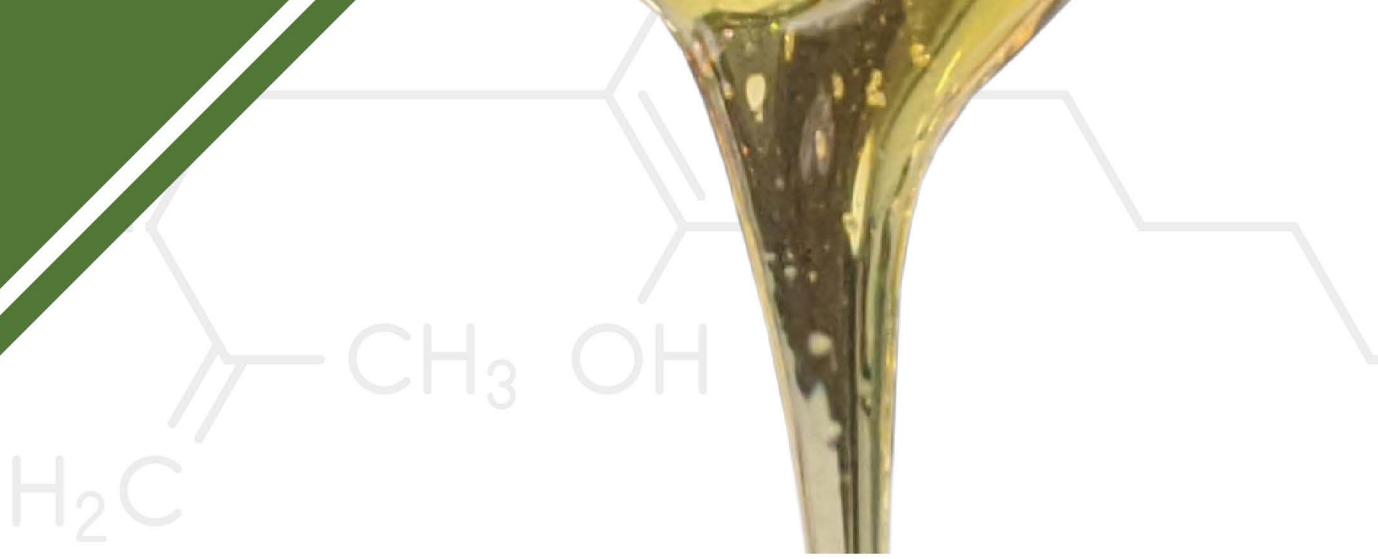


Advanced Hemp & Botanical Extraction Guide



Advanced Hemp & Botanical Extraction Guide

A Guide to the Process

From the makers of
Supercritical CO₂ Extraction Equipment



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Advanced Hemp & Cannabis Extraction: A Guide to the Process

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About extraktLAB

extraktLAB is a brand of United Science and manufactures cutting-edge, hemp and cannabis processing equipment in an ASME accredited, ISO 9001:2015 certified, 30,000 ft² facility in St Croix Falls, WI. extraktLAB also operates its *Institute for the Advancement of Bioprocessing and Formulations* in a fully operational, GMP certified, USDA Certified Organic hemp processing facility occupying an 80,000 ft². Demonstrations and tours are held weekly. This facility is located in Osceola, WI.

Founded in 2008 by Ph.D. separation chemists and engineers, extraktLAB equipment is renowned for full turnkey extraction capabilities. These include: **cold trap terpene collectors, winterization equipment, wiped film evaporators, falling film evaporators, bucking machines, high performance liquid chromatography equipment, supercritical CO₂ extractors**, and **manufacturing execution software** with batch recording capability.

extraktLAB's equipment is known for having the highest throughput, smallest footprint, lowest energy consumption and most scalable CO₂ extraction process in the industry. In fact, customers can scale to process 10 tons of hemp extracted per day in an extremely small area using only a small amount of power. Conversely, it is important for cannabis businesses to keep their operation sized for smaller cannabis extraction applications.

extraktLAB provides extraction equipment, engineering, consulting and design services. Our team is standing by to help both experienced and novice producers create and operate manufacturing facilities designed to meet or exceed ISO and GLP/GMP standards.



Why not schedule a CBD Jam Session after you have spent time with this guide to learn more about extraction? <https://extraktlab.com/cbdjamsession>



Why Produce CBD Oils or Cannabis Extracts?

