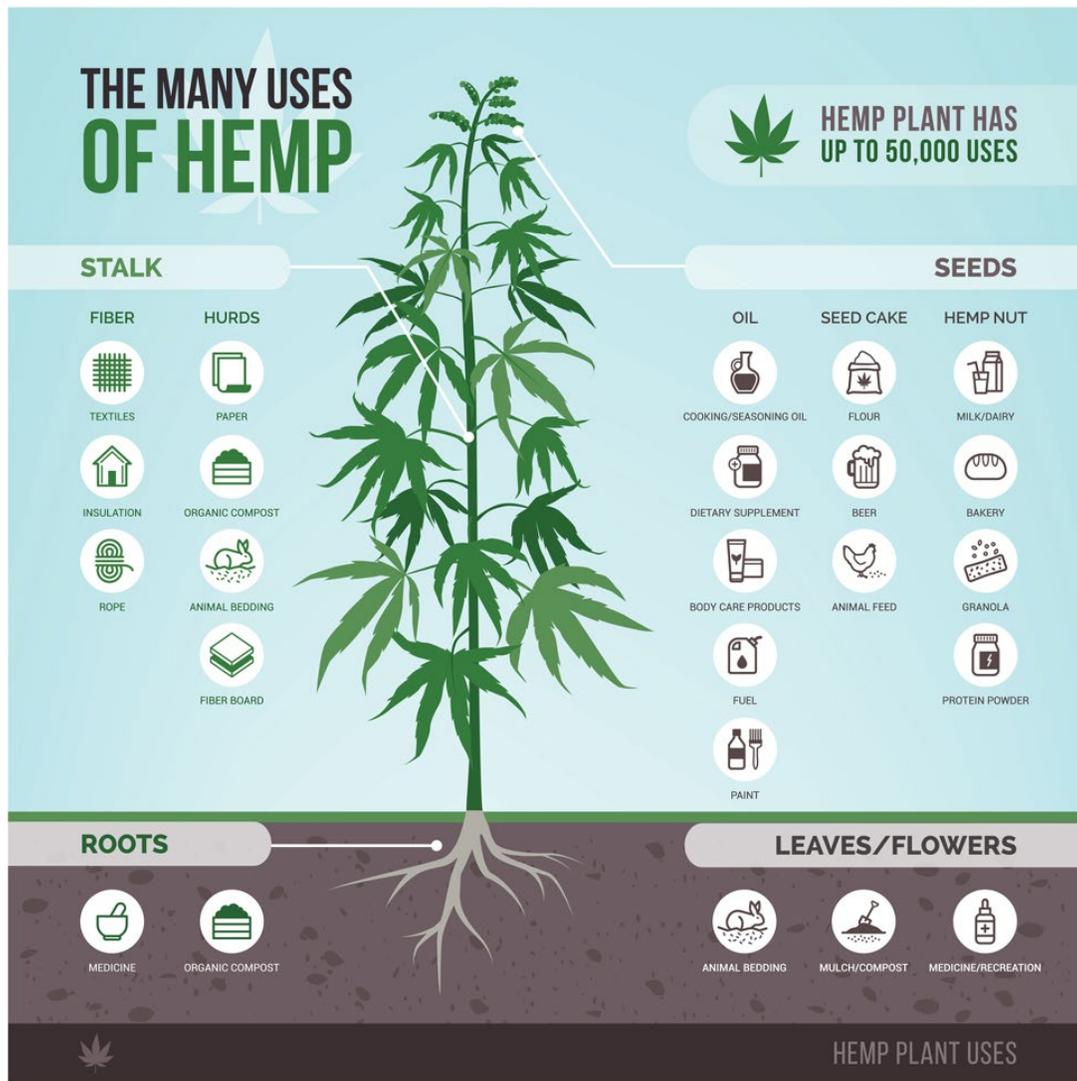
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Introduction

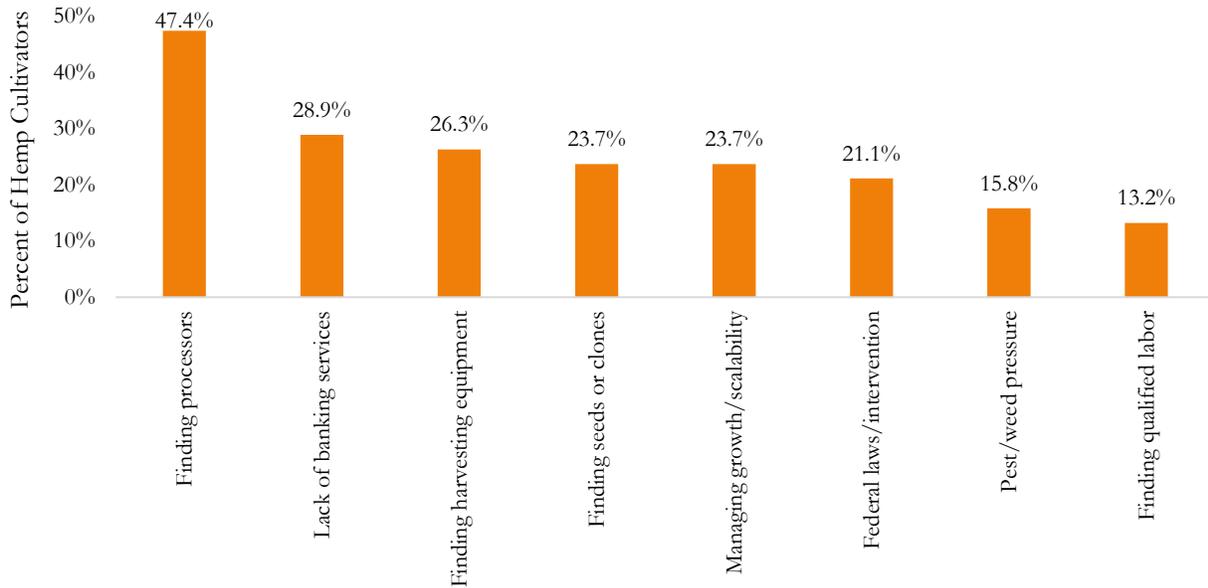
Industrial hemp produces several components — broadly, stalks, seeds, roots, leaves and flowers — that processors may direct toward a variety of commercial applications. In total, these components may have as many as 50,000 potential uses, according to some estimates. Exhibit I1 shares examples. With bast and hurd fibers from the stalks, product developers may make goods such as rope, insulation, textiles, compost and paper. Called hemp nuts, whole hemp seeds may serve as a baked good or granola ingredient, or they may undergo processing into various products. If crushed, then hemp seeds yield oil and seed cake. The oil has potential use in food-grade and industrial products. For example, the oil could be used for cooking or including in dietary supplements, or it may fit in formulations for fuels or paints. The protein-rich seed cake could be processed into food or animal feed. The leaves and flowers have compounds, such as cannabidiol (CBD), connected to health and wellness benefits. They also could serve as a compost feedstock or animal bedding material.

Exhibit I1 – Industries Impacted by Industrial Hemp



Despite the opportunities to convert industrial hemp into a myriad of products, hemp producers experience challenges related to participating in the hemp marketplace. See Exhibit I2. Results from research shared in a Hemp Industry Daily report indicate that finding processors has been the challenge experienced by the greatest proportion of hemp cultivators (Hemp Industry Daily 2019a).

Exhibit I2 – Challenges Faced by Hemp Cultivators



Source: Hemp Industry Factbook (Hemp Industry Daily 2019a)

As production-related challenges are resolved and markets develop for hemp, estimates point to growing sales potential for hemp-based products. During 2018, sales of U.S. hemp-based products totaled \$1.1 billion, according to reporting from the Hemp Business Journal and New Frontier Data. Sales growth has been significant since 2012 when sales totaled \$0.26 billion. See Exhibit I3. The data series also includes sales projections. It shares that U.S. hemp-based product sales are projected to increase to \$2.6 billion by 2022 (Sumner 2019f).

*Exhibit I3 – U.S. Hemp-Based Product Sales, 2012 to 2022 Estimate**



* “e” refers to year with estimated data.

Source: Hemp Business Journal and New Frontier Data (Sumner 2019f)

Exhibit I4 illustrates the projected change in U.S. hemp-based product sales by category from 2018 to 2022, according to data from the Hemp Business Journal and New Frontier Data. Note that the 2022 data are estimates. As shown, hemp-derived CBD sales are projected to increase by roughly 233 percent. For industrial applications, the reporting suggests that sales will increase by 232 percent. Other product categories have more subtle projected growth. Dollar sales growth is projected to reach 53.8 percent for consumer textiles, 41.3 percent for food, 35.3 percent for other consumer products, 30.8 percent for personal care products and 14.9 percent for supplements (Sumner 2019b and Sumner 2019d).

*Exhibit I4 – U.S. Hemp-Based Product Sales by Category, 2018 and 2022**



* 2022 data are estimates.

Source: Hemp Business Journal and New Frontier Data (Sumner 2019b and Sumner 2019d)

As noted, sales of hemp-based industrial products have strong projected growth through 2022, according to New Frontier Data and Hemp Business Journal estimates. By subcategory, the automotive sector is projected to represent the largest share of the industrial market, as measured in dollar sales, for industrial hemp in 2022. Bedding materials, oil wells and greenbuilding sectors rank as the second, third and fourth most significant industrial-related hemp uses, respectively, based on 2022 projected sales (Sumner 2019e).

In most cases, product developers have focused on innovating goods that use specific parts of the hemp plant — for example, fiber from the stalks, oil from the seeds or CBD extracted from flower systems. Hemp farms may also have an opportunity to create an experience tied to hemp production and harvest. For example, during October 2019, a Vermont hemp farm opened to the public for a weekend and allowed customers to pick their own hemp. The farm has said it would consider providing the pick-your-own experience again during fall 2020 (Thurston 2019).

The following sections describe markets for several hemp plant components: stalks, seeds and cannabinoids. However, entering the hemp marketplace and successfully offering products made from these components will require satisfying several conditions:

- Hemp producers and companies must understand the extent of demand for particular hemp-based products and the preferences that drive consumer choices for those products. This condition is important for producing goods that resonate with buyers.
- Producers must focus on how value chains may develop. Because the hemp industry is in its infancy, value chains aren't yet well-established. If a producer intends to only grow industrial hemp, then he or she should have a contract with a buyer before investing in raising a hemp crop. If an entity intends to integrate the value chain, then it requires expertise in operating enterprises at each stage of the value chain — from production to storage and transportation to processing to distribution to sales — and adhering to regulations at each stage of the chain. Vertically integrated entities should also know the preferences important to end users as those preferences will drive their decisions throughout the value chain.
- Identifying a unique niche within the industrial hemp industry may enable entrepreneurs to carve out a competitive advantage and position themselves for succeeding in the marketplace by differentiating what they offer.
- Although planning and research are important to identify opportunities well-suited to a producer or business, succeeding in the marketplace depends highly on how a business manages its operations and executes on branding and messaging about its products.

1. Stalk

Hemp stalks produce two types of fiber: bast and hurd (Schlutenhofer and Yuan 2017). Of a hemp stalk’s total volume, the hurd represents roughly 60 percent to 70 percent. The other 30 percent to 40 percent is bast fiber (Magwood 2016). During a retting process, the two types detach. During this process, binding agents, such as pectin, degrade (Schlutenhofer and Yuan 2017). Retting may rely on microorganisms, moisture, chemicals or mechanical means to break down compounds that attach hurd and bast fibers. Exhibit 1.1 summarizes five retting processes and describes characteristics of the fiber resulting from each process (Thayer et al. 2017). Any issues that occur during retting may negatively affect fiber quality and consistency (Schlutenhofer and Yuan 2017).

Exhibit 1.1 – Retting Processes

Method	Process	End-Product Attributes
Dew retting	Leave fibers in the field, and moisture from the environment breaks down fibers	Coarse, light brown fiber
Water retting	Bacteria facilitate fiber separation	High-quality fiber
Warm water retting	Cover fiber with water for 24 hours; then, heat for two days to three days	Clean, uniform fiber
Green retting	Mechanization facilitates fiber separation	Fiber suitable for textiles, paper and fiberboard
Chemical retting	Added chemicals facilitate fiber separation	---

Source: Cornell University (Thayer et al. 2017)

The two types of fiber have varying characteristics. Long bast fibers grow near the outer stalk layer of a hemp plant. Fibers located in a hemp stalk’s core are known as the hurd (Schlutenhofer and Yuan 2017). The short hurd fibers have a woody characteristic (Johnson 2018). Exhibit 1.2 details the composition of both fiber types. Bast fibers are cellulose-rich, and hurds average higher levels of hemicellulose and lignin than bast fibers do (Schlutenhofer and Yuan 2017). Bleaching hemp fibers presents challenges, and this has contributed to the plant’s limited use as a fiber (Mahapatra 2018).

Exhibit 1.2 – Bast and Hurd Hemp Fiber Composition

	Bast Fibers	Hurd Fibers
Cellulose	73% to 77%	34% to 48%
Hemicellulose	7% to 9%	21% to 25%
Lignin	2% to 6%	17% to 19%

Source: Trends in Plant Science (Schlutenhofer and Yuan 2017)

When growing hemp as a fiber crop, producers can harvest roughly 60 days post-planting (Bennett 2019). Some research suggests the importance of timing the harvest to coincide with hemp flowering beginning. At that stage, producers may capture higher hemp fiber yields, and the hemp fibers themselves may have enhanced strength and quality (Schlutenhofer and Yuan 2017).

Supply constraints have limited hemp fiber’s use in some sectors, such as textiles. Of the hemp producers who participated in a 2018 survey, 2.3 percent reported producing hemp exclusively for fiber. Hemp Industry Daily reports that annual hemp fiber production totals roughly 600,000 metric

tons, which is far less than production of other fibers such as cotton. Challenges include that producers haven't had ready access to hemp cultivars developed for their fiber, and decortication technology is antiquated (Fernandez 2019). Domestically produced hemp fiber also competes with international supplies. China serves as the main hemp fiber supplier internationally, so U.S. hemp fiber prices and supplies would compete with Chinese product (Journal-Advocate 2018).

Bast and hurd fibers have many potential uses. The following sections summarize how firms have incorporated hemp fibers in a variety of products. To summarize, bast fibers may work well in textiles; paper; and industrial products, such as composites, caulking and brake and clutch linings. Hurd fibers may be used to make paper, building materials and animal bedding (Johnson 2018).

1.1 Bioplastics

Hemp has several key characteristics that create opportunities for its use in bioplastics. For one, its cellulose levels are similar to the levels found in other materials used in plastics. Hemp being a biodegradable material also makes it a good candidate (Sumner 2019e). Presently, hemp-based bioplastics are composites that use natural hemp fiber — in particular, a microtized hemp hurd — to reinforce polymer materials. Currently available hemp biocomposites tend to have rigidity and durability, and the amount of hemp often ranges from 10 percent to 30 percent. Future opportunities in the bioplastics space include extracting and using the cellulose found in hemp fiber to create other bioplastic materials. Industry lacks cost-effective methods for cellulose extraction, however, so this barrier would need to be addressed (Eichner 2018).

The automotive industry has the potential to incorporate hemp fiber into vehicle components. A 2012 study from the Center for Automotive Research explored how bio-based materials could fit in vehicle parts. The bast fibers found in hemp may reinforce bio-based composites or serve as a filler. These natural fibers could displace composite fillers and reinforcements such as fiberglass and talc. In terms of specific components, door interiors, seatback linings, package shelves and floor panels all have the potential to use fibers such as hemp, flax and sisal (Hill, Swiecki and Cregger 2012).

