Increasing Total Attainable CBD at Lower Production Cost Using Innovative Hemp Processing

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Overview

Current CBD market projections by *The Brightfield Group*, predict the CBD market to be worth USD$22B by 2022.[1,2] With the introduction of the Agriculture Improvement Act of 2018 (2018 US Farm Bill), the market price of CBD is predicted to decrease dramatically, as supply will surge, transitioning from marijuana-derived to industrial hemp-derived feedstocks.[3,4] While the current high price of CBD allows enough room in profit margin to allow for inefficient CBD production methods, the eventual decrease in CBD market price will erode these margins until only the most efficient producers will see significant profitability.

The greatest overall efficiencies will be found in changes to the entire production process, starting from harvesting methods employed in the collection of CBD feedstock from field hemp, to the CBD extraction process.

We will demonstrate here how, using an innovative processing technology, significant efficiencies can be instilled in CBD production, starting from harvesting and feedstock production, and propagating throughout the entire process.

The "Flowers Only" Misconception

The current harvest mentality has been appropriated from the marijuana industry, where the flower is the cannabis fraction of interest. This, along with mass-scale agricultural methods, has led to a number of harvesting methods designed to remove solely the flowers.

In reality the leaves, with their lower concentration of CBD, contain 2-3 times more CBD per acre than the flowers. The leaves are largely ignored due to the difficulty of collecting them; as leaves dry rapidly and are incompatible with the mass harvesting methods conventionally employed.

The CBD content in the leaves scales linearly with the CBD content in the flowers. A recent publication demonstrated that in order to predict if a cannabis plant will yield high-CBD flowers, the CBD content of the leaves could be tracked as a dependent variable.[5] In fact, a sample set of 16 strains had an R^2 value of 0.92.[5] This works conversely as well, with the CBD content in cannabis leaves having a minimum of 0.5% CBD, and increasing with the CBD content of the flowers.

The mass proportion of leaves to flowers (w/w) varies greatly for different varietals, though 20:1 is a conservative value. Figure 1 is a chart demonstrating the proportion of total % CBD in the flowers and leaves against leaves/flowers ratios of 15:1 to 30:1. Data used is from Ritchins, RD. *et al,* PLoS ONE, (13) **7**, 2018.