Extracting CBD oil from industrial hemp plants is one of the fastest-growing, most stable, and value-added segments of the broader cannabis industry. Extraction allows manufacturers to transform hemp or cannabis biomass into bulk ingredient essential oils, waxes, cannabinoids, terpenes, crystals or distillate oil. These high-quality oils are then transformed into novel food ingredients, supplement active ingredients, or additives in cosmetics. CBD oils are typically available in CBD pills, water soluble formulations, tinctures, and edibles.

Extracts make up a major portion of retail sales. In their recent study¹, The World Health Organization showed that CBD has a great safety track record and has a limited number of adverse events. The report notes that there has been no evidence of any public health related problems associated with the use of purified CBD. The report did review several therapeutic applications and benefits of CBD oil on the endocannabinoid system. According to the report, hemp oil benefits include aiding in skin conditions to mitigating forms of epilepsy and multiple sclerosis.

¹ Geneva. *CANNABIDIOL (CBD) Critical Review Report Expert Committee on Drug Dependence Fortieth Meeting.*

Other benefits of extracting biomass into oils are strictly practical. It is much easier to store 1000 kg of oil than 1000 tons of biomass. In addition, the resulting extracted CBD oils are not prone to biofouling² and are shelf stable when properly stored.^{3, 4}

The hemp extraction business has the promise of sustainable profits for years to come. The BrightField group estimated that CBD-infused products would grow to a \$22B USD global category over the past several years, up from \$627M USD in 2018.⁵ The global cannabis market is estimated to reach \$630B USD up from \$12B in 2019.⁶ There has been an explosion of new cannabis oil companies entering the industry, and the European market is expected to grow over 400% through 2023.⁷ The path to success requires expert guidance and effective manufacturing solutions with quality cannabidiol oil output to serve customers and drive growth.

This guide offers practical advice on how to approach starting and growing a successful cannabis business. It also describes **extraktLAB's comprehensive manufacturing solutions** designed to serve as your successful foundation.

“We are proud to be the only manufacturing equipment company in the cannabis industry offering the most comprehensive turnkey extraction solutions with the deepest expertise in separations science.”



² Appendino, G.; Gibbons, S.; Giana, A.; Pagani, A.; Grassi, G.; Stavri, M.; Smith, E.; Raman, M. M. Antibacterial Cannabinoids from Cannabis Sativa: A Structure-Activity Study. *J. Nat. Prod.* **2008**, 71 (8), 1427–1430. <https://doi.org/10.1021/np8002673>.

³ Citti, C.; Pacchetti, B.; Vandelli, M. A.; Forni, F.; Cannazza, G. Analysis of Cannabinoids in Commercial Hemp Seed Oil and Decarboxylation Kinetics Studies of Cannabidiolic Acid (CBDA). *J. Pharm. Biomed. Anal.* **2018**, 149, 532–540. <https://doi.org/10.1016/j.jpba.2017.11.044>.

⁴ Turner, C. E.; Hadley, K. W.; Fetterman, P. S.; Doorenbos, N. J.; Quimby, M. W.; Waller, C. Constituents of Cannabis Sativa L. IV: Stability of Cannabinoids in Stored Plant Material. *J. Pharm. Sci.* **1973**, 62 (10), 1601–1605. <https://doi.org/10.1002/jps.2600621005>.

⁵ Brightfield. US CBD Market to Grow 700% Through 2019 <https://www.brightfieldgroup.com/press-releases/cbd-market-growth-2019> (accessed Dec 15, 2019).

⁶ Arcview Market Research, “*State of Legal Marijuana Markets, 5th Edition*”; 2019.

⁷ Brightfield. Europe’s CBD Market is Estimated to Grow Over 400% Through 2023 <https://www.brightfieldgroup.com/press-releases/europe-cbd-market-through-2023> (accessed Dec 15, 2019).

What is the Best Extraction Method?