Making automobile parts from hemp fiber has a history. Henry Ford notably converted hemp, wheat and soybean cellulose into plastic for a prototype vehicle during the 1940s (Gastelu 2019). More recently, other manufacturers have shown interest in building vehicles with hemp-based materials. For one, **Mercedes** has reportedly produced more than 50 automotive parts and components from natural fibers such as hemp. **Chrysler** constructed door panels for its Sebring using EcoCor, a material consisting of 25 percent hemp, 25 percent kenaf and 50 percent propylene. A firm called Johnson Controls produces EcoCor (Hill, Swiecki and Cregger 2012). The all-electric **BMW i3** used a plastic-hemp blend for door panels, which measure roughly 10 percent lighter because of the hemp. Not only did the hemp offer a functional benefit, but it also provided a unique interior finish as the hemp was exposed (National Hemp Association 2015). Racecars have also had hemp fiber as part of their composition. **Porsche** makes doors for its 718 Cayman GT4 Clubsport with hemp and flax. The composite material displaced carbon fiber as a polymer resin reinforcement (Gastelu 2019).

Packaging is another potential use for hemp-based bioplastic. Jars and cosmetics containers are examples (Nakaya 2019). **Sana Packaging** has entered into the bioplastics marketplace. Using a blend of 30 percent hemp and 70 percent corn-based plastic, the company creates packaging for the cannabis industry (Coons 2019). To make four types of hemp-based plastic polymers, the **Hemp**

Plastic Company uses hemp biomass that's a byproduct from other hemp processing (Guzman 2018). Examples include the biomass not needed when extracting CBD or making hemp nutritional products. Hemp's portion of the polymer can be as much as 100 percent (Nakaya 2019). In its process, the Hemp Plastic Company has a focus on controlling costs. That's enabled its hemp plastic's price to be a small portion of what alternative biodegradable polymers cost. The company's production capacity in 2019 totaled 50 million pounds — just a fraction of worldwide plastic output that reaches 300 million tons (Guzman 2018).

1.2 Textiles

New Frontier Data and the Hemp Business Journal reported hemp-based consumer textile sales totaled \$119 million during 2018, and at the time, consumer textiles represented 10.8 percent of all hemp-based product sales, according to the estimates (Sumner 2019d). Projections released by New Frontier Data and the Hemp Business Journal suggest some growth potential for hemp-based consumer textiles. By 2022, sales are projected to increase to \$183 million. Despite the growth in dollar sales, New Frontier Data and the Hemp Business Journal forecast suggests that consumer textiles will represent a smaller share of the overall hemp-based product market in 2022 as consumer textiles are projected to represent 7 percent of total sales (Sumner 2019b).

Preparing hemp fibers for textile uses requires five steps. See Exhibit 1.2.1. The process begins with retting, which causes the pectin that attaches hemp fibers to degrade; Exhibit 1.1 lists possible retting methods. Next, decortication separates bast and hurd fibers. Then, a softener or roller conditions the fibers to soften them, and fibers are combed to remove any physical contaminants and prepare fibers for spinning. The process ends with spinning to make hemp yarn, which naturally has a dark tan or brown color. Hydrogen peroxide can bleach hemp fiber, but bleaching is difficult. Dyeing the fibers is an alternative. Textiles made from hemp have several notable characteristics as the hemp resists moths, insulates well, provides durability and fades less than cotton. It is also biodegradable (Mahapatra 2018) and said to be flame-retardant and antimicrobial (French 2019).

Exhibit 1.2.1 – Steps in Hemp Fiber Processing for Textile Applications

Step	Summary
Retting	Detach bast and hurd fibers as pectins degrade.
Decortication	Remove bast fiber from woody core.
Softening	Use a softener or roller.
Combing	Hackling, or combing, culls woody material and prepares fiber for spinning.
Spinning	Make yarn through wet or dry spinning processes.

Source: Textile Today (Mahapatra 2018)

Several firms have integrated hemp into textile products. In 1997, **Patagonia** began adding hemp as a component in apparel items. The company has blended hemp, which has linen-like qualities, with recycled polyester, organic cotton and spandex (French 2019). Using a blended hemp, organic cotton and TENCEL lyocell material, the Patagonia hemp collection in spring and summer 2019 included men's and women's items, such as tees, shorts, tanks and shirts. Some items contained as much as 55 percent hemp, but the proportion varied by item. During fall 2019, Patagonia marketed items such as pants, bib overalls, coats, long-sleeved shirts and sweatshirts that included hemp fiber (Patagonia 2019). A May 2019 piece from the company stated that China has supplied the hemp

used in Patagonia’s hemp clothing (French 2019). A 2016 piece from the company described that Patagonia has worked with the Hemp Fortex textile mill in Jincheng, China, and the mill sources hemp from the Shanxi Province (Dumain 2016). Looking ahead, Patagonia has said that it has interest in sourcing domestically grown hemp and has engaged with producers to determine how to access a U.S.-raised supply (French 2019).

During March 2019, **Levi Strauss & Co.** introduced a hemp-cotton clothing line (Feloni 2019) as part of its Wellthread collection. The collection — a collaborative effort with Outerknown — included a trucker jacket, western shirt and slim fit jeans made using some hemp. To condition hemp for use in clothing, Levi Strauss and its partners developed a process that would soften hemp fibers. After undergoing the “cottonization” process, hemp fibers look and feel similar to cotton. The cottonization process itself consumes relatively little energy and chemical inputs (Levi Strauss & Co. 2019). With this process, the water impact is also less significant. The jeans and jacket are made from 69 percent cotton and 31 percent hemp. Looking ahead, Levi Strauss anticipates that it could introduce a 100 percent hemp product in roughly five years (Feloni 2019).

Opportunities for hemp-based textiles extend to uses other than clothing. Michigan-based **420bed** set a goal to make an all-hemp mattress, but managing hemp-related input costs and available supply posed problems. In spring 2019, the company introduced its hemp mattress (Fernandez 2019). The mattress is one-fifth hemp, which has 10 times the strength of cotton. The company sources hemp used in the mattress from Kentucky, and an Illinois facility manufactures the product (Puhr 2019).

In terms of textile applications, hemp fiber may also be incorporated into rugs, carpets, ropes, canvas and sailcloth (Mahapatra 2018).

1.3 Building Materials

According to estimates released by New Frontier Data and the Hemp Business Journal, U.S. greenbuilding-related hemp sales are forecast to total \$38 million during 2022 (Sumner 2019e). Several building materials have been developed to include hemp as a component. The following section describes two hemp-based building materials: hempcrete and hemp wood.

Made from hemp hurd, lime and water, hempcrete has thermal properties that make it well-suited as an insulation for walls, roofs, sub-slabs and windows (Magwood 2016). However, its appearance resembles drywall more so than concrete (Popescu 2018). It weighs about one-eighth as much as concrete, yet it insulates well and retains thermal mass. It can insulate structures made using wood, steel or concrete (Woods 2018). Other benefits associated with hempcrete include fire resistance and durability, and it works with typical framing methods (Magwood 2016).

Hemp hurds converted into hempcrete often measure 5/64 inches (0.2 centimeters) to 1 inch (2.54 centimeters) in length and 3/64 (0.12 centimeters) to 13/64 (0.52 centimeters) in width. As a target, three-quarters to 90 percent of the hemp hurd particles should have 3/64- to 3/4-inch lengths (0.12 centimeters to 1.9 centimeters). When using hurds to make hempcrete, fines should represent no more than half a percentage point of the hurd material, and fiber content should be relatively low or none. Before combining the hurd with the water and lime, the hurd itself should contain less than 20 percent moisture (Magwood 2016). Canada-based **Plains Hemp** markets hemp hurds in 33- or 40-pound bags that can serve as raw material for hempcrete. Plains Hemp identifies several advantages

to building with hempcrete. They include that the material is breathable, carbon-neutral, fire-resistant and pest-resistant (Plains Hemp 2013). Converting the hemp fibers into pulp needed for hempcrete depends on a kraft pulping process that yields a byproduct called black liquor, which contains lignin residues, organic sulfides and other chemicals. Each ton of pulp produced generally yields seven tons of black liquor. To minimize this waste, the U.S. Environmental Protection Agency funded research to take place at the University of California, Riverside (Hemp Industry Daily 2019e).

Lime has antimicrobial and antifungal properties, so it discourages mold development (Magwood 2016). Still, some recommend that builders not place the material near the ground because of mold and rot concerns. Coating the material with plaster or covering it with magnesium oxide boards may protect the hempcrete (Popescu 2018). When mixing the components, the lime binder should coat the hurds, but the mixture should allow for maintaining some voids because those spaces trap air. Those voids or pockets give hempcrete its thermal characteristics (Magwood 2016).

Post-installation and -drying, hempcrete releases no gases or toxins. During mixing and before the material cures, the lime has caustic properties, so people should avoid inhaling the dust and exposing their skin to the wet material (Magwood 2016). From a cost perspective, hemp building materials may be more expensive than conventional alternatives, particularly if the raw hemp is imported (Woods 2018). Also, no international standards or codes dictate how to use hemp as a building material, so inspections and building code exemptions have been required (Popescu 2018).

Hemp fiber may also undergo processing to form a wood substitute. Fibonacci LLC has committed to opening a facility in western Kentucky to produce **HempWood**, a material meant for applications such as flooring, cutting boards, skateboards (Hemp Today 2019b), furniture and woodworking projects. The facility, which required an investment that exceeded \$5.8 million, will employ an estimated 25 full-time workers (The Lane Report 2019). To make HempWood, Fibonacci will leverage an algorithm-driven process to create a highly dense hardwood-like material that is similar to oak (Hemp Today 2019b). Based on technology used by China's bamboo industry and SmartOak, the algorithm dictates the final product's hardness, density and stability. Compared with oak, the hemp-based material should have roughly 20 percent greater density. HempWood has an added adhesive — one that is likely predominantly soy-derived — to close the open spaces within the hemp fibers and enhance density (Erwin 2018). Not only was HempWood designed to be denser than oak, but it also should be available at a lower price point (Dalheim 2019).

Initially, Fibonacci intended to open its Kentucky facility by early 2019 (Erwin 2018). To ensure a sufficient raw material supply, the company established contracts with Kentucky farmers, who were to make more than 800 tons of hemp stalks available to the facility. An update published in June 2019 reported that the facility had delayed its opening until third-quarter 2019 as it needed to secure an industrial wood press certified by UL, a safety certifier. Ultimately, Fibonacci would like to manufacture HempWood at seven other facilities in the U.S. (Dalheim 2019).

1.4 Other Uses

Innovation has pointed to hemp fiber's applicability in several other products. The following list summarizes a subset of these opportunities.

- **Absorbent:** Hemp fiber's qualities also make it a candidate for serving as an absorbent material in industrial settings. Hemp Inc. is one firm that has introduced products meant to absorb oil. Made from kenaf and hemp, its DrillWall product forms a barrier around drill bits used to explore areas for gas and oil resources. Without the seal created by the hemp absorbent, drilling lubricant has the potential to seep into the drilling area and pollute groundwater. Hemp Inc. also makes Spill-Be-Gone from kenaf and hemp. It has been used to absorb oil following oil spills (Altinger 2018).
- **Animal Bedding:** Shredding hurd fibers creates an animal bedding that releases little dust, which may support animals' respiratory health. Its good absorbency means it may last longer than competing bedding materials. Hemp bedding is also unpalatable. Given that a domestic supply of hemp-based bedding hasn't been available, users have had to pay for importing the material (Rice 2018). Based in Manitoba, Canada, Plains Hemp markets a horse bedding made from hemp fibers, and it claims the bedding's absorption properties enable it to hold six times its weight in moisture. Stated advantages of the hemp-based horse bedding include it controlling odor, offering good insulative properties and degrading well into an organic fertilizer (Plains Hemp 2013).
- **Baler Twine:** Using hemp as a component of baler twine represents another opportunity. Of the baler twine used currently, a large proportion is plastic (Freese 2019). A hemp-based twine could serve as a natural alternative.
- **Ethanol:** A 2017 study from researchers at the University of Kentucky and Idaho National Laboratory studied a production system that would allow for harvesting hemp grain and stems, which could be converted into ethanol. For every dry ton of hemp stems, the researchers estimated ethanol production to total roughly 82 gallons (Das et al. 2017).
- **Growing Medium:** Several firms have introduced growing medium products made from hemp fiber. The BioComposites Group markets Terrafibre grow mats, which feature hemp fiber but no soil. Designed for raising short-rotation crops such as microgreens, sprouts and wheatgrass, the mats slip into standard-sized growing trays, and they retain water well. As an alternative to mats, the company also manufactures growing cubes. The cubes blend the bast and hurd fibers with a starch-based binder. Their ability to hold water and insulate seeds encourages seeds to grow (BioComposites Group).
- **Paper:** Hemp has a history in papermaking. Some estimates suggest that hemp fiber was used to make 75 percent to 90 percent of the world's paper until 1883. Relative to wood-based paper, hemp paper can go through the recycling process more times (Mahapatra 2018). Several firms have begun offering hemp paper. Tree Free Hemp, based in Colorado, started making hemp paper in 2013, and by 2017, it had completely localized the process in that it uses Colorado-raised hemp to make specialty paper used for art projects and concert posters. The paper is made from a blend of hemp pulp and recycled materials (McKee Simmons 2017). For cosmetic packaging, Neenah has released hemp board papers, which are available in four colors and four coating finishes (Utroske 2019).
- **Prosthetics:** ecoTEKindustries discovered how to make prosthetics that use hemp in place of other materials such as carbon, fiberglass and Kevlar. The process ecoTEKindustries followed to make prosthetic materials could be replicated to create other items, such as boats, surfboards and RVs. In March 2018, the company submitted its provisional patent application to protect the intellectual property tied to the hemp prosthetic. It has also partnered with N.C. State University on research and testing (Cano 2019).

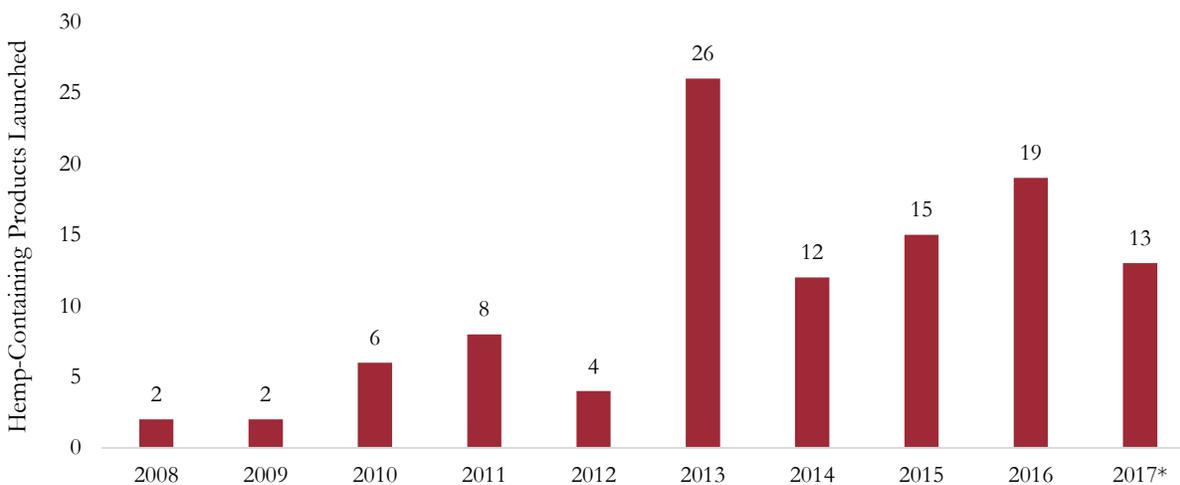
2. Seeds

Classified as an achene or nut (Callaway 2010), hemp seeds can be used as whole seeds or undergo processing to separate the protein and oil (Johnson 2018). In December 2018, the U.S. Food and Drug Administration (FDA) provided responses to three generally recognized as safe (GRAS) submissions for ingredients made from hemp seed. In the submissions, Fresh Hemp Foods Ltd. suggested that hulled seed, protein powder and seed oil derived from whole hemp seeds were GRAS, and in its response, FDA had no questions about the submissions. The three ingredients had minimal CBD and THC content; the trace levels were attributed to seed commingling with other hemp plant components during harvest and processing. Although Fresh Hemp Foods Ltd. submitted the GRAS notices, the safety conclusions would be applicable to products from other manufacturers that have the same product specifications (Food and Drug Administration 2018).