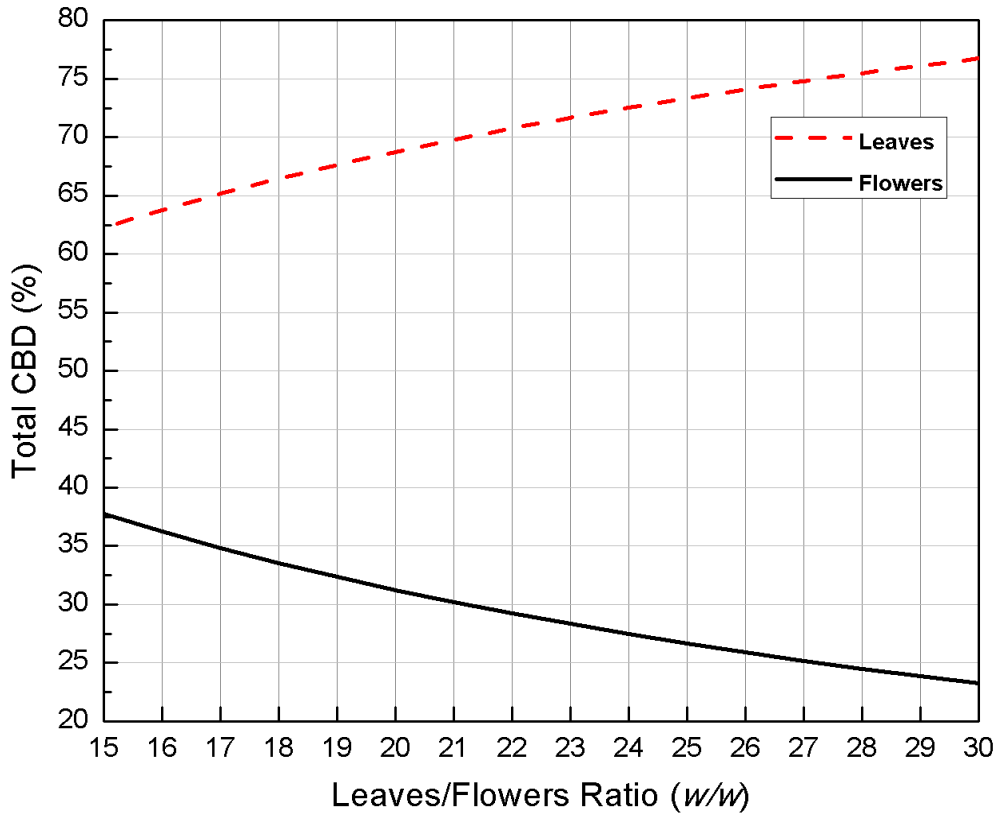

Figure 1 - *Percentage of total CBD varying with mass ratio of leaves to flowers*

Assuming the leaves and flowers combined make up 30% of the hemp biomass (*w/w*), for every tonne of whole plant material there would be 300 kg of leaves and flowers. If the average leaves to flowers ratio is 20:1, this would mean 286 kg of leaves and 14 kg of flowers for each tonne of hemp biomass.

Table 1 - Total CBD attainable from "High-CBD" Cultivars

Total Hemp (kg)	1000	1000	1000	1000	1000	1000	1000	1000
Total Green Microfiber @ 30% (kg)	300	300	300	300	300	300	300	300
Leaves @ 95% (kg)	286	286	286	286	286	286	286	286
Flower @ 5% (kg)	14	14	14	14	14	14	14	14
Flower CBD (%)	1.00%	2.00%	3.00%	4.00%	5.00%	6.00%	7.00%	8.00%
Total Flower CBD (kg)	0.14	0.29	0.43	0.58	0.72	0.86	1.01	1.15
Leaves CBD (%)	0.11%	0.22%	0.33%	0.44%	0.56%	0.67%	0.78%	0.89%
Total Leaves CBD (kg)	0.32	0.63	0.95	1.27	1.59	1.90	2.22	2.54
Average Microfiber CBD (%)	**0.15%**	**0.31%**	**0.46%**	**0.61%**	**0.77%**	**0.92%**	**1.07%**	**1.23%**
Total CBD (kg)	**0.46**	**0.92**	**1.38**	**1.84**	**2.30**	**2.76**	**3.22**	**3.68**

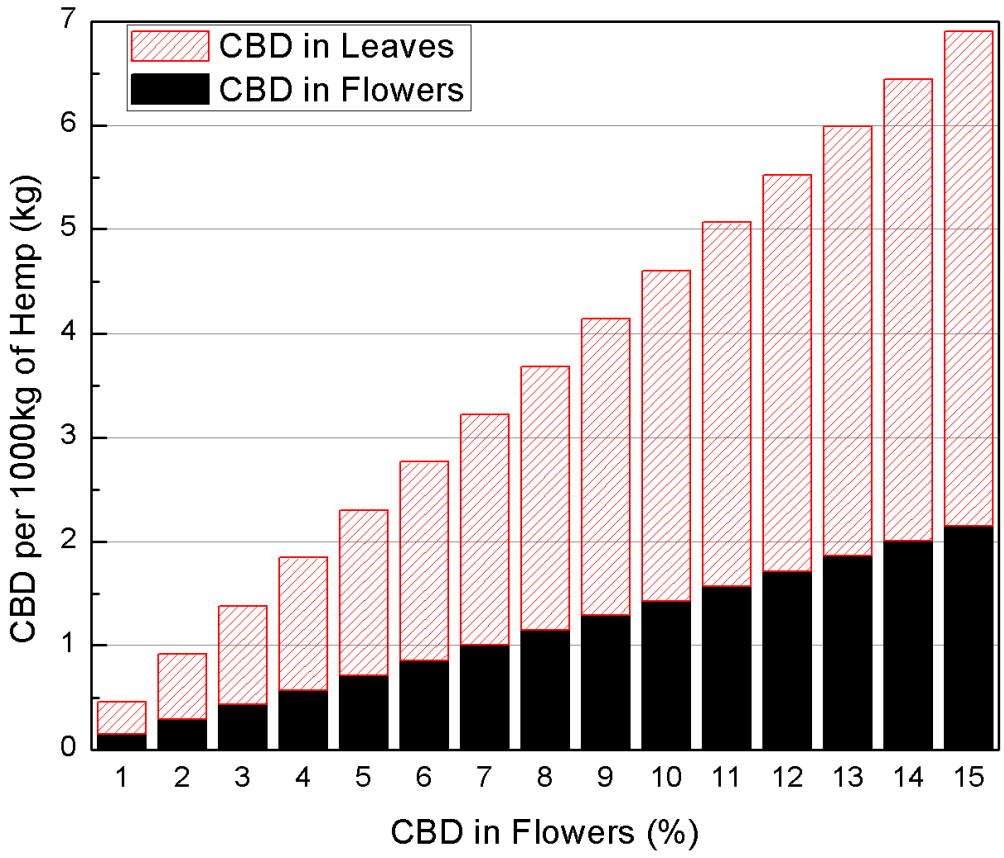

Figure 2 - *Total quantity of CBD per tonne (1000kg) of industrial hemp varying with concentration of CBD in the flowers and leaves*

Figure 2 (data from Table 1) demonstrates that, depending on the percentage of CBD in the flowers (and therefore the leaves by correlation), the total quantity of CBD per tonne of hemp biomass scales far more rapidly should the leaves be harvested and processed as well. Logistically, this means that processing the hemp leaves in addition to the flowers, as opposed to solely the flowers would produce the same quantity of CBD with only ~⅓ of the land, labour, cost, and time.

Harvesting Methods

As the efficiency gains proposed rely on the collection of industrial hemp leaves (while minimizing CBD losses), below is a summary of conventional harvesting techniques, and a breakdown of their processing steps, and ability to maintain the integrity of CBD bearing fractions.

HempTrain™ Harvesting Method

The technology behind the HempTrain™ Advanced Processing Plant, developed by Canadian Greenfield Technologies Corp., enables the collection of all CBD-bearing biomass,

with a significant number of capital and operational cost reductions. As HempTrain™ systems are capable of processing the entire hemp plant, the suggested harvesting method process is depicted in Figure 3.

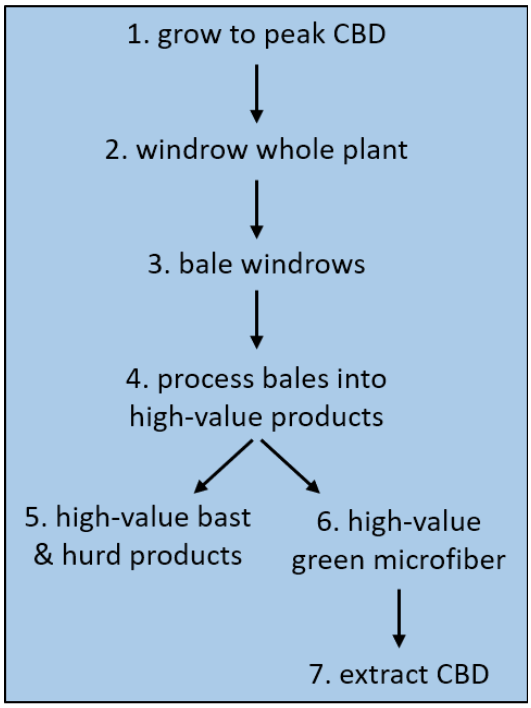

Figure 3 - *HempTrain™ Harvesting Method Process Diagram*

As shown in Figure 3, after the industrial hemp is grown to peak CBD values, the entire plant can be cut into a windrow. This step requires only a windrower (swather, mower, etc.), or gentle combining, as opposed to the conventional and aggressive capital-intensive harvester. This step minimizes flower damage and leaf material losses due to handling and wind.

The hemp should dry to moisture levels below ~20%, in order to mitigate mold formation. As the HempTrain™ Advanced Processing Plant is capable of processing both round and square baled straw, any baler can collect these windrows, ensuring the collection of leaf material with minimal handling and material losses.

The HempTrain™ Advanced Processing Plant can then process and separate the baled straw into three distinct product streams; a coarse long, strong bast fiber, a clean, size-specified hurd, and a concentrated, refined green microfiber containing all leaf and flower material. These products can then be sold or used individually.