Potential uses for the hemp seeds, oil and seed cake vary from foods to industrial goods to personal care products (Johnson 2018). With respect to the food market, a Manitoba Harvest representative interviewed for a 2017 story shared that relatively few U.S. households were considered hemp food users. The representative estimated household penetration at 1 percent, according to the story in Food Business News. The U.S. lagged behind Canada, which the Manitoba Harvest representative estimated to have a 5 percent household penetration for hemp foods (Watrous 2017).

As more hemp-based food products are released, consumers will have more choices. Mintel has measured the number of hemp-containing products launched in recent years. Exhibit 2.1 shares the number of U.S. annual launches for hemp-containing products between 2008 and mid-November 2017, according to Mintel data shared by Agriculture and Agrifood Canada. As illustrated, relatively few products launched in the U.S. from 2008 to 2012. More recently, U.S. consumers have had access to more new hemp-containing products. In total, the U.S. had 107 hemp-containing products launched during the observed period, and roughly one in four hemp-containing products launched globally were in the U.S. (Agriculture and Agrifood Canada 2018).

Exhibit 2.1 – U.S. Hemp-Containing Product Launches, 2008 to 2017



* 2017 data are through mid-November.

Source: Mintel (Agriculture and Agrifood Canada 2018)

From 2008 to mid-November 2017, the top three product categories for newly launched hemp-containing products in U.S. health and wellness retail markets were meal replacements and other drinks; snack, cereal and energy bars; and beverage mixes. Products in these categories represented two-thirds of total U.S. hemp-containing products launched from 2008 to mid-November 2017, according to Mintel and Euromonitor data reported by Agriculture and Agrifood Canada (Agriculture and Agrifood Canada 2018).

SPINS, a market research firm, has tracked hemp food sales and found that such sales have grown. For the year preceding Feb. 25, 2018, the firm reported that U.S. retail sales in natural, specialty gourmet and conventional channels increased by 4.9 percent for hemp foods. Dollar sales totaled \$43.6 million, which doesn't count sales made online and through retail outlets such as Whole Foods, Trader Joe's, ALDI, Costco and convenience stores. Note, these data reflect sales only of products where a hemp-derived ingredient is the primary ingredient or has been prominently marketed as an ingredient (Watson 2018b).

Within the overall hemp-based food market, the SPINS data show three categories contributed the most to the total: shelf-stable grocery products, such as hemp seeds, bars and milk; frozen products; and refrigerated products. Of these three, frozen product sales had increased most significantly in the previous year. Exhibit 2.2 shares SPINS' sales estimates for the best-selling hemp foods. As illustrated, contributing the most to total sales were the nuts, trail mix and dried fruit product category and the shelf-stable plant milk category (Watson 2018b).

Exhibit 2.2 – Top Hemp Food Product Categories by Sales, Year Preceding Feb. 25, 2018

Product	Dollar Sales	Percent Sales Growth
Nuts, trail mix, dried fruit	\$15 million	11.5%
Shelf-stable plant milk	\$13.5 million	11.6%
Cold cereal	\$5.8 million	26.2%
Shelf-stable wellness bars and gels	\$3.8 million	(46.0%)

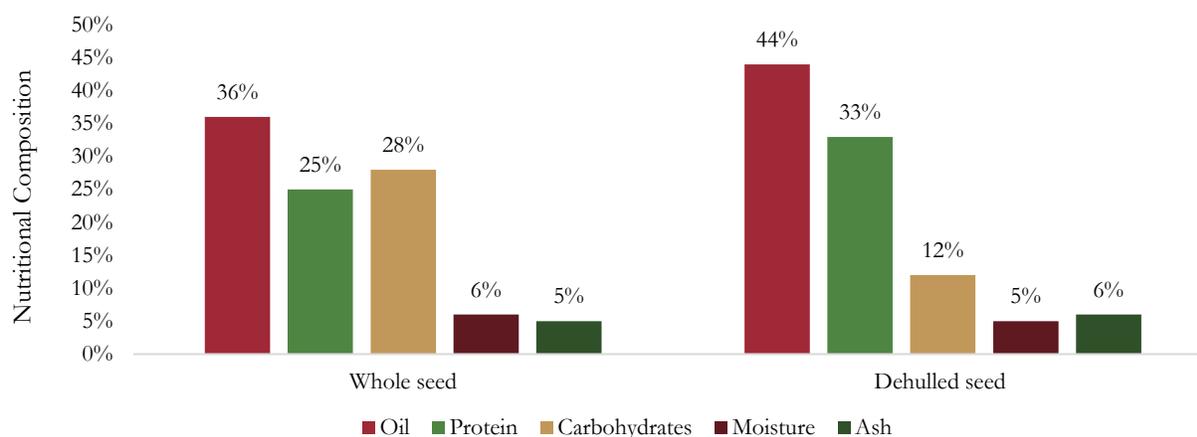
Source: SPINS and FoodNavigator-USA (Watson 2018b)

The following discussion highlights opportunities for using whole hemp seeds, hemp oil and hemp seed cake in multiple product applications.

2.1 Whole Hemp Seeds

Whole hemp seeds contain oil, protein and carbohydrates. The specific proportions depend on whether the seed has had its hull removed. Exhibit 2.1.1 reports typical compositional data for whole hemp seeds and seeds that have been dehulled. As noted, the seeds contain a relatively high oil content. Whole seeds typically are 36 percent oil compared with 25 percent protein and 28 percent carbohydrates. Removing the hull typically decreases the hemp seed's carbohydrate level to 12 percent and increases oil and protein content to 44 percent and 33 percent, respectively (Callaway 2010). Hemp seeds that have had their shell or hull removed are known as "hemp hearts" (Goesch 2016). Iron, magnesium and zinc are other key nutrients found in hemp (Watson 2018b).

Exhibit 2.1.1. – Whole Hemp Seed and Dehulled Hemp Seed Nutritional Composition



Source: American Oil Chemists’ Society (Callaway 2010)

Whole hemp seeds have multiple potential applications. Historically, hemp seed was one component of wild bird feed sold commercially (Callaway 2010). In the field, birds can cause damage to a hemp crop, which suggests birds like the seed. Penn State University Extension has noted that mourning doves in particular have been drawn to hemp in fields (Roth et al. 2018). Minnesota has explored how its producers may consider growing hemp to serve the bird seed market, though the Association of American Feed Control Officials will need to approve hemp. One component of the effort involved personnel from the Minnesota Department of Natural Resources, Minnesota Department of Agriculture, Minnesota Ornithologists’ Union, All Seasons Wild Bird Stores and Millikin University collaborating on a study that looked into whether birds would accept hemp as a food. Anecdotal evidence suggested the birds liked hemp seed about as much as they liked white proso millet, but the birds tended to prefer black oil sunflower seed more than the hemp seed. Chickadee, nuthatch and cardinal were three species that liked the hemp seed, and the hemp seed may not attract house sparrows and squirrels (Williams 2018). Several firms offer bird feed products made from hemp seed. Online, Green’s Feed Incorporated markets **Volkman** Birds Delight Canary Diet in 50-pound units. The product mixes hemp with canary grass seeds, steel cut oat chips, golden German millet, rape seed, flax seed and Nyjer seed (Green’s Feed Incorporated 2019). According to a June 2019 search on Chewy.com, an online pet product retailer, **Higgins** and **Kaytee** brands have also included hemp seed in bird food mixes.

Whole hemp seeds or derivatives of the seed may also have potential in feeds formulated for other animals. However, during May 2019, the Association of American Feed Control Officials released a statement indicating that no animal feed nor pet food had received the necessary regulatory approvals to incorporate hemp or hemp-derived ingredients (Fairfield 2019). Two groups — the Hemp Feed Coalition and Friends of Hemp — have explored feed opportunities for hemp ingredients. That exploration includes developing applications to submit to the FDA to receive approval for using hemp components as feed ingredients. Ultimately, species that could potentially consume hemp-based feeds include cattle, poultry, swine and fish. Fish may represent a particularly strong market because they require a dietary form of omega-3, and hemp seeds are a good source. Companion animals, however, represent another possibility. With companion animals, the research needed to support hemp’s safety as a feed ingredient takes less time — maybe 30 days. For animals that would be slaughtered and processed for human consumption, the safety tests — considered

“lifecyle studies” — take more time because the research must determine whether consuming an ingredient such as hemp throughout an animal’s life would make that animal safe for humans to consume. The first hemp ingredient that Friends of Hemp has shown interest in having approved is cold-pressed hemp oil intended for companion animal products (Einstein-Curtis 2019).

During 2019, Farm Journal asked farmers and ranchers about their interest in raising and using hemp via a survey. Livestock producers who had at least one of the following animals and received an invitation could participate in the research: beef cattle, dairy cattle, hogs and poultry. Farmers who raise row crops and produce corn, soybeans or wheat could also respond. One question asked respondents to indicate whether they would feed cannabis to animals; note, the survey didn’t differentiate between cannabis with high and low THC levels. One-quarter of the responding producers said they strongly agreed with the “I would use cannabis in animal feed” statement, and 23 percent indicated they agreed. Eighteen percent of those responding noted that they somewhat disagreed or strongly disagreed (Henderson 2019).

The seeds themselves also have food uses. Several suppliers market hemp hearts for the food market. The hearts tend to have a mild grassy flavor, and from a texture perspective, they share similarities with pine nuts (Goesch 2016). Cooking Light has noted using hemp hearts as a topping on salads or pizza, or hemp hearts may serve as an ingredient to mix into granola, cereal or popcorn. Hemp hearts may also be applied as a crust on proteins such as chicken and fish (Krstic 2017).

Although whole hemp hearts have multiple possible uses and are nutrient-dense, U.S. households have adopted hemp hearts on a relatively limited basis, according to a story from FoodNavigator-USA. In the story, the founder of **Humming Hemp** acknowledged her company developed hemp bars as a strategy to encourage more households to consume hemp products. Branded with the hummingbar name, the bars list hulled hemp seeds and hemp protein as ingredients. They launched during March 2019, and by October 2019, Humming Hemp had secured nationwide distribution for the bars in Kroger retail outlets (Shoup 2019a). **Manitoba Harvest** has viewed the marketplace similarly. It has added hemp seeds as an ingredient in granola, bars and other applications that make hemp hearts easy to consume and that appeal to mainstream consumers (Crawford 2019a).

In Missouri, retailers such as Hy-Vee and Lucky’s stock granolas that feature hemp as an ingredient, and they offer hemp seeds or hearts.

By undergoing some processing, hemp can become an ingredient to create other products. For example, grinding hemp seed, blending the slurry with water and filtering the blend yields a plant-based hemp “milk” that tastes slightly nutty. From a nutritional perspective, a story from AgWeb indicates that hemp milk supplies a moderate amount of protein — less than cows’ milk and soy milk but more than almond milk — and it tends to have a thick viscosity. Fortifying hemp milk with calcium, phosphorus and key vitamins may improve the product’s nutritional profile (Leach 2019). **Hudson River Foods** is one firm that has launched hemp milk products, and shelled hemp seed represents a key ingredient in the various Tempt hemp milk iterations. In addition to a regular and unsweetened original hemp milk, Hudson River Foods offers vanilla, chocolate and coconut flavors (Hudson River Foods 2019). The hemp beverage line from **Pacific Foods** also offers a range of dairy-free options: unsweetened hemp original, hemp original, unsweetened hemp vanilla, hemp vanilla and hemp chocolate. All include hulled hemp seed as an ingredient (Pacific Foods 2019).

During the Expo West show in spring 2019, **Elmhurst 1925** became the first firm to launch a non-dairy creamer made from hemp. In western New York, the company raises the hemp it uses in its products, and the process used to make the creamer prevents the need to add gums and emulsifiers. This first hemp creamer had an “original” flavor and wasn’t sweetened, but the company has noted interest in adding flavored varieties (Newhart 2019). Three flavors were available during October 2019: French vanilla; hazelnut; and a golden-milk option with added turmeric extract (Elmhurst 2019). Elmhurst sells its hemp-based creamers online and in retailers such as Whole Foods and Wegmans (Newhart 2019). In an interview with FoodNavigator-USA, an Elmhurst representative shared about the company’s interest in finding uses for the hemp protein that’s a byproduct of hemp milk processing. One option may be making a chicken substitute (Crawford 2019b).

Toasting hemp seeds is another option as the process tends to lead hemp seeds to develop a savory umami flavor (Callaway 2010). **NOW Foods** shares that its 12-ounce packages (28.35 grams) of toasted hemp contain omega-3s, omega-6s, fiber, protein and iron. The company suggests that buyers use the certified organic toasted seeds, which are lightly seasoned with sea salt, to top salads or yogurt, serve as a snack or be included as an ingredient in recipes (NOW Foods 2019).

Sprouting hemp seeds also adds value. Typically, a sprouted grain has a sprout that’s not as long as the grain before it sprouted, but no one standard dictates the process or defines final product characteristics. Digestibility, nutritional profile, nutrient bioavailability and flavor may vary between sprouted grains and grains that haven’t sprouted. Sprouting may also decrease insoluble fiber, antinutrient and gluten content and increase soluble fiber and nutrient levels. Plus, it may make some nutrients more bioaccessible. Overall, sprouted grain sales have weakened somewhat; however, SPINS estimates that U.S. retail sales grew for several sprouted grains product categories in the year preceding Oct. 7, 2018. They included frozen entrees, 343 percent growth; shelf-stable hot cereals, 57 percent growth; and shelf-stable bars and gels, 25.5 percent growth. The bread and baked goods category, which is the largest category, posted a 4.2 percent reduction (Watson 2018a).

Hemp seeds may have an opportunity to tap into consumers’ interest in plant-based proteins. Nielsen data from the year preceding March 23, 2019, found that roughly one in five people who buy meat also buy meat alternatives (Nielsen 2019b). In 2009, **Good Seed Burger** began as a food truck serving the Austin, Texas, community, but by 2014, the company’s entrepreneurs had transitioned their focus to selling hemp seed burgers as a consumer packaged good (Juntti 2018). Good Seed Burger had four products listed on its website during October 2019. All four were marketed as “hempseed burgers,” but each had a different flavor profile: curried sweet potato, wild mushroom cauliflower, all American and spicy Italian (Good Seed Burger 2012). Natural and conventional retailers carry the products in stores throughout more than half of the U.S. When developing its burgers, the company has strived more for offering unique flavors than necessarily creating a product that mimics meat (Juntti 2018).

2.2 Hemp Seed Oil

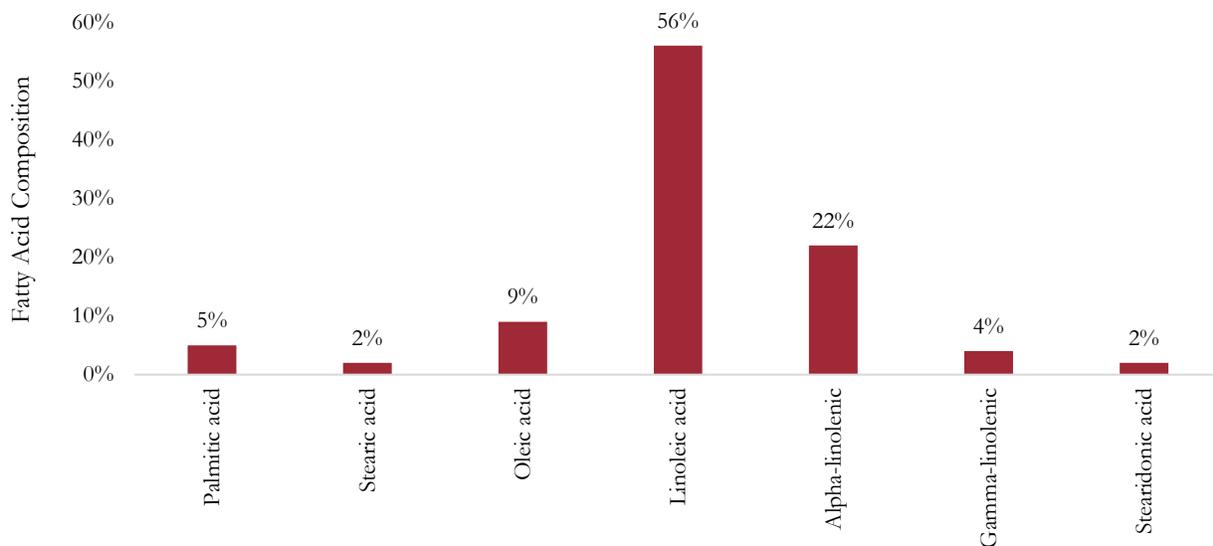
Oil extracted from hemp seeds contains high polyunsaturated fat content. See Exhibit 2.2.1. Typically, the oil is 84 percent polyunsaturated fat. For comparison purposes, flax oil contains 76 percent polyunsaturated fat, and sunflower and soybean oils typically are 63 percent polyunsaturated fat. Hemp seed oil has a relatively low omega-6-to-omega-3 fatty acid ratio — 2.5. The ratio in

sunflower oil and olive oil exceeds 100. It's 6.9 in soybean oil and 1.8 in rapeseed oil. Also, hemp oil contains relatively little saturated fat (Callaway 2010).