The green microfiber fraction can be used “as-is” for infused products, or as an extraction feedstock for CBD, other cannabinoids, and terpenes. If CBD is of primary interest, processing fresh/green feedstock is optimal. For more on this, please read documentation available on www.canadiangreenfield.com/hemptrain/.

Note: For hemp grown tall, it is advisable to ensure that the cut sections of stalk are not much greater than ~3' (~1m) in length, before baling, in order to facilitate processing for high quality bast fiber. Fiber that is greater than ~3' will reduce processing throughput while adding no additional commercial value. Additionally, certain types of feedstock with a higher content of bast fiber (greater than 15% w/w), as well as certain bale configurations may significantly affect the throughput capacity. Feed rate and manner of loading may change significantly depending on feedstock.

Two-Pass Harvesting Method

The two-pass harvesting method is derived from a combination of conventional techniques used in both the marijuana and seed agriculture industries. In the collection of marijuana, the flower is the valuable commodity, as the quantities of THC or CBD in the leaves are too low to affect consumers without concentration through extraction. Likewise, there are no seeds in the leaves of most agricultural crops, and conventional harvesting technology has therefore been developed to remove the seed head and destroy the remaining fraction.

Figure 4 depicts the conventional two-pass harvesting methodology. This method requires the use of capital-intensive harvesters, dryers, and refinement steps. Furthermore, processing of the remaining hemp straw requires an additional processing step, using either a HempTrain™ Advanced Processing Plant or a conventional decorticator.

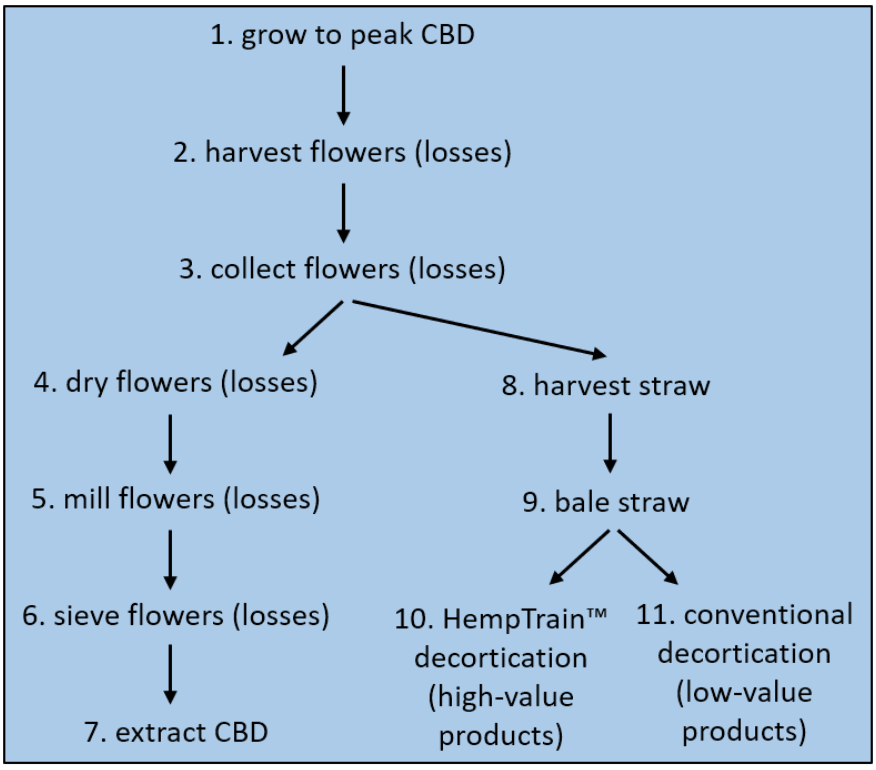

Figure 4 - *Two-Pass Harvesting Method Process Diagram*

As shown in Figure 4, after the industrial hemp is grown to peak CBD values, the harvester cuts the flowers portion of the plant (top portion), collecting it in a hopper. This

process can be damaging to the CBD-containing trichomes on the flower, as the equipment is designed to break open seed pods. The flowers must then be collected, increasing handling and potential CBD-loss.

The flowers are then prepared for extraction. This often requires a drying step. Care should be taken when drying the flowers, as high heat and mechanical agitation will lead to greater trichome breakdown and loss. As the flowers yet contain significant quantities of hurd and bast fiber (~50% w/w), these will decrease the efficiency of the dryer (reduced throughput or reduced CBD), as well as decreasing the concentration of CBD in the extraction feedstock.

A second pass is required to harvest the remaining hemp from the field. Either a harvester is used to mulch the hemp and remove the leaves, or a windrower/swather is used to cut down the hemp and lay it in the field for retting (a process where fungus breaks down the interface between fibers). Whichever method is used there is almost complete loss of leaf material. If a HempTrain™ is owned or available, it is our suggestion that the remaining hemp be windrowed and baled once the moisture is below ~20% (to mitigate mold formation and retain the leaves).

Note: For hemp grown tall, it is advisable to ensure that the cut sections of stalk are not much greater than ~3' (~1m) in length, before baling, in order to facilitate processing for high quality bast fiber. Fiber that is greater than ~3' will reduce processing throughput while adding no additional commercial value.

Once the straw is collected, it can be processed. Processing the hemp straw will enable additional revenue per acre, by creating either high-value products (using a HempTrain™ Advanced Processing Plant), or low-value products (using conventional decortication).

Hand Collection Method

The hand collection method is again derived from the marijuana industry, where flowers are the most valuable part of the plant, as the quantities of THC or CBD in the leaves are too low to affect consumers without concentration through extraction. As this method is incredibly time and labor intensive, it only works when carried out on small acreage by low-cost labor (often referred to as "orchard-style" cultivation).

Figure 5 below depicts this method as essentially the same as the *two-pass harvesting method*, replacing the harvester with hand collection. This method requires two harvesting passes as well.

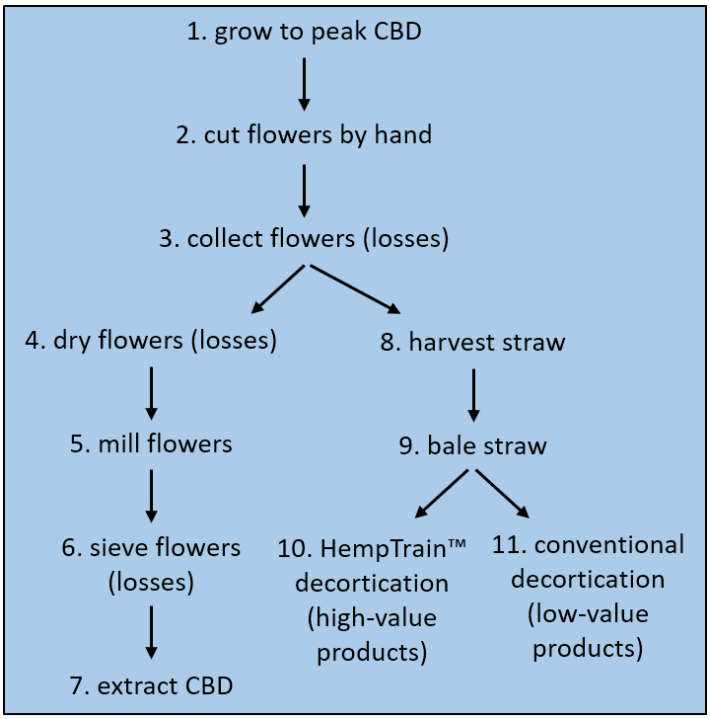

Figure 5 - *Hand-Collection Harvesting Method Process Diagram*

Once the industrial hemp is grown to peak CBD values, a team of personnel either walk through the hemp field, cutting off all flowers and collecting them, or the entire plant is cut for hang drying, followed by flower collection. While there are certainly losses with so much handling, they are significantly less than the losses created by a harvester.

The flowers are then prepared for extraction in a similar fashion to the two-pass harvesting method. This often requires a drying step. Care should be taken when drying the flowers, as high heat and mechanical agitation will lead to greater CBD breakdown and loss. As the flowers yet contain significant quantities of hurd and bast fiber, these will decrease the efficiency of the dryer (reduced throughput or reduced CBD), as well as decreasing the concentration of CBD in the extraction feedstock.