As suggested by the ratio of omega-3s to omega-6s, hemp seed oil is a rich source of omega-3 fat. Exhibit 2.2.1 illustrates that hemp seed oil contains more than 20 percent alpha-linolenic acid (ALA) — the plant-based form of omega-3 fat. Most common oils don't contain as much ALA. Flaxseed oil, which contains 61 percent omega-3s, is an exception. Rapeseed oil and soybean oil, which are generally regarded as relatively good omega-3 fat sources, tend to contain about 13 percent and 8 percent ALA, respectively (Callaway 2010). Hemp seed oil's high omega-3 concentration may attract attention among consumers interested in increasing their consumption of omega-3 fats. The 2019 iteration of the International Food Information Council Foundation's annual food and health survey, which collected responses from more than 1,000 American adults, found that 70 percent view omega-3 fatty acids as healthy. Women were slightly more likely than men to say they perceive omega-3s as healthy. Of the total respondents, more than 40 percent said they make an effort to "try to consume" omega-3 fatty acids (International Food Information Council Foundation 2019).

Unlike many seed oils, hemp seed oil contains traces of gamma-linolenic acid (GLA) and stearidonic acid (SDA) — 4 percent and 2 percent, respectively (Callaway 2010). GLA has been recognized for its anti-inflammatory role. In the body, SDA is a precursor to eicosapentaenoic acid (EPA), an omega-3 fat noted for its heart health benefits. The conversion from SDA to EPA happens more efficiently than the conversion from ALA acid to EPA (Watson 2018b).

*Exhibit 2.2.1. – Hemp Seed Oil Fatty Acid Composition**



* Composition for oil extracted from Finola cultivar
Source: American Oil Chemists' Society (Callaway 2010)

Given this typical fatty acid composition, hemp seed oil isn't well-suited for deep-frying (Callaway). Salad dressings would be more suitable applications (Watson 2018b). Alternatively, the hemp seed oil could be used as a "finishing" oil (Goesch 2016). From a flavor perspective, hemp oil that has been cold-pressed tends to taste somewhat like walnuts and sunflower seeds (Callaway 2010).

Products intended for human consumption have incorporated hemp seed oil in various formats. **Manitoba Harvest**'s product line includes liquid hemp oil and hemp oil soft gels. The company positions the soft gels as a convenient option to ingest omega fats, and for the liquid oil, Manitoba Harvest suggests including it in dressings, sauces or dips (Manitoba Harvest 2019a).

SPINS has tracked hemp-based herbal supplement sales, which are largely sales of hemp seed oil supplements that supply omega-3 fats. Within the natural channel, sales of those hemp products dropped by 9.9 percent in the year preceding Dec. 30, 2018. Possible explanations include evolving consumer preferences. Note, the natural channel includes co-ops, associations, independent retailers and large regional chains that sell at least \$2 million annually through full-format stores and report that natural and organic products represent at least half of their sales (Smith et al. 2019).

As mentioned previously, two industry groups have taken a lead in spearheading applications that the FDA can use to consider approving hemp-derived ingredients for feed uses. The first focus has been to work toward receiving an approval to add cold-pressed hemp seed oil to companion animal foods (Einstein-Curtis 2019). In May 2019, AAFCO clarified that animal feed or pet food should contain no hemp or hemp products because of the lack of regulatory approval (Fairfield 2019).

Some firms have introduced hemp ingredients into pet products, and some market products made with hemp-derived ingredients as “chews” or “supplements” to differentiate their products from regulated feeds. The National Animal Supplement Council has worked toward developing a pet supplement quality seal audit program as pet supplements have had a “regulatory void” (Phillips-Donaldson 2018). During July 2019, **Innovet Pet** released information about its new products that feature hemp seed oil and wild Alaskan salmon oil. Considered a daily supplement, the products' branding focuses on delivering omega fatty acids (Tyler 2019b).

Beauty and personal care products have also had hemp-derived ingredients, including hemp seed oil, added to them. In beauty products, hemp seed oil contributes moisturizing properties due to its omega-3 fats, and it's been an ingredient option for personal care product manufacturers for some time (Reisch 2019). A piece from SPC Magazine that was republished by Cosmetics Business further described possible benefits attributed to hemp seed oil's use in body care products. The oil can soften skin and give products such as lotions, shampoos, soaps and lip balm a smooth after-feel. Additionally, the oil's GLA content may offer a degree of sun protection (Cosmetics Business 2016).

In some cases, brands — particularly those considered “established” brands — have appeared more willing to use hemp seed oil than they have been interested in working with CBD given its regulatory uncertainty (Li 2019). Two companies that have pursued using hemp seed oil in their products are Estee Lauder and L'Oreal. **Estee Lauder** launched its Hello Calm face mask during 2018. The mask features hemp seed oil in its formulation. An herbal concentrate in the Kiehl brand portfolio, which is part of **L'Oreal**, includes hemp seed oil. For people who have skin susceptible to blemishes and redness, the product is said to provide a calming effect (Reisch 2019).

Dr. Bronner's has been a leading North American organic liquid and bar soap brand. For roughly two decades, Dr. Bronner's has added hemp seed oil to its soaps. Prompting the addition was hemp seed oil would enable the soap to produce a smooth lather, and it would help the company achieve a reformulation goal (Foster 2012). Many of Dr. Bronner's products include organic hemp seed oil.

The oil is listed in ingredient statements for the company's pure-castile liquid soap, pure-castile bar soap, organic sugar soaps, organic lotions, organic shaving soaps, hair care products and organic lip balms (Dr. Bronner 2019). Each year, Dr. Bronner's requires roughly 20 tons of hemp seed oil to produce its products, according to a May 2019 story from TreeHugger. The company has indicated interest in ultimately buying the hemp seed oil it needs from domestic suppliers (Martinko 2019).

During the early 2000s, Supre introduced topical products targeted to the tanning market. Hemp seed oil was a featured ingredient in maximizers branded with the **Hempz** name. The brand enjoyed success in tanning salons and added a moisturizer to its portfolio. Later, it developed other products such as shower gels, lip balm, color care hair products and bronzers (Lotion Today).

Oil extracted from hemp seeds also has industrial uses. For example, several companies use hemp seed oil as a key ingredient in wood finishes and waxes. Based in Michigan, **Wise Owl Chalk Synthesis Paint** offers hemp seed oil as a liquid oil and a furniture wax. The "Hemp Seed Oil" contains only hemp seed oil, and applying the product creates a water-resistant coating. The oil can enhance bare wood or wood that has had stain or paint applied (Wise Owl Chalk Synthesis Paint 2017). Called a drying oil, hemp seed oil will cure within two weeks to 30 days of being applied, and the cured surface will have a hardened, solid finish. Applying more coats can further enhance a surface's water resistance (Chouinard 2016). The "Hemp Oil Furniture Wax" blends hemp seed oil and beeswax to form a seal on painted surfaces or wood (Wise Owl Chalk Synthesis Paint 2017).

Hemp Shield claims to have created the first wood finish and deck sealer that included hemp seed oil in its formulation, and it also offers a treatment designed specifically for log homes. According to the company, the small particle size of the hemp seed oil enhances its ability to penetrate into wood surfaces, and the two products offer a high level of UV resistance (Hemp Shield 2016).

Given its drying oil properties, other industrial uses for hemp seed oil include varnishes and coatings. In cases where flaxseed oil or linseed oil work well, hemp seed oil may perform well, too (Callaway 2010).

Hemp seed oil also has possible application as a biodiesel feedstock. At the University of Connecticut, a team of researchers used transesterification to convert virgin hemp seed oil into biodiesel. The team found 97 percent of the hemp oil feedstock converted to biodiesel, which indicates an efficient conversion. Of the lab tests conducted on the hemp-based biodiesel, all were passed. Relative to alternatives, the hemp-based biodiesel may perform better at low temperatures, according to one test result (Buckley 2010). A thesis from a student studying at the University of Gavle in Sweden described various hemp biodiesel characteristics based on a review of existing literature. The review found that the hemp biodiesel had a lower sulfur level, which suggests that it is a relatively clean-burning fuel. Plus, the hemp biodiesel had a higher flash point than the biodiesel made from soybean and rapeseed oils. This metric indicates the hemp biodiesel can be safely handled, stored and transported. Two weaknesses of hemp biodiesel mentioned in the literature were poor kinematic viscosity and poor oxidative stability. To correct these issues, the hemp biodiesel could have chemical additives included (Alcheikh 2015).

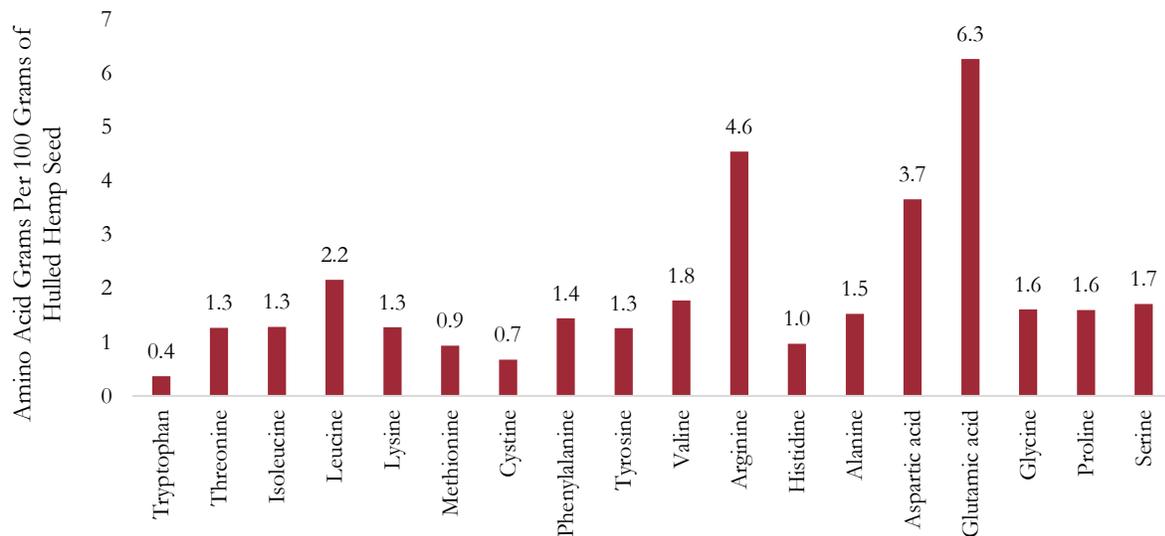
2.3 Hemp Protein

In March and April 2019, more than 1,000 Americans participated in the International Food Information Council Foundation’s annual food and health survey, and roughly one-quarter said they were eating much more or somewhat more plant-based protein at the time than they consumed a year earlier. Also, 34 percent of the respondents said they consumed plant-based protein at least daily (International Food Information Council Foundation 2019).

Plant-based protein powder holds a small but growing share of the market, according to a NutraIngredients-USA story from December 2018. DuPont Nutrition and Health has noted interest in plant proteins among mainstream consumers focused on fitness (Menayang 2018). Leadership from Manitoba Harvest, a company that markets hemp products, indicated during second-quarter 2018 that the protein powder category had the potential to grow (Watson 2018b).

Hemp protein has the potential to tap into the trend of increasing plant-based protein consumption. It delivers nine essential amino acids (Goesch 2016). Exhibit 2.3.1 presents amino acid levels in 100 grams of hulled hemp seeds, according to data published in USDA’s FoodData Central database. As noted, the amino acids found in the highest levels are glutamic acid, arginine and aspartic acid. Of the essential amino acids, those found at the highest levels in hemp protein are leucine and valine (USDA Agricultural Research Service 2019).

Exhibit 2.3.1. – Amino Acid Profile of Hulled Hemp Seeds



Source: USDA Agricultural Research Service (2019)

Within the plant-based protein marketplace, hemp protein being a complete protein gives it an advantage. In cases when a protein lacks the complete profile, manufacturers may blend proteins to create a final product with a more desirable profile. Hemp’s complete protein feature led it to being named as a plant protein “rising star” by Lumina Intelligence, a market researcher (Menayang 2018).

Despite the opportunity for hemp protein products, some formulations have had challenges with flavor, color and shelf life. To address the flavor issue, **Axiom Foods** launched a 58 percent protein product named Cannatein. Made from hemp hearts, Cannatein has a neutral flavor, light color and two-year shelf life (Gelski 2018). Blending is another approach to manage flavor. **Nutiva** developed a blend of hemp protein and protein derived from peas, sunflowers and pumpkins (Watson 2018b). The plant protein blend from **Manitoba Harvest** — branded with the Hemp Yeah! name — combines protein from hemp and peas. The company also offers a line of powdered protein that lists hemp protein as its exclusive protein ingredient (Manitoba Harvest 2019a).

Elev8 Hemp markets Fair Trade Certified coffee blended with organic hemp protein — 1.2 ounces of protein per 12-ounce package (34 grams of protein per 340.2-gram package). One decaffeinated option is available, and Elev8 Hemp markets several caffeinated products that each deliver a unique flavor. Elev8 Hemp also infuses tea bags with organic hemp protein powder. Black tea and green tea options are available (Elev8 Hemp 2019). Hemp protein is a top ingredient in the three flavors of **Hemplete** hemp protein bars. Each protein bar also has added organic hemp seeds. In addition to marketing protein bars, Hemplete also sells two hemp protein powders, which consumers can mix into smoothies and shakes (Hemplete 2019).

An opportunity may also exist to process hemp protein into flour. During October 2019, Whole Foods released its 2020 forecast of the top 10 food trends. One of the trends — called “Flour Power” — suggests that consumers will seek out innovative flours to use at home and buy in consumer-packaged goods. The company noted that “super” flours, which it defined as those that offer protein and fiber, will be on-trend, too (Whole Foods Market 2019). **Hippie Butter** is one company marketing hemp seed flour as a gluten-free option. It recommends the flour for bread, muffin, cookie or waffle uses, or the flour can be added to smoothies (Hippie Butter 2019).

Hemp-derived ingredients may eventually represent one component of feed rations meant for cattle, poultry, swine or fish, and hemp protein is one possibility for such rations. Receiving FDA approval for including hemp in feed may occur in the future as the Hemp Feed Coalition and Friends of Hemp group pursue hemp feed approvals (Einstein-Curtis 2019).

Some companies have marketed pet products with hemp protein ingredients. During September 2019, **Pet Releaf** launched three variations of Boom Bars into independent retailers. The company markets the bars as hemp-infused protein supplements for dogs, and it notes the products’ complete amino acid profile. One formulation specifically caters to needs of senior dogs (Tyler 2019a).

Victory Hemp markets Hemp Protein50 as a protein option for pet treat manufacturers. Buyers may choose from 50 percent, 33 percent or 23 percent protein (Victory Hemp 2019).

3. Cannabinoids and Other Compounds

Cannabinoids have a role in regulating the body's endocannabinoid system, which affects how the body functions, adapts and achieves homeostasis (Krawiec 2018). An individual's endocannabinoid system has two types of receptors: CB1 and CB2. These receptors link the endocannabinoid system to the body's other systems, including the nervous system, muscular system, endocrine system, respiratory system and circulatory system, according a video produced by CV Sciences, and cannabinoids can send signals directed to the CB1 and CB2 receptors. The body produces its own endocannabinoids: anandamide and 2-AG. However, the CB1 and CB2 receptors can also accept signals from plant-based phytocannabinoids (CV Sciences 2018b).

Cannabis sativa contains phytocannabinoids, but other phytocannabinoid sources include clove oil, peony and ginger. Some suggest that people who have conditions such as fibromyalgia, migraines, multiple sclerosis and seizures may have too little endocannabinoid activity in their bodies. As a result, supplementing with phytocannabinoids may have value (Krawiec 2018). Cannabinoids may play a role in correcting inflammatory issues and helping the body recover from injury (Velasquez-Manoff 2019). To study the properties and health effects of cannabinoids and terpenes, the National Center for Complementary and Integrative Health (NCCIH) provided about \$3 million in funding during September 2019 to nine groups that will research how these compounds may relieve pain. NCCIH is part of the National Institutes of Health (National Institutes of Health 2019).

Delivery of Cannabinoids in Products

Cannabidiol (CBD) and tetrahydrocannabinol (THC) are two recognized cannabinoids. In products, cannabinoid delivery can take different forms. An isolate, for example, offers one cannabinoid as a purified form that has no taste or odor (Krawiec 2018). Isolates often have a clear appearance, too (Hendrix and MacKay 2019). Unlike isolates, extracts may have an odor or flavor (Krawiec 2018). Firms selling hemp products also tend to classify extracts in one of two groups: broad-spectrum or full-spectrum. However, both terms are considered marketing terms, not technical definitions, according to a New Hope Network webinar sponsored by CV Sciences. A full-spectrum extract may contain traces of THC, whereas products bearing the term broad-spectrum extract tend to have had THC removed (Hendrix and MacKay 2019).

Cannabinoid Regulatory Landscape

Note, the U.S. Food and Drug Administration (FDA) has stated that food and supplement products containing CBD cannot legally be marketed in interstate commerce (Schultz 2018). Epidiolex, a prescription drug approved for epilepsy treatment, includes CBD as an ingredient (Fusaro 2019). Given Epidiolex's drug status, the FDA stipulates CBD should not qualify as a nutraceutical or dietary supplement (Velasquez-Manoff 2019). That said, the FDA has committed to exploring avenues to regulate cannabis ingredients' use. A May 2019 public hearing enabled stakeholders to voice their opinions on this topic (Fusaro 2019). The agency also collected more than 4,000 public comments about CBD products through July 16, 2019 (Vonder Haar 2019).

In comments of its own, the FDA has suggested that it would like to expedite the rulemaking process for CBD products, but it has also acknowledged concerns about CBD product safety, CBD manufacturing safety and accuracy in CBD product advertising (Vonder Haar 2019). In other comments to industry made during spring 2019, the FDA indicated it would "take enforcement

action” if CBD brands make “over-the-line claims.” It recognized that the marketplace has had many CBD entrants, but it has limited resources and has chosen to focus enforcement in instances where brands have articulated disease claims (Watson 2019f). In terms of the ultimate pathway used to regulate CBD, much isn’t known. At one time, the agency had indicated that the new dietary ingredient route could be a viable path. Submitting a generally recognized as safe (GRAS) dossier to the agency for review is a possible alternative. Conducting the necessary research and compiling the results to show product safety but not submitting the package to the FDA could lead to self-affirmed GRAS status. If materials are submitted to the agency, then the FDA would review and respond via a letter, which would indicate whether the agency has comments or questions about the submission. The FDA doesn’t “approve” products subject to GRAS submissions (Schultz 2018).

Two companies have communicated that they have reached self-affirmed GRAS status for select hemp extracts. During September 2018, CV Sciences described itself as having the first hemp extract to reach the self-affirmed GRAS status. The self-affirmation was specific to CV Sciences’ hemp-derived CBD gold extract (CV Sciences 2018a). In May 2019, Manitoba Harvest and Hemp Oil Canada announced self-affirmed GRAS status for their broad-spectrum hemp extract, which would be used in protein powders, oil drops, an oil spray and softgels (Manitoba Harvest 2019b).

During November 2019, the FDA announced that it lacked the scientific evidence to know whether CBD is safe, and it emphasized its view that CBD is not a generally recognized as safe ingredient in food meant for humans or animals. Plus, the agency noted that CBD dietary supplements are unlawful. Warning letters sent from the agency to firms marketing CBD products suggested that companies interested in adding CBD to their products may need to compile food additive petitions instead of seek generally recognized as safe status. The FDA directed 15 warning letters to firms offering CBD products. With the November 2019 warning letters, the agency appeared to have broadened its attention to CBD product claims related to stress, anxiety and pain (Daniells 2019b).

To give consumers an update about CBD’s regulatory status, the FDA published guidance in November 2019. The update stressed the illegality of incorporating CBD in foods or dietary supplements, and it listed potential safety problems associated with CBD intake. Those include possible liver injury; drug interactions; negative effects on male reproductive health; sleepiness; diarrhea; poor appetite; mood changes; and uncertainty about implications for children, pregnant women and breastfeeding mothers. Other issues raised in the update included concerns about cumulative exposure to CBD, variations between CBD content published on labels and tested CBD levels and presence of contaminants in CBD products (Food and Drug Administration 2019).

The FDA has released no opinion specific to extracts. Some brands tout that all compounds found in a full-spectrum extract — cannabinoids, flavonoids, terpenes and fatty acids — have benefits when consumed in combination. This concept is termed the “entourage effect” (Watson 2019d).

In an October 2019 survey, a relatively large share of respondents indicated they lacked knowledge about CBD’s regulatory status, which may have prompted the FDA’s consumer update in November 2019. Conducted for the Natural Products Association, the survey collected input from 1,000 registered voters, and it found that roughly half didn’t know that FDA “has not approved any safety, purity, manufacturing, or ingredients standards for CBD, meaning that all CBD products are illegal.” Fifty-seven percent said they had familiarity with CBD products, and 36 percent shared they

had recently used or currently used a CBD product. For some, having more regulatory surety would incentivize them to try CBD. Of those who had not used CBD products, three in 10 said they were more likely to try CBD if FDA were to approve a safe level of consumption, and 76 percent of respondents who were CBD users said such (Schultz 2019a).

Recognizing that consumers do consume CBD, the Arthritis Foundation announced a series of CBD recommendations in September 2019 to help guide consumers through CBD choices. The announcement marked the first of its kind by a major patient advocacy group. In its recommendations, the Arthritis Foundation didn't suggest CBD as an arthritis symptom treatment. Instead, the recommendations intended to help consumers make informed choices about CBD products. They included selecting products made from U.S.-produced hemp, discussing CBD products with a doctor and not choosing products that contain THC. The guidance also stressed that CBD and arthritis medications may have interaction effects (Hemp Industry Daily 2019b).

The following sections share more about hemp-derived compounds.

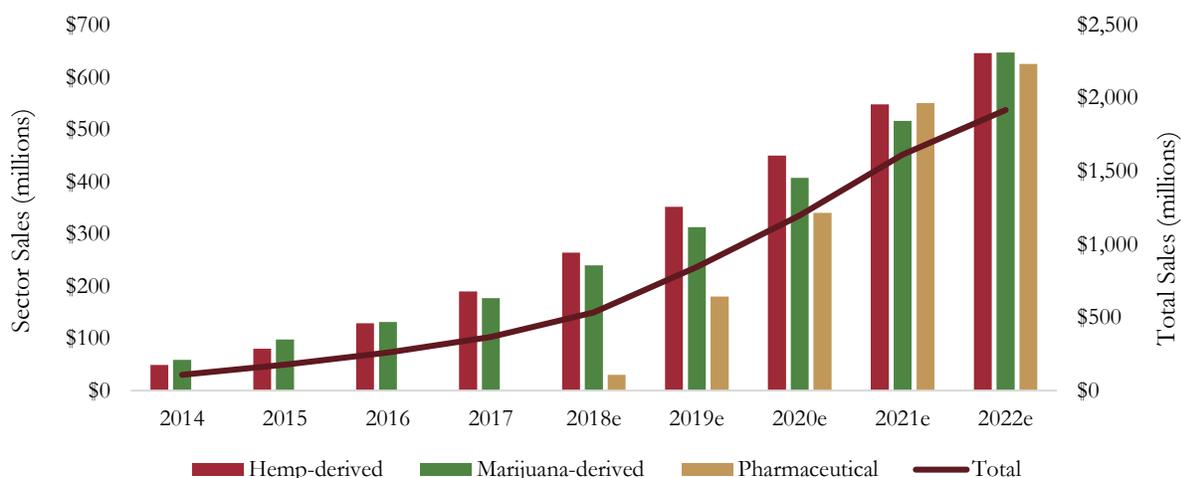
3.1 CBD

Considered an antioxidant, CBD may provide immune system benefits and anti-inflammatory properties (Krawiec 2018). It may also play a role in addressing anxiety, insomnia and chronic pain (Grinspoon 2018). As mentioned earlier, a CBD-containing drug — named Epidiolex — has received approval as an epilepsy treatment (Fusaro 2019). Other research has linked CBD to serving as therapies for inflammatory bowel disease (Esposito et al. 2013) and schizophrenia (McGuire et al. 2017). More research is needed to determine how CBD may influence such health conditions. Also, despite the positive health effects thought to be connected to CBD, the compound may also pose side effects, such as nausea, fatigue, irritability and medication interactions (Grinspoon 2018).

CBD Sales and Projections

The Hemp Business Journal and New Frontier Data have tracked CBD sales in past years and presented future sales projections. Those data suggest that the total U.S. CBD market will grow from \$108 million during 2014 to an estimated more than \$1.9 billion in 2022. Contributing to the total are sales of hemp-derived, marijuana-derived and pharmaceutical CBD. Note, the pharmaceutical sales estimates in the chart are for Epidiolex. During 2017 — the most recent year with actual sales in this data series — hemp-derived CBD accounted for 52 percent of the total CBD sales. Given pharmaceutical CBD's introduction and sales growth, the five years of projected CBD sales point to hemp-derived CBD becoming a smaller share of the total — roughly one-third of total CBD sales during 2022 (New Frontier Data 2018).

Exhibit 3.1.1 – U.S. CBD Market by Sector, 2014 to 2022 Estimate*



* “e” represents the data are estimates for the year.

Source: Hemp Business Journal and New Frontier Data (New Frontier Data 2018)

SPINS has reported CBD sales for products sold in the U.S. natural channel, which is composed of full-format establishments such as co-ops, associations, independent retailers and large regional chains with annual sales that reach at least \$2 million. Of total sales, at least half must originate from natural or organic products for the establishment to fit in the natural channel. For the year preceding Dec. 30, 2018, CBD herbal supplement sales in the natural channel exceeded \$52.7 million, which made CBD rank as the top-selling herbal supplement for 2018. Relative to the other ranked herbal supplements, CBD sales also experienced the most significant growth from 2017 to 2018 — 332.8 percent growth. Note, Whole Foods Market sales aren’t included in the natural channel sales data reported by SPINS. Despite its strong performance in the U.S. natural channel, CBD didn’t break into the top 40 for herbal supplements sold during 2018 in U.S. mainstream multi-outlets, which include supermarkets, drugstores, mass market retailers, military commissaries, buyer’s clubs and dollar stores (Smith et al. 2019).

Estimates released by other firms suggest bigger market potential for CBD products. Nielsen estimates published during June 2019 indicated that hemp-derived CBD sales may reach \$6 billion by 2025, assuming hemp-derived CBD food and beverage sales are legal. However, Nielsen acknowledged the CBD market’s volatility and recognized that regulation, available supply and CBD acceptance will ultimately influence true market potential. By product category, the firm projects that food and beverage sales will represent 44 percent of total hemp-derived CBD sales — \$1.7 billion for CBD beverages and \$950 million for CBD edible foods. The edible foods category includes products such as confections, gum and snacks (Nielsen 2019a).

In its 2019 Hemp Business Factbook, Hemp Industry Daily estimated hemp-derived CBD retail sales in the U.S. to total between \$1.1 billion and \$1.3 billion in 2019. It also projected substantial sales growth. By 2024, the Hemp Industry Daily projections suggested hemp-derived CBD retail sales would range between \$9.3 billion and \$11.3 billion (Hemp Industry Daily 2019d).

Brightfield Group projects strong CBD sales potential. The firm estimates CBD product sales in 2023 could exceed \$23 billion, and of this total, food and beverage sales would sum to about \$2.5

billion. For food and beverage sales to reach this level, Brightfield Group assumes some sort of FDA action will legalize CBD use (Watson 2019a).

In terms of understanding the companies fueling these sales, FoodNavigator-USA published market share estimates from Brightfield Group, a market research firm, in July 2019. The estimates suggest that the top four CBD firms held a 22.6 percent share of the market: CW Hemp, 7.1 percent; CV Sciences, 6.4 percent; Green Roads, 5.1 percent; and Medterra, 4 percent (Watson 2019a).

CBD Product Formats

As mentioned previously, CBD-containing products have an uncertain regulatory landscape. However, some brands have elected to already add CBD ingredients to their offerings, including food, beverage and personal care products. To deliver CBD, gummies have gained popularity as a product format. However, some consumers have an aversion to the gelatin found in gummy products (Fusaro 2019). According to Brightfield Group, tinctures have been the most commonly used CBD ingestible, but as food and beverage products more frequently have CBD incorporated in them, the food and beverage category may capture a greater share (Watson 2019a). Research from SPINS has also analyzed CBD sales according to product format. In the U.S. natural channel during 2018, it found that alcohol-free tinctures were the most popular CBD products sold. Capsules and softgels were other common formats. Also, marketing messages for much of the CBD sold in the U.S. natural channel had “non-specific health focuses.” The top two more specific benefits tied to CBD products were mood support and sleep (Smith et al. 2019). Firms that have used non-specific health messages may have chosen this approach given the FDA’s regulatory position.

Beverage Products

As the Nielsen projections suggested, beverages have the potential to develop into a sizeable CBD product category (Nielsen 2019a). Products may focus on delivering just the CBD, or they may include other ingredients — possibly B vitamins, guarana extract, caffeine and L-theanine. To incorporate CBD or hemp extracts into a beverage, however, product developers face challenges because some ingredient options aren’t soluble and could have uniformity, clearness and taste issues. Possible solutions are to form an oil-in-water emulsion that uses small oil particles or add an emulsifier (Wisener 2019).

Elev8 Hemp markets a ready-to-drink CBD-infused lemon iced tea and CBD-infused iced coffee. Packaged in a bottle and can, respectively, the iced tea and iced coffee products each contain 10 milligrams of CBD per unit. The 12-ounce (0.35 liters) cans contain less than 1 gram (0.035 ounces) of sugar and just 15 calories. The iced tea bottles each contain 16.9 fluid ounces (0.5 liters) of product, and the tea contains no sugar or calories (Elev8 Hemp 2019).

During March 2019, **Weller** introduced its sparkling water and CBD blend. Available in three flavors, the sparkling water label lists that each unit supplies 25 milligrams of CBD. Weller uses an extract. Unlike some brands that have hesitated to market products with the term “CBD,” Weller places a statement about CBD on its sparkling waters’ labels because it says consumers appear to be more familiar with “CBD” than “hemp extract.” The product has had distribution in channels such as coffee shops and independent grocery stores (Shoup 2019c). Wegman’s, Lucky’s, Sprouts, Fairway Markets and Lassen’s all carry Weller products. Before Weller began making sparkling water, it marketed coconut bites (Avery 2019). As CBD-infused snacks, coconut bites each contain 5 milligrams of CBD, but they deliver the compound from a full-spectrum hemp extract raised in

Colorado (FoodBev Media 2018). When Weller launched the coconut bites, it began with e-commerce distribution. The company viewed e-commerce as a critical channel because consumers look online for hemp information (Ortenberg 2018). Weller also markets a drink mix powder. With its sparkling water, drink mix and coconut bite product mix, Weller has a product that fits in multiple dayparts, which helps consumers use CBD at multiple stages in their days (Juntti 2019).