While the first pass was conducted by hand, the second pass can be carried out using either a harvester - used to mulch the hemp and remove the leaves, or a windrower/swather - used to cut down the hemp and lay it in the field for retting. Whichever method is used there is almost complete loss of leaf material. If a HempTrain™ is owned or available, it is our suggestion that the remaining hemp be windrowed and baled once the moisture is below ~20% (to mitigate mold formation and retain the leaves).

Once the straw is collected, it can be processed. Processing the hemp straw will enable additional revenue per acre, by creating either high-value products (using a HempTrain™ Advanced Processing Plant), or low-value products (using conventional decortication).

This is an extremely time and labour expensive harvest method, with very high cost per acre. When the price of CBD decreases substantially, this will be a very difficult business model to sustain.

Greenhouse Method

The greenhouse method is carried out entirely by those in the marijuana industry. For meaningful production, resources must be dedicated to high CBD varietals, which can include high THC values as well. This method requires a very high cost per acre to produce CBD, as well as the sacrifice of real estate that could be used to grow marijuana.

Figure 6 depicts the process involved in the production of CBD using the greenhouse method. It should be noted that due to the size of these plants, there is substantially less leaf matter (the leaves-to-flowers ratio is smaller than that of industrial hemp). It should also be noted that due to high amounts of THC, CBD products produced from these harvests often either include THC and are sold medically (or recreationally in Canada), or require capital intensive supercritical CO_2 (sCO_2) extraction to isolate the CBD from the THC.

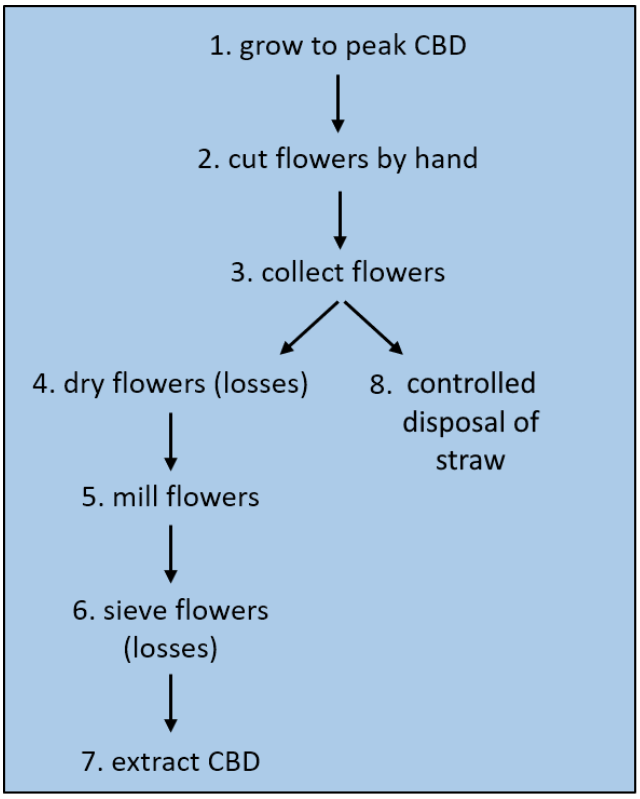

Figure 6 - *Greenhouse Harvesting Method Process Diagram*

The greenhouse method of harvesting often requires the use of skilled laborers, and even multiple harvests. The hemp is grown to peak CBD and the flowers are cut by hand. These are then collected and dried in ovens. Once dried, the flowers are broken up, milled, sieved, and

used as an extraction feedstock. The remaining plant is disposed of in an expensive and controlled manner.

The ratio of leaves to flowers in these plants is much lower, and there is substantially more flower due to control of the growth environment. Furthermore, should plants have high THC and CBD, the presence of THC reduces the concentration of CBD in the leaves.

Finally, should the concentration of THC be greater than 0.3%, chromatographic isolation or distillation is required, which are themselves expensive steps.

Double Header Harvesting Method

The double header harvesting method makes use of specialized harvesters from Europe and Asia. These harvesters have two headers, which can be set at the heights of the flower and the base of the industrial hemp stalk. When harvesting the field, these harvesters cut at both heights simultaneously, sending the flowers into a hopper and the hemp straw into a windrow.

These harvesters are designed for small acreage and are very expensive. Figure 7 depicts the harvesting process flow used for this methodology.

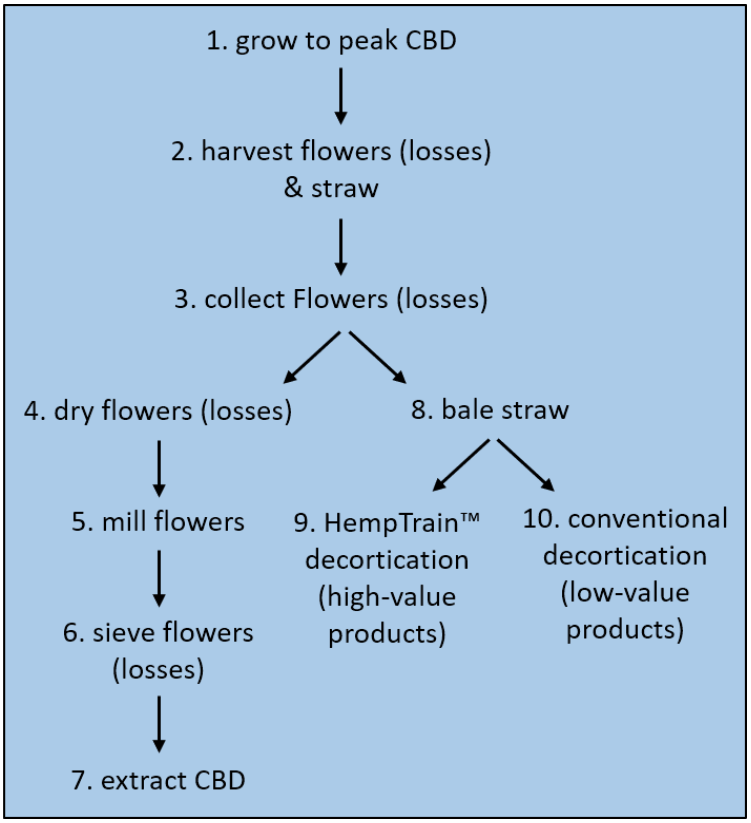

Figure 7 - *Double Header Harvesting Method Process Diagram*

Once the hemp is grown to peak CBD, the harvester can cut the flowers and straw at the same time. This harvesting method is similar to the two-pass harvesting method, though the

harvester need go over the field only once. As with the two-pass harvesting method, there are substantial losses to both flowers and leaves in both the harvest and collection steps.

The flowers are then dried, milled, sieved, and ready for extraction. As large dryers are often used for this step, there is substantial loss to the CBD both by thermal degradation and handling.

As for the straw, if a HempTrain™ Advanced Processing Plant is owned or available, it is our suggestion that the windrowed hemp be baled once the moisture is below ~20% (to mitigate mold formation and retain the leaves). Once the straw is collected, it can be processed. Processing the hemp straw will enable additional revenue per acre, by creating either high-value products (using a HempTrain™ Advanced Processing Plant), or low-value products (using conventional decortication).

Note: For hemp grown tall, it is advisable to ensure that the cut sections of stalk are not much greater than ~3' (~1m) in length, before baling, in order to facilitate processing for high quality bast fiber. Fiber that is greater than ~3' will reduce processing throughput while adding no additional commercial value.

This is an expensive method, as the harvester is a substantial capital cost.

Whole Plant Milling Method

Whole plant milling is a capital-intensive processing method. Though it does not require a harvester, it does require a hammermill (or hammermills) capable of processing the entirety of the hemp harvest. Furthermore, due to the diluted and low concentration of CBD in the milled product, extraction also becomes very capital intensive.

Figure 8 is the process flow diagram for the whole plant milling method. This method requires the fewest steps, but rapidly becomes cost prohibitive.