Recess, another sparkling water brand, focused on developing a product that helps its customers to feel balanced and productive. Each unit contains 10 milligrams of CBD hemp extract. Plus, the drinks, flavored with fruit juice, deliver other compounds, such as ginseng and L-theanine. Initially, Recess limited its distribution to online and New York City retailers. However, a NewHope360 story from October 2018 noted plans for the brand to expand its distribution to creative offices, cafes, fast-casual restaurants and natural products grocers (Blumenfeld 2018). The company has also noted the potential to distribute its drinks in U.S. vending machines. Although Recess launched its business with sparkling water, it intends to diversify in the future. During 2019, the brand unveiled its first retail store in New York and shared that it intended to open a second store in Los Angeles. With the retail locations, Recess gives consumers an opportunity to “experience the brand,” which emphasizes helping feel productive and calm (Thomas 2019).

Lumen has developed a patent-pending process designed to create a cold-pressed hemp juice. To make the “whole plant” juices, the company uses hemp flowers and leaves, not the seeds. During 2019, Lumen introduced these high-pressure-processed juices as “hemp elixirs.” Blended with other notable ingredients such as turmeric, ginger and moringa, the hemp juice is sold as a “superfood shot” (Watson 2019c) in 2-fluid-ounce units (0.06 liters). Named Immune and Restore (Wisener 2019), the elixirs contain a little naturally occurring CBD, not the isolated compound. At retail, the elixirs may be stocked as a supplement or grocery product (Watson 2019c).

Startups aren’t the only beverage businesses to explore opportunities related to hemp. During September 2019, **Coors Distributing** announced that it would add nonalcoholic Colorado’s Best Drinks products and DRAM Apothecary waters to its distribution options. The Denver-area distributor serves restaurants, grocery stores, event venues and other retail locations — more than 1,000 in total. Coors Distributing noted interest in distributing the hemp-infused beverages as a strategy to satisfy growing demand for nonalcoholic drinks. Colorado’s Best Drinks makes sodas and flavored drinks that feature hemp infusions, and DRAM Apothecary offers sparkling waters that blend hemp and botanical extracts (Hemp Industry Daily 2019c).

Food Products

Like Weller, which entered the CBD business via snacks, several other firms have introduced foods that incorporate CBD as an ingredient. **Spectrum Confections**, founded by the man who developed Jelly Belly products, has formulated miniature jelly beans with 10 milligrams of CBD per bean. The CBD-infused beans are available in 38 flavors, including sugar-free and sour iterations (Fusaro 2019). Oregon-based **A Boring Life** has also introduced snacks with added hemp extract. Each serving of its lavender-flavored almonds, sweet and spicy walnuts and dark chocolate and sea salt almonds contains 25 milligrams of organic hemp extract (A Boring Life 2019). The company suggests that the CBD in the extract absorbs well because of the omega-3 fats found in the nuts. Planned distribution channels for the nut products include the brand’s own website, Amazon and retail grocers. The company has participated in programs from CanopyBoulder, a business

accelerator (Kaiserman 2019). **NatureBox**, an e-commerce snack company that names millennials as a key audience, introduced a CBD Wellness product line during 2019. The CBD Wellness line features fruit snacks made from whole fruit and hemp extract. Consumers responded positively to the product's launch. It was a sell-out in the first week (Hyslop 2019).

Frozen products have also incorporated CBD as an ingredient. A father-son duo recognized an opportunity to introduce an Italian ice product with added CBD, and their product development efforts ultimately led to forming **Mt. Everetts Frozen Creations**. The family had experience in offering Italian ice but not those with added CBD. Each 5-ounce cup (141.75 grams) includes 30 milligrams of CBD. Consumers may purchase the CBD-containing Italian ice cups in lemon, cherry or mango flavors (Allabaugh 2019). Distribution has included sales to Colorado-, Florida- and Nevada-based dispensaries, and e-commerce focuses on distribution in the East Coast area. When developing the Mt. Everetts Frozen Creations products, the family received feedback from a number of industry players that focused on how adding CBD oil to a water-based product would be impossible (Small 2019). The oil lacks solubility in water, so it doesn't tend to mix well. Other products typically have some sort of fat-containing ingredient, such as coconut oil or ice cream, to act as a carrier for the compound (Ruiz 2019). For Mt. Everetts Frozen Creations, it developed a process to create nanoparticle-like CBD molecules that would work in the frozen ice (Small 2019).

Another set of food brands has indicated interest in introducing CBD products after regulatory requirements become clearer. For example, **Ben & Jerry's** announced interest in developing an ice cream made with CBD. **Mondelez** has said that it doesn't have plans to incorporate CBD into products that are part of its "family brands." However, introducing new brands that feature CBD-containing products could be possible for the company (Fusaro 2019).

CBD also has potential in the **food service space**. For the 2019 What's Hot Culinary Survey, the National Restaurant Association surveyed professional chefs who were members of the American Culinary Federation. Three-quarters of the respondents identified the top culinary trend to be cannabis and CBD-infused drinks, and three-quarters selected cannabis and CBD-infused food as the No. 2 trend (Food Ingredients First 2019). Quick-service restaurant Carl's Jr. listed a CBD burger as a one-day item on one location's menu during April 2019. Named the Rocky Mountain High CheeseBurger Delight, the menu item had two beef patties, pepper jack cheese, waffle fries, pickled jalapenos and a CBD-infused sauce. The store location only sold the item to customers who were at least 18 years old. Also, it limited customers to two (Rubino 2019).

Although offering finished goods is one CBD opportunity, another strategy involves manufacturing and marketing hemp-infused ingredients. Oils, butter or water-soluble CBD are frequently incorporated ingredients into products (Fusaro 2019). New York-based **Azuca** infuses sugars, syrups and flakes with CBD and sells these ingredients online to consumers or through wholesale agreements to manufacturers. The infused sugars and syrups could be added to batters, doughs and drinks, and the flakes are intended for savory applications. The company has sought intellectual property protection for its approach to creating hydrophilic — or water-friendly — cannabinoid particles that absorb quickly after being consumed. With fast absorption, consumers may be less likely to consume too much CBD (Garcia 2019).

Cosmetics and Personal Care

Mainstream retailers have appeared to feel less concerned about stocking topical cosmetic-like products than edibles, and a growing list of cosmetics companies have introduced formulas that contain CBD as a component. **Cannuka** is one brand marketing CBD-containing cosmetics. It sells products such as lip balm, body cream, skin balm, face cream and after-sun cream that incorporate CBD isolate and hemp seed oil (Cannuka 2019). Select Neiman Marcus locations have sold Cannuka products (Reisch 2019). Other distribution channels for the brand include Ulta Beauty, Dermstore and boutiques in cities throughout the country (Cannuka 2019).

In addition to operating as a hemp-derived phytocannabinoid supplier, **Folium Biosciences** has created its own cosmetics that include CBD as a component (Reisch 2019). The company offers cellulose face masks made with broad-spectrum phytocannabinoid oil and moisturizing cream infused with CBD. It categorizes such products as “cosmeceuticals” (Folium Biosciences).

In April 2019, Unilever-owned **Schmidt’s Naturals** announced that it would launch hemp- and CBD-containing deodorant products later in the year. Distribution of the hemp-based deodorant was planned to begin widely in U.S. Target stores. Schmidt’s Naturals also noted plans to distribute a deodorant made with CBD in states where marijuana is legal (George-Cash 2019).

Like for food and supplement products, cosmetic products containing CBD should avoid making medical claims because doing such may cause the product to be recognized as a drug (Reisch 2019).

Consumer Insights

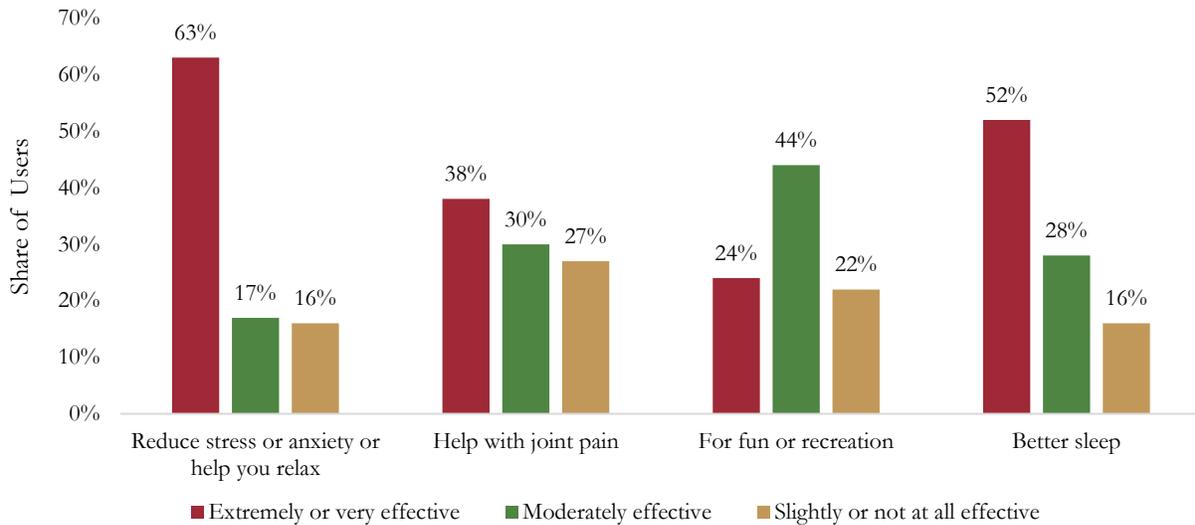
Certain consumer segments have created a market for CBD products and consumed them for various purposes. To gauge CBD use among Americans, Consumer Reports recruited more than 4,000 individuals to participate in a survey during January 2019. According to the nationally representative survey, 26 percent of the respondents had tried CBD products at some point in the two years preceding the survey (Gill 2019). Gallup conducted its own poll from June 19 to July 12, 2019, to measure CBD use among American adults. Gallup found that 14 percent of the respondents said that they were CBD users. Half indicated they didn’t use CBD products, and 35 percent noted not being familiar with CBD products (Brenan 2019).

Both surveys — those conducted by Consumer Reports and Gallup — identified characteristics shared by consumers who use or have tried CBD products. Of those who responded to the Consumers Reports survey and had tried CBD products, roughly 14 percent indicated that they used a CBD product every day. Most of the CBD users — 74 percent — indicated that they didn’t have side effects after using CBD. In terms of why people choose to use CBD, the top two reasons were reducing stress or anxiety or relaxing and helping with joint pain (Gill 2019). In the Gallup research, the three conditions for which the greatest share of CBD users noted consuming CBD were pain, 40 percent of respondents; anxiety, 20 percent; and insomnia or sleep, 11 percent (Brenan 2019).

In terms of CBD’s effectiveness, nearly two-thirds of the consumers responding to the Consumer Reports survey and who used CBD to decrease stress, reduce anxiety or relax reported that CBD was extremely or very effective for these purposes. Roughly half of the consumers who chose to use CBD for better sleep said CBD was extremely or very effective for this purpose. Smaller shares of users indicated CBD’s efficacy in helping with joint pain or providing fun or recreation. See Exhibit

3.1.2. Of the consumers who noted using CBD to address a certain health issue, 22 percent indicated that the CBD replaced the need to take a prescription or over-the-counter medication. Forty-eight percent hadn't used a medication to address the health problem, and 30 percent used CBD and medication in combination (Consumer Reports 2019).

Exhibit 3.1.2 – CBD Efficacy by Use Reason

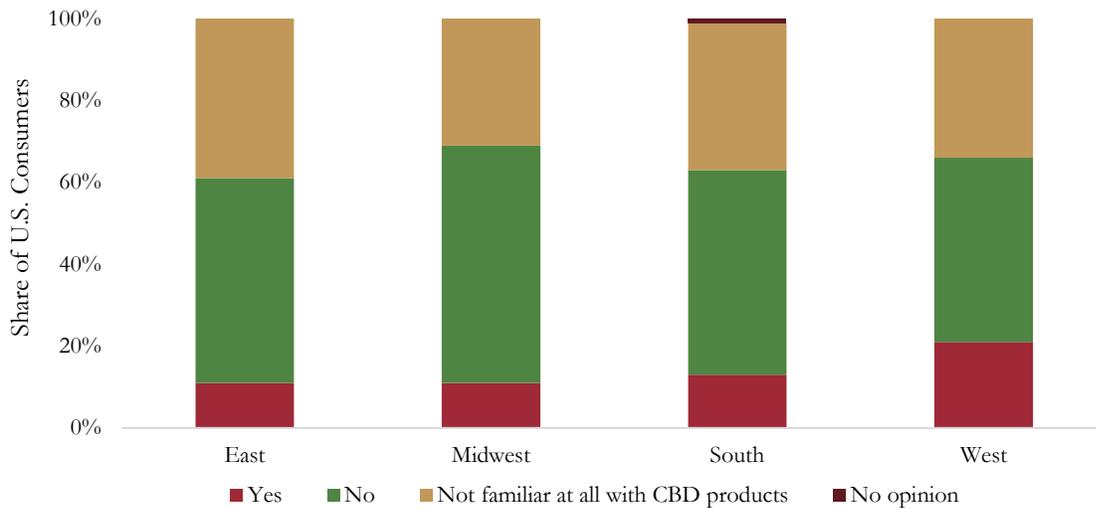


Source: Consumer Reports (2019)

Overall, CBD use has been more common among younger consumers than older consumers. Of the consumers participating in the Consumer Reports survey, 40 percent of 18- to 29-year-olds said they had tried CBD. Survey respondents who were at least 60 years old indicated they were less likely to have tried CBD; just 15 percent noted that they had tried CBD. Among middle-aged survey respondents, 32 percent of 30- to 44-year-olds had tried CBD, and 23 percent of 45- to 59-year-olds had (Gill 2019). In the Gallup poll, 20 percent of 18- to 29-year-olds indicated that they use CBD compared with 16 percent of 30- to 49-year-olds, 11 percent of 50- to 64-year-olds and 8 percent of those who were at least 65 years old. Familiarity with CBD also declined with age; “not familiar at all with CBD products” was one option that respondents could select when answering whether they personally use CBD products. Nearly half of consumers who were at least 65 years old said they weren't familiar at all with CBD products. The share of those who were unfamiliar was lower for the other age groups: 36 percent for 50- to 64-year-olds, 30 percent for 30- to 49-year-olds and 26 percent for 18- to 29-year-olds (Brenan 2019).

The Gallup poll results also illustrated how CBD use has varied by geographical region. Exhibit 3.1.3 shows that adult consumers in the western U.S. were more likely to use CBD than adult consumers from other areas of the country (Brenan 2019).