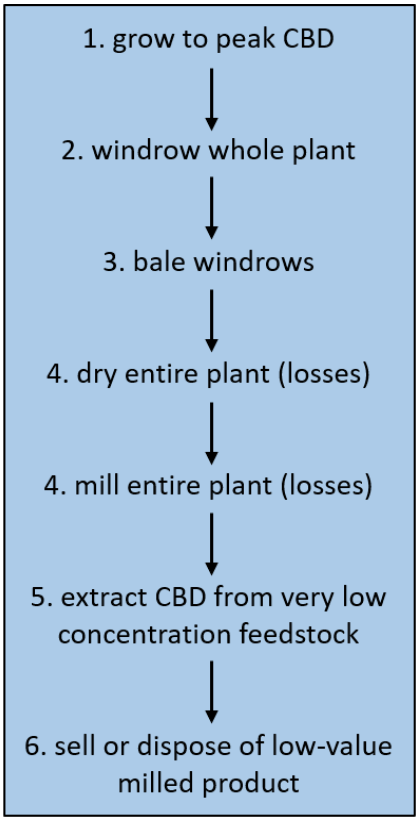

Figure 8 - *Whole Plant Milling Method Process Diagram*

As depicted in Figure 8, once the plant is grown to peak CBD, it is then cut and windrowed to preserve the flower and the leaves. The windrow is then baled and transported to a drying facility. Once dried all plant material is hammermilled. Hammermills are damaging to hemp fiber, hurd, and CBD. This process creates a significant amount of dust, that must all be captured as it contains a portion of CBD and care must be taken to mitigate combustion risk.

Once dried and hammermilled, the product containing fiber, hurd, and dust are then used as extraction feedstock. Assuming no leaf or flower losses whatsoever (25-30% of the hemp plant), this approach would require ~3-4 times the conventional extraction quantities to be processed through extraction in order to extract the CBD. This method essentially requires extraction to be performed on the entirety of the baled material in order to extract the CBD. Finally, the milled product remaining after extraction is very low-value.

Chaff Collection Method

Some farmers use chaff collectors to salvage some green mass during a pass. The efficiency of this approach is not determined, but would require a harvester, chaff collector, and the same drying, milling, sieving, and extraction procedures required by the double header, two-pass, and hand collection harvesting methods.

Harvesting Method Comparison

	HempTrain™	Two Pass Harvesting	Hand Collection	Greenhouse	Double Header Harvesting	Whole Plant Milling	Chaff Collection
Retain all leaves and flowers	✓					✓	✓
Harvesting Windrower only	✓		✓			✓	
Concentrated extraction feedstock	✓		✓	✓			
Minimal-loss CBD	✓						
Additional high-value products (bast, hurd, green microfiber)	✓						
Single Step Continuous Process	✓						

Conclusions

The future of the CBD industry will depend entirely on the efficiencies involved in the harvesting, processing, and extraction steps of industrial hemp. HempTrain™ is the only known process capable of collecting all CBD-bearing material with minimal losses in a quick, clean, and efficient manner. In addition, HempTrain™ decreases the capital expenditure required to enter the CBD production business, as well as the required equipment, labor, and land costs. Finally, the extraction feedstock created by HempTrain™ is almost entirely CBD-containing, and therefore maximizes the total CBD which can be obtained per acre.

Acknowledgements

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References

1. Elisabeth Garber-Paul. CBD Market Will Hit $22 Billion by 2022: Exclusive Look at New Report. *Rolling Stone* (2018). at <https://www.rollingstone.com/culture/culture-news/new-study-cbd-market-22-billion-2022-722852/>
2. Sara Brittany Somerset. Will CBD Entirely Eclipse The Cannabis Market? *Forbes* (2018). at <https://www.forbes.com/sites/sarabrittanysomerset/2018/09/12/will-cbd-entirely-eclipse-the-cannabis-market/#743215bb7beb>
3. Julie Weed. US Farm Bill Will Make CBD Production Legal And Cheaper. *Forbes* (2018). at <https://www.forbes.com/sites/julieweed/2018/12/19/us-farm-bill-will-make-cbd-production-legal-and-cheaper/#99ae10547ba7>
4. Eli Harrington. “We’ll Cut CBD Oil Price in Half in Less Than Five Years,” Say Vermont’s Largest CBD Oil Producers. *Heady Vermont* (2018). at <https://headyvermont.com/well-cut-cbd-oil-price-in-half-in-less-than-five-years-say-vermonts-largest-cbd-oil-producers/cannabis/>
5. Richins, R. D., Rodriguez-Uribe, L., Lowe, K., Ferral, R. & O’Connell, M. A. Accumulation of bioactive metabolites in cultivated medical Cannabis. *PLoS ONE* **13,** e0201119 (2018).