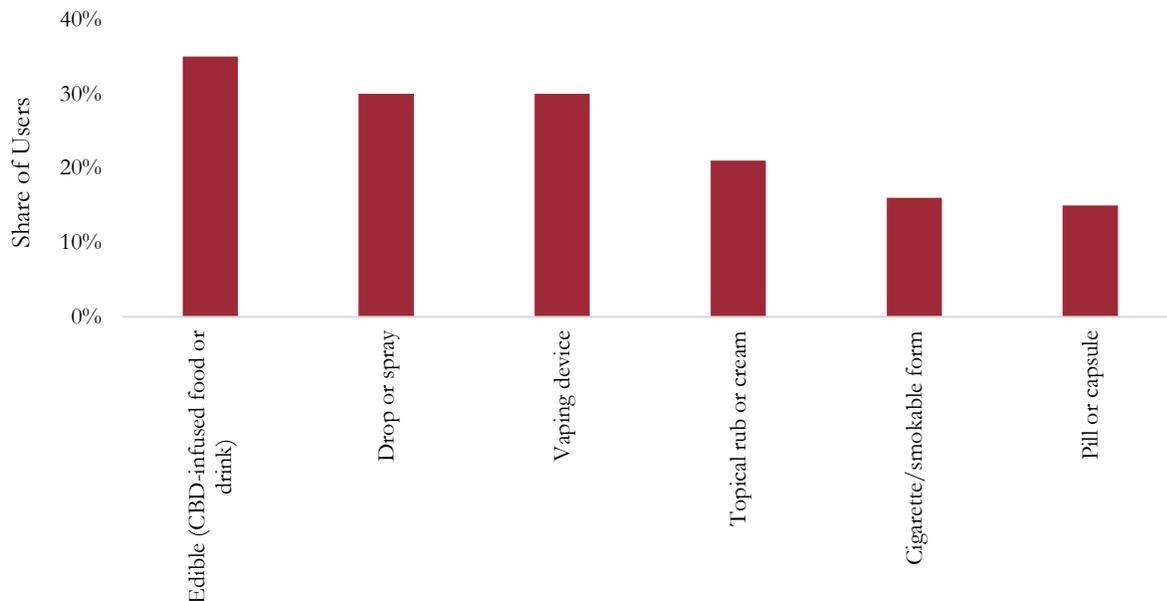
Exhibit 3.1.3 – CBD Use by Geographical Region



Source: Gallup (Brenan 2019)

With respect to how consumers choose to use CBD, the Consumer Reports survey respondents could select the CBD forms they usually use, and the greatest share said they usually choose edibles, such as foods and drinks infused with CBD. More than one-third of the respondents shared that they usually use a CBD-infused edible. See Exhibit 3.1.4. One in three consumers indicated usually using drops or sprays or vaping devices, and roughly two in 10 shared that they usually use a topical CBD product, such as a rub or cream. Consumers were least likely to name smokable CBD and pills or capsules as CBD products they usually use (Gill 2019).

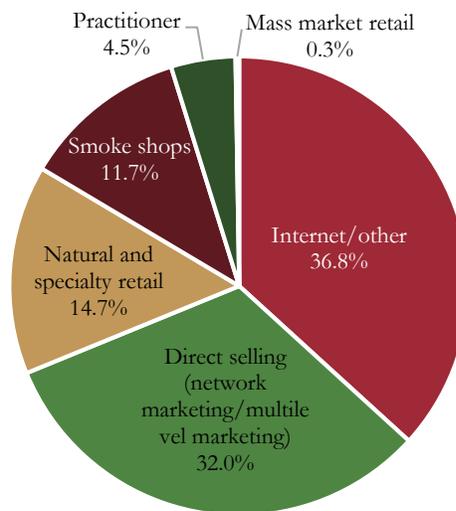
Exhibit 3.1.4 – CBD Forms Usually Used by Survey Respondents



Source: Consumer Reports (Gill 2019)

CBD sales have occurred in several channels. See Exhibit 3.1.5. The two channels that generated the greatest share of hemp-derived CBD sales in 2018, according to reporting from New Frontier Data and the Hemp Business Journal, were “internet/other” and “direct selling.” Note, direct selling refers to network marketing and multilevel marketing. Collectively, these two channels contributed more than two-thirds of total hemp-derived CBD sales in the U.S. Mass market retailers and practitioners sold very little hemp-derived CBD. Other distribution channels and the share of sales they contributed were natural and specialty retail, 14.7 percent, and smoke shops, 11.7 percent (Sumner 2019c).

Exhibit 3.1.5 – U.S. CBD Sales by Distribution Channel, 2018



Source: Hemp Business Journal and New Frontier Data (Sumner 2019c)

The Consumer Reports survey research also worked to understand how sales vary by channel. Based on the survey responses, 40 percent of respondents said they usually buy CBD products from a cannabis dispensary, but retail stores and online retailers serve as other relatively common CBD purchase locations. Thirty-four percent of respondents said they usually purchase CBD at retail stores, and 27 percent said they usually buy their CBD products from an online retailer (Gill 2019).

Pet Products

The pet and animal industry also holds potential for CBD. Mammals, birds, fish, reptiles and invertebrates have cannabinoid receptors, and some research, particularly in dogs and mice, indicate that CBD use may yield positive effects in animals (Sumner 2019a). For example, research conducted at Colorado State University explored how dogs with epilepsy responded to CBD during a trial conducted in 2016 and 2017. Of the 16 dogs involved in the study, nine received a CBD treatment, and seven received a placebo. Consuming CBD oil for 12 weeks reduced seizure frequency in 89 percent of the dogs participating in the treatment group (Guiden 2019).

In terms of sales, New Frontier Data and Hemp Business Journal data suggest that hemp-derived CBD sales in the pet and animal market totaled \$48 million during 2018. See Exhibit 3.1.6. Projections point to marked sales growth in the next few years. By 2022, sales of hemp-derived CBD targeted to animals and pets are projected to increase to \$298 million (Sumner 2019a).

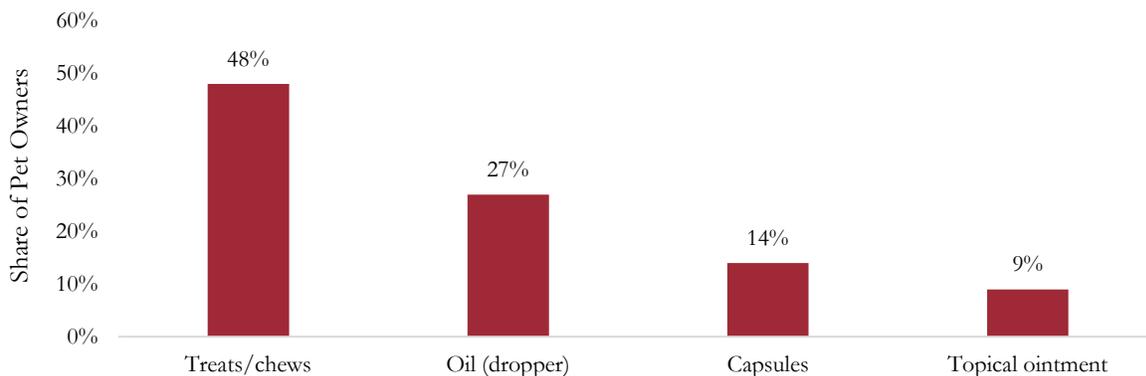
Exhibit 3.1.6 – Hemp-Derived CBD Sales in Pet and Animal Market, 2017 to 2022



Source: Hemp Business Journal and New Frontier Data (Summer 2019a)

During July 2019, Acosta conducted a consumer survey to learn more about CBD adoption and use. It also explored CBD use in pets and found that 10 percent of pet owners said they buy CBD products for their pets. Roughly half of those said a veterinarian suggested the purchase. In terms of why pet owners have provided CBD to their pets, nearly four in 10 said pain-related reasons. Anxiety reasons were cited by 32 percent of pet owners, and 29 percent of pet owners said general wellness was a motivation for their pets using CBD products. Exhibit 3.1.7 presents the top CBD product formats that pet owners said they give their animals. As noted, the largest percentage of pet owners said they give their pets treats or chews that contain CBD (Acosta 2019).

Exhibit 3.1.7 – Types of CBD Products Pet Owners Give to Their Pets



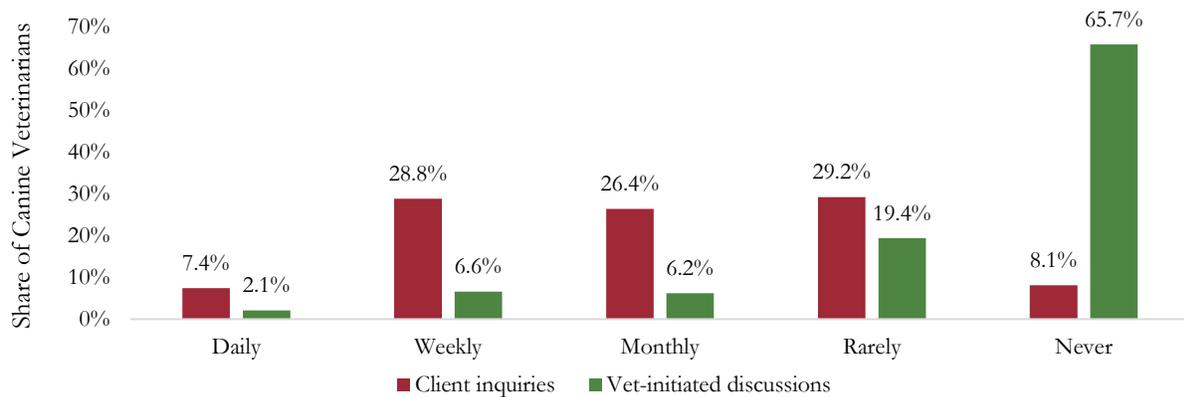
Source: Acosta (2019)

As noted in the Acosta research, veterinarians have played a role in shaping CBD use among pets. A study that analyzed responses from U.S. canine veterinarians found, however, that pet owners are more likely than veterinarians to initiate discussions about CBD use in dogs. The researchers invited veterinarians who participate in the Veterinary Information Network to complete an online, anonymous survey during spring 2018. Exhibit 3.1.8 illustrates that nearly two-thirds of veterinarians said they never initiate discussions about CBD with clients (Kogan et al. 2019). Veterinarians may not initiate CBD product discussions because of certain conditions created by state boards. In some

states, boards of veterinary medicine or pharmacy may limit veterinarians from prescribing, handling, dispensing or recommending CBD (Boothe 2019).

In the Veterinary Information Network research, the top three diseases or conditions that led clients to ask about CBD product information or that caused veterinarians to initiate discussions about CBD products were pain management, anxiety and seizures. Note, the likelihood that clients inquire about CBD use in pets varied according to whether veterinarians practiced in states that have legalized recreational marijuana. States with legal recreational marijuana were those where veterinarians reported daily and weekly CBD-related inquiries more commonly (Kogan et al. 2019).

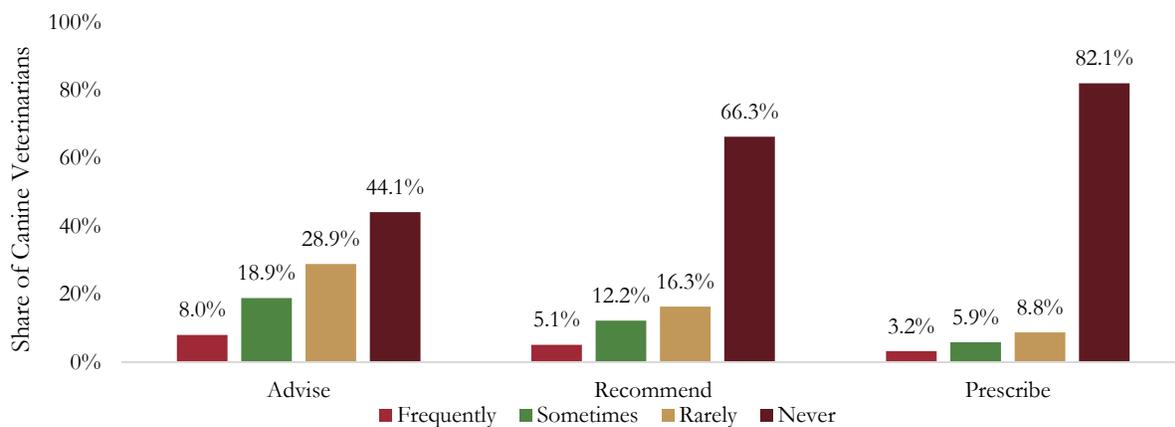
Exhibit 3.1.8 – Frequency of CBD-Related Veterinarian-Pet Owner Consultations



* n = 2,112 for client inquiries and n = 2,128 for vet-initiated discussions
 Source: Frontiers in Veterinary Medicine (Kogan et al. 2019)

In terms of the substance of veterinarian-client discussions about CBD, veterinarians participating in the survey were less likely to recommend or prescribe CBD products than they were to advise clients on use of CBD products. See Exhibit 3.1.9. Eight in 10 veterinarians who responded to the question said they never prescribe CBD products compared with two-thirds who said they never recommend CBD products and 44 percent who said they never advise on CBD products (Kogan et al. 2019).

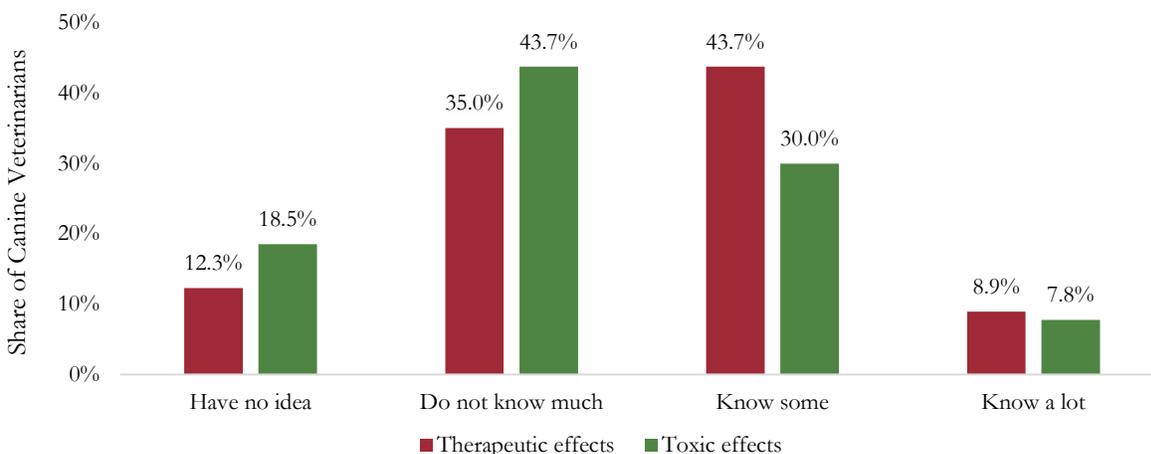
Exhibit 3.1.9 – Frequency of Veterinarians Advising, Recommending or Prescribing CBD Products



* n = 2,125 for advising, n = 2,124 for recommending, and n = 2,130 for prescribing
 Source: Frontiers in Veterinary Medicine (Kogan et al. 2019)

Another reason veterinarians participating in the survey may tend to not initiate CBD product discussions with clients is because they lack knowledge about the products’ potential therapeutic and toxic effects. Of the 2,126 respondents who answered, Exhibit 3.1.10 shows that a relatively small share of canine veterinarians said they knew a lot about CBD products’ therapeutic and toxic effects. The veterinarians also indicated that they tend to know less about hemp and CBD products’ toxic effects than they do about the products’ therapeutic benefits (Kogan et al. 2019).

Exhibit 3.1.10 – Canine Veterinarians’ Knowledge of Hemp/CBD Product Therapeutic and Toxic Effects



* n = 2,126

Source: *Frontiers in Veterinary Medicine* (Kogan et al. 2019)

Firms that have introduced CBD products meant for animal use include King Kanine, Pet Releaf and Honest Paws (Sumner 2019a). **King Kanine** markets oils, treats, topical balms and sprays that include CBD as an ingredient. In addition to exploring domestic CBD sales for pets, King Kanine also sells product internationally and notes that the international interest in trying pet-targeted CBD products has grown (Pet Business 2018).

To offer CBD pet products, **Pet Releaf** has invested in a vertically integrated supply chain. Through a joint venture, it grows certified organic hemp in Colorado, and the company has access to a specific hemp strain named PR-33. Pet Releaf operates its own kitchen to make its Edibites products. Pet Releaf describes its Edibites products as “the ultimate daily supplement.” Other products that it offers include hemp oils and capsules. A relatively new product uses liposome technology to enable pet owners to maximize the efficacy of delivering hemp extract. Pet Releaf has said that it has plans to serve international markets. The company noted that it would enter the Japanese market during January 2019 (Pet Business 2019b).

Honest Paws markets a variety of CBD products, including oils and soft chews, intended for animal use (Honest Paws 2019). At the 2019 Global Pet Expo, Honest Paws began U.S. retail distribution of its products (Pet Business 2019a), and it also launched a new product — peanut butter infused with a full-spectrum CBD oil meant for dogs (Tyler and Semple 2019).

Product Challenges

In terms of developing and marketing CBD products, the industry has had some challenges arise. For example, some brands have cited flavor as one challenge to address. CBD can have an unpleasant flavor, particularly if the dosage is high, so manufacturers must find ways to avoid the final good taking on that flavor (Fusaro 2019). Accurate labeling has been another issue for CBD products. A May 2019 story from The New York Times summarized findings from Journal of the American Medical Association-published research that evaluated CBD content in 84 products marketed online. CBD content in 26 percent of these products was less than the label indicated, and the level was higher than indicated for 43 percent of the products (Velasquez-Manoff 2019).

Distribution

Some retailers have opened distribution channels for brands seeking to market their CBD products. On a limited geographic scope, two large drug store chains — **CVS** and **Walgreens** — have both agreed to distribute CBD products (Velasquez-Manoff 2019). The two retailers have noted that they would first stock creams, patches and sprays made using CBD ingredients. Online, **Walmart** also sells CBD-containing topical products (Reisch 2019). Retailers including **Sephora**, **Barneys** and **Neiman Marcus** have committed to marketing CBD beauty products (Li 2019). When choosing CBD products, Sephora tested products for their texture, absorption, potency and results. It also exclusively featured products made from full- or broad-spectrum hemp extract raised in the U.S. (Devash 2019). With its online marketplace, **Credo** markets beauty products made from hemp seed oil and CBD (Credo). Some challenges have complicated retailers from offering CBD products. **Thrive Market**, an online natural and organic membership-based grocer, had offered supplements and topical products made from hemp ingredients, but it pulled those products from its site during June 2019. At the time, the market's payment processor mandated that the online market no longer sell hemp and CBD items. Thrive Market was committed to carrying CBD options for its customers, however, and by August 2019, CBD products had returned to the company's website (Gazdik 2019).

Retail represents a key stage of the value chain as securing distribution enables a brand to reach potential buyers. During the Natural Products Hemp and CBD Summit held in conjunction with Natural Products Expo West 2019, three retailers participated in a panel discussion. Overall, the panelists seemed to view their hemp offerings as fairly saturated. To consider stocking a new product, the retailers noted they would look for differentiated options. A unique mode of delivery is an example. The retailers also noted how they look for brands they carry to have a compelling story.

In terms of where to expect CBD products in the future, Brightfield Group has indicated that gyms may represent an opportunity. Some independent gyms or those that have few locations already make CBD products available to members. Offering samples to gym members or asking gyms to stock and sell CBD products may serve as a distribution channel (Watson 2019a). Spas and nail salons may also build demand for CBD topical products. These establishments may choose to integrate CBD products into their massage, pedicure and manicure services. As such, brands may identify an opportunity to develop CBD products intended for in-salon use. Additionally, spas and salons that operate retail shops may stock CBD products to sell directly to their clients (Curtis 2018).

Certifiers

Certification programs have been introduced to validate information about hemp products and methods used to produce them. The hemp and hemp-derived CBD product testing, auditing,

verification and certification service from **NSF International** launched in October 2019. Based on a test method from the Association of Official Analytical Chemists (AOAC), the NSF program focuses on certifying several variables. They include ensuring that the THC content doesn't exceed allowable levels; measuring the presence of pesticides, heavy metals and other contaminants; and testing for E. coli, Salmonella and other microbes (Schultz 2019b).

With its certification program, the **U.S. Hemp Authority** takes a comprehensive approach to auditing and certifying the hemp-based product supply chain. Developed for hemp-based foods, dietary supplements and cosmetics, the U.S. Hemp Authority Certification Program requires each supply chain actor — growers, processors, manufacturers, bottlers, packagers, labelers and so forth — to receive its certification seal or hold a certification from another qualified group that Where Food Comes From, the U.S. Hemp Authority's selected auditor, approves. If neither of these conditions are true, then the supply chain actor would need to comply with the U.S. Hemp Authority's audit requirements and receive an annual certificate of compliance. Supply chain actors participating in the U.S. Hemp Authority's certification program must pay a licensing fee and submit to annual audits, which involve an added fee, to use the program's seal. A copy of the authority's seal is included in Exhibit 3.1.11 (U.S. Hemp Authority 2019).

Exhibit 3.1.11 – U.S. Hemp Authority Seal



Source: U.S. Hemp Authority (2019)

3.2 Other Cannabinoids

Several firms have recognized the opportunity to offer products that contain a variety of cannabinoids formulated in various proportions. In an interview with Hemp Today, Scott Reese, CEO at C-Beyond Health, said, “The future lies in exacting combinations of the right cannabinoids in the right ratios to achieve health outcomes for particular conditions” (Hemp Today 2019a). Thus, looking beyond CBD may lead to identifying other potentially valuable cannabinoids.

The regulatory environment, however, is a factor to consider for all cannabinoids. A story from NutraIngredients-USA summarized an August 2019 webinar hosted by the United Natural Products Alliance (UNPA), and the webinar highlighted the importance of regulatory considerations. According to an analysis by UNPA, several pharmaceutical companies suggested that they have begun research on multiple cannabinoids — potentially at least 10 of them — in comments they made to the FDA. If pharmaceutical innovation yields commercialized drugs that feature other

cannabinoids, then supplement formulators and food and beverage businesses may have limited opportunity to include those cannabinoids in products of their own if the FDA regulations preclude drug ingredients from being included in supplements and foods. Thus, the UNPA president posed this question about what regulatory action to request of the FDA: “Is the ask to please clarify CBD is a lawful ingredient, or is that shortsighted and should it be more broad to cover other cannabinoids, in which case which ones, and why?” (Watson 2019e).

The following discussion introduces cannabinoids other than CBD that have received attention in the marketplace. Note, more research is necessary to fully understand each cannabinoid’s role in the body and wellness and how cannabinoids work in combination. This summary highlights assumptions or preliminary information reported by industry, though further research is likely needed to validate these possibilities.

Cannabigerol (CBG)

In cannabis, cannabigerol (CBG) exists at relatively low levels — often roughly 1 percent (Gold 2019). That’s because the compound begins as CBGA. The acid form of CBG can transform into THCA and CBDA, which then convert into THC and CBD, respectively (Koslow 2019), when exposed to heat or aged (Gold 2019). The CBGA may also convert into CBCA, which ultimately becomes CBC, another cannabinoid (Colbert 2018). Any CBGA that doesn’t change forms can convert into CBG (Koslow 2019). Because of this pathway to synthesizing several cannabinoids, some in industry recognize CBG as a “mother” or “stem cell” cannabinoid (Lassalle 2019).

To maximize the CBG content in harvested material, growers would need to harvest hemp plants early before the CBGA converts into other types of cannabinoids. Select plant breeders have studied how to increase CBG concentrations (Koslow 2019). These breeders may look to exploit a genetic mutation that prevents the conversion process described earlier from taking place (Colbert 2018).

Although limited research has focused on understanding how CBG may influence health and wellness, initial findings suggest that the compound may have antifungal, anti-inflammatory, antibacterial and antimicrobial properties. It also may play a role in appetite stimulation, neuroprotection, cancer cell death (Koslow 2019), blood pressure regulation and pain mitigation (Gold 2019). Additionally, it may help to manage intraocular pressure — a glaucoma precursor — and counteract THC’s effects (Koslow 2019). Anandamide, a cannabinoid found naturally in the human body, increases its levels in response to CBG, and the anandamide compound has a connection to appetite, sleep and memory regulation (Railis 2018). It also influences mood as it’s called a “bliss” molecule. As stated earlier, further research can better articulate health benefits associated with CBG intake. From a consumer perspective, CBG awareness is likely low as consumers are just becoming comfortable with THC and CBD as cannabinoids (Lassalle 2019).

Product-related CBG innovation has been somewhat limited. The compound’s cost represents a chief barrier. In August 2019, Green Entrepreneur reported that CBG cost five times to six times more than CBD (Koslow 2019). The expense is significantly attributed to the low CBG content in hemp plants. Additionally, chromatography used to extract such small quantities of CBG in plant material adds costs (Lassalle 2019).

Despite the expense, some firms have experimented with CBG product development. For example, **Axim Biotechnologies** has patented several consumer product formulas that incorporate CBG as an ingredient. One innovation is a topical cream made with CBG and CBD. Axim Biotechnologies has also indicated it will look into developing a powder (Koslow 2019). During summer 2019, **Socati Corp.** released two new CBD-CBG blends. Available in oil and water-soluble formulations, the products contain no less than 80 percent CBD and 4 percent CBG. Intended for use in consumer-packaged goods, the products contain no detectable THC. Socati has a patented process that uses chromatography to extract the THC, and the company has said that offering THC-free options is crucial to get large retailers, such as Target and CVS, on board with cannabinoid products (Shoup 2019b). **Geocann** is another entrant into the CBG market. With two products announced in September 2019, Geocann offers one formula that blends CBD and CBG. The second product solely features CBG (Daniells 2019a). **Steve's Goods** sells a CBG isolate online in quarter-, half- and full-gram increments. The company cautions that CBG is a CBD and THC precursor. In addition to offering the CBG isolate, Steve's Goods also markets CBG oil, including those in watermelon and blueberry flavors (Steve's Goods).

Cannabinol (CBN)

Another cannabinoid, cannabinol (CBN) is present at low concentrations in cannabis — at less than 1 percent CBN on average. CBN is thought to form as heat or oxygen exposure converts THC into the CBN compound (Railis 2018). Existing research hasn't conclusively determined whether CBN has psychoactive properties. In some cases, research has pointed to the compound being non-psychoactive, but in other findings, CBN has been mildly psychoactive (Breus 2019). Preliminary research has suggested CBN may have several health- and wellness-related benefits. Media coverage has pointed to CBN having anti-inflammatory properties, supporting bone tissue growth, serving as a sleep aid, stimulating appetite, working as an anti-convulsive agent (Railis 2018), influencing cancer cell growth and helping glaucoma patients. With respect to its effect on sleep, CBN may help with prolonging sleep. CBN's appetite stimulation characteristic makes it different from CBD, which may suppress appetite (Breus 2019). Consuming CBN with other cannabinoids may yield better results (Palermino 2019).

Several product developers have added CBN to certain product formulations. **Kin Slips** created strips that deliver cannabinoids when a user places a strip under his or her tongue. Branded with the Shut Eye name, one product delivers 5 milligrams of CBN and 5 milligrams of CBD to users. During September 2019, distribution was limited to select Californian medical cannabis suppliers (Kin Slips). **Mary Medicinals** markets a CBN-CBD blend as a tincture that's applied under the tongue. Called The Remedy CBN: CBD, each bottle contains 200 milligrams of CBN and 200 milligrams of CBD. It shares that administering the tincture provides a dosage that's simpler to measure (Mary's Medicinals 2019).

Cannabichromene (CBC)

Cannabichromene (CBC) is a cannabinoid found to not be intoxicating or addictive (Precision Plant Molecules 2019). To yield CBC, the acid form — CBCA — ages or experiences exposure to heat (Railis 2018). Precision Plant Molecules, a hemp-derived ingredients supplier, has said that CBC may convert into two other cannabinoids: cannabicyclol (CBL) and cannabicitran (CBT). Depending on the variety, CBC may follow CBD as the second most prevalent cannabinoid (Precision Plant Molecules 2019). Benefits attributed to the acid form of CBC have included antimicrobial, analgesic,

antiviral and anti-inflammatory properties (Railis 2018). Some reports also link CBC to having antifungal characteristics, easing depression-related symptoms and providing neuroprotective benefits (Precision Plant Molecules 2019).

Firms have begun to introduce CBC isolates, which product developers can use in combination with other cannabinoids to customize cannabinoid levels in products (Black 2019). During August 2019, **Precision Plant Molecules** announced it was the first to offer a highly pure CBC distillate. It sells the product as a bulk ingredient or an option to add to an extract (Precision Plant Molecules 2019).

Tetrahydrocannabivarin (THCV)

Similar in structure to THC, tetrahydrocannabivarin (THCV) originates from CBGV converting into THCVA and then THCV. Heat or light can facilitate the conversion (Weedmaps 2019). Research hasn't conclusively determined whether THCV possesses psychoactive properties (Houston 2018). In cannabis, THCV tends to exist at low levels. Industrial hemp hasn't been a good source (Weedmaps 2019). However, some attention has turned to enhancing the THCV content of industrial hemp (Houston 2018). When THCV is present at low levels, extracting the compound may be cost-prohibitive. Another challenge associated with THCV involves the need to conduct an analysis that specifically measures differences in THCV and THC content (Weedmaps 2019).

Like for all cannabinoids, further research will help to better articulate possible health effects associated with THCV. It may have anticonvulsant and antipsychotic properties (U.S. National Library of Medicine 2019). The compound also reportedly has the potential to suppress appetite; help with glycemic control in diabetic patients; regulate blood sugar; decrease seizure incidence in patients with epilepsy; serve as a Parkinson's disease therapy (Weedmaps 2019); form bone; promote sleep; and act as an anti-inflammatory, anti-nausea, anti-cholesterol and neuroprotective compound. Members of the **Medical Cannabis Research Consortium of Marin** and **GW Pharmaceuticals** have shown interest in THCV-based treatments or therapies (Houston 2018).

3.3 Terpenoids

As compounds that contribute aroma and flavor to cannabis extracts, terpenoids have properties that discourage predators from harming plants and encourage pollinator activity. They can also have a bitter flavor. The specific terpenoid content varies by strain, and it is affected by production-related factors such as temperature, growing medium, nutrients and sunlight. Typically, the terpenoid content in *cannabis* flower systems ranges from 2 percent to 5 percent (Erickson 2019).

Terpenoids may provide certain health and wellness benefits. For example, bisabolol has aromas and flavors that are fruity, nutty and like coconut, and it has possible antibacterial and anti-inflammatory health effects. Limonene is known for its sweet, citrusy flavor and aroma, and it may have properties that relieve stress, elevate mood and serve as an antibacterial agent. As another example, the floral, rose-like and woody linalool has been noted for its anti-anxiety and sedative properties. Determining how these and other terpenoids interact with one another and cannabinoids will require further study (Erickson 2019). Terpenoids may contribute to the entourage effect, which suggests that terpenoids influence or enhance the effect cannabinoids have in the body. Some in industry indicate that the terpenoid profile helps to dictate how a variety affects someone using a product made from that variety (Christensen 2019).

Extracting cannabinoids with ethanol causes terpenoid losses as the terpenoids volatilize following ethanol's removal. Given this and their potential health effects, terpenes have been added to final goods. Often, formulators attempt to create terpenoid blends similar to naturally occurring ones. In some cases, however, products may contain much higher terpenoid levels, which may create a public health problem. To add terpenoids to products, formulators may use terpenoids isolated from *Cannabis sativa*, or they may source terpenoids from other plant sources. Examples include lavender (genus *Lavandula*) and citrus (genus *Citrus*) (Erickson 2019).

3.4 *Plant-Derived Cannabinoid Competitors*

Growing hemp and extracting the cannabinoids represents just one approach to creating a cannabinoid supply. Some companies have invested in processes designed to biosynthesize the compounds. **Farmako**, based in Germany, has developed a method that uses a modified bacterium to produce cannabinoids. During the continuous process, bacteria secrete cannabinoids, and a proprietary process then captures those cannabinoids from broth in fermentation tanks. This efficiency will enable the process to yield cannabinoids that can sell at lower prices. Farmako's bacteria-driven process shares similarities with vitamin C production, which frequently involves bacteria to make the compound added to foods and beverages (Watson 2019b).

Yeast-based cannabinoid production has also gained attention. Compared with growing hemp and extracting the cannabinoids, leveraging a microbial fermentation process can eliminate pesticide contamination concerns, and the process has the potential to achieve high yields and reduce costs. Microbial fermentation may also enable industry to synthesize cannabinoids that are new or difficult to extract. The concept is that yeast cells can convert cannabinoid precursors into certain cannabinoids (Watson 2019d). **Hyasynth Biologicals** is one company innovating in this space. It developed a process for synthesizing cannabinoids from yeast, and its process leads to standardized cannabinoid production without traces of THC. Possible markets for the company's synthesized cannabinoids include cosmetics and pharmaceutical products (Reisch 2019).

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