There are several ways to extract CBD oils from hemp. The most popular methods use supercritical CO₂ or ethanol to dissolve cannabinoids that are in the resinous plant trichomes, leaving the undissolved plant material to be discarded as waste. Although both extraction methods have been widely deployed, supercritical CO₂ extracts are considered by the public to be cleaner and safer than ethanol derived oils for the following reasons:

1. **Purity:** Ethanol extracts carry with them known and unknown risks related to prolonged and repeated exposure to unnatural denaturant chemicals^{8,9} that are added to pure ethanol to make the extraction method affordable. Although these chemicals are often removed to “safe” levels, they are not fully removed from extracts. The remaining solvent contaminants are called chemical residuals by the FDA⁹ and must be controlled and tested because the residuals have “no therapeutic benefit” and in some cases are toxic or carcinogenic at high levels.¹⁰
2. **Testing using invalid test methods:** A partial list of common denaturants include: acetone, isopropyl alcohol, hexane, hexanes, heptane, butanol, methyl tertiary butyl ether.¹¹ Testing for “safety” is required but residuals are not always measured in hemp extracts with validated test methods¹² considering the specific denaturant mixture used in extraction. Rather, a generic solvent method is typically employed. This means the risk of missing a major potential contaminant is highly increased.

⁸ eCFR — Code of Federal Regulations- TTB Alcohol and Rules for Specially Denatured Alcohol https://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&sid=fc3be5d2e97afdd4aed5fb7b5c26309c&rgn=div5&view=text&node=27:1.0.1.1.17&idno=27#se27.1.21_11 12 (accessed Dec 8, 2019).

⁹ Medicines Agency, E. *ICH Guideline Q3C (R6) on Impurities: Guideline for Residual Solvents Step 5*.

¹⁰ *USP 467 Residual Solvents; 2007*.

¹¹ eCFR — Code of Federal Regulations- TTB Alcohol and Rules for Specially Denatured Alcohol https://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&sid=fc3be5d2e97afdd4aed5fb7b5c26309c&rgn=div5&view=text&node=27:1.0.1.1.17&idno=27#se27.1.21_11 12 (accessed Dec 8, 2019).

¹² McArdle, J. V. Residual Solvents. In *Specification of Drug Substances and Products: Development and Validation of Analytical Methods*; Elsevier Ltd., 2013; pp 143–154. <https://doi.org/10.1016/B978-0-08-098350-9.00007-2>.

3. **Unknown risk of negative health consequences:** Health dangers of such additives are well documented¹³ but only partially understood in the context of cross factors including age, health, drug interactions, effects on the brain and cognitive & emotional function, and susceptibility to negative health consequences. Despite all the years of research, more research investigating the long-term solvent exposure in humans is needed to accurately assess risk. Due to these reasons, the healthy, natural CBD you expect from hemp may not be so healthy.
4. We encourage consumers to **look for a “Made with CO₂ Label”**. CO₂ derived hemp and CBD oils are widely regarded as the highest quality, chemical residue free oils produced. CO₂ extraction has advantages over ethanol as the extraction media on many different levels. Drastically lower operating costs are a key benefit of CO₂ extraction. Over time, lower operating costs accumulate and continue to build value throughout the life of the equipment.

For more information:

Visit our blog at <https://extraktlab.com/co2-extraction-vs-ethanol/>

to download the white paper titled, “*A Critical Analysis and Comparison of Ethanol and CO₂ Extraction Techniques for CBD Derived from Hemp*”, which examines the hidden costs of ethanol extraction.

Chemical residuals in ethanol extracts are completely avoidable using CO₂ extraction methods.

¹³ (PDF) Overview of impurities in pharmaceuticals: Toxicological aspects
https://www.researchgate.net/publication/259150621_Overview_of_impurities_in_pharmaceuticals_Toxicological_aspects
(accessed Jan 6, 2020)



HOW TO PRODUCE CANNABIS OR CBD OILS:

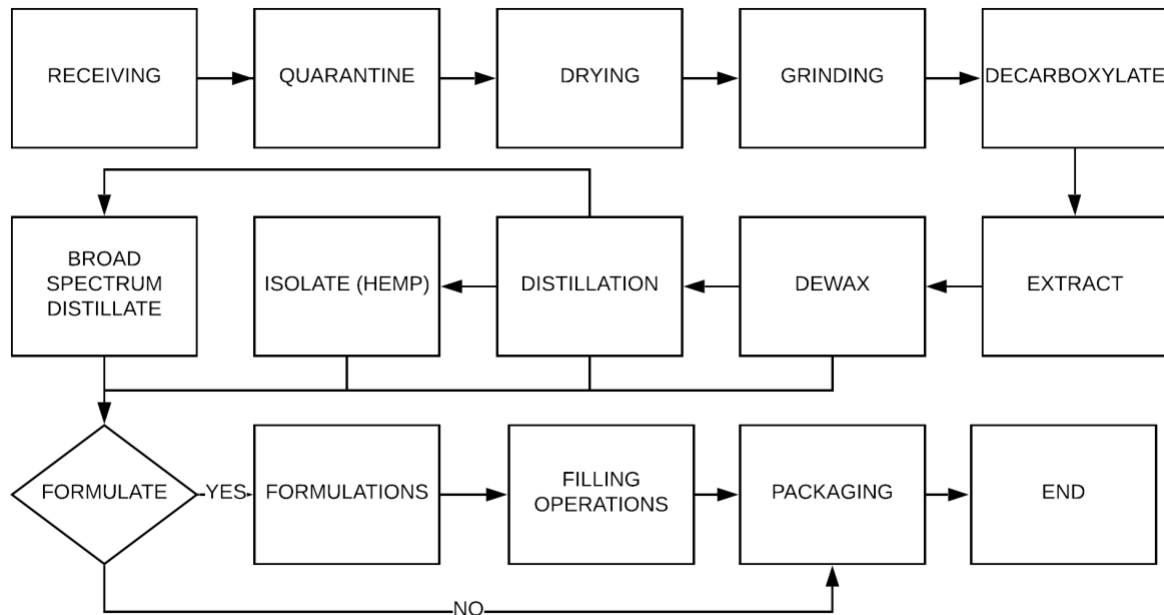


Figure 1. Plant Workflow

extraktLAB
Looking for help in your extraction business?
20 min CBD Jam Session

FREE
Schedule today!

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Why not schedule a CBD Jam Session after you have spent time with this guide to learn more about extraction? <https://extraktlab.com/cbdjamsession>

Step 1: Biomass Preparation



Bucking

Hemp or cannabis biomass preparation starts with removing the flower from the stems. This process is often referred to as bucking and can be accomplished with a bucking machine or by hand. Watch the shuckNbuck in action at extraktlab.com/bucking-machine.

Bucking machines eliminate the labor-intensive part of obtaining the flower. One alternative to bucking is to chop the entire plant (stock, stem, seed, and flower) in a commercial combine. However, including the entire plant reduces extraction throughput by as much as a third, and may produce low quality isolate and distillate.

Hemp or cannabis biomass is much easier to buck when it includes less than 10% moisture. To dry cannabis biomass, we recommend hanging the whole plant inverted for 24-48 hours in a 40m², humidity and temperature-controlled room. This size of control room can serve cannabis greenhouses up to 4000 m².

A hemp dryer on the other hand will dry large volumes of material. Drying equipment employed in this case can include fluidized beds, rotary kiln dryers, or belt driven infrared dryers. As an alternative to machinery, many hemp farmers let their crops dry in the field. This works well as long as the harvest time is cool and dry.



Grinding



Figure 2. Ground hemp biomass from extraktLAB's shuckNbuck.

For each of these processes, our equipment consultants work with you to obtain the right grinder combination. In addition, our design team can help you with important items such as HVAC and safety hazards associated with the process.

Once the hemp or cannabis has been bucked and dried, it is granulated. In general, smaller particles (200-1000 microns) are desirable and tighter particle diameter distributions are better for extraction throughput. Also, sticks, stems, and seeds that made it through the bucking process should be removed before grinding. Several kinds of mills are available on the market to accomplish these goals including hammer mills, shear mills, and cone mills.

Depending on the desired processing volume, a typical grinding operation will include a hammer or a cone mill. The mill is assisted with vacuum cyclone collection.



Decarboxylation



Once the materials are milled, they can be extracted or further processed to convert the acidic forms of CBD or THC into neutral molecules. This further processing is known as decarboxylation¹⁴ and the resulting biomass is referred to as decarb material.

Conversion of the acidic to the neutral form is desirable from the standpoint of throughput and for formulation reasons. However, acid forms are also desirable for specific types of

formulations. Decarboxylating is required for a quality distilled product.

Decarboxylating before extraction has the advantage of speeding up the extraction process and allowing the gentle collection of pure, full-spectrum terpenes (as shown above), which do not have any cannabinoids using fractional distillation with a cold trap condenser like the extraktLAB [terpTRAP](#). Because decarboxylation involves the use of heat and vacuum pressure, the evaporation point of the terpenes is low enough to be removed from the biomass without damaging the terpenes themselves. Once removed, the cold trap chilled condenser will collect full spectrum terpenes that would otherwise be unobtainable further down the processing line. The terpTRAP contains a four-gallon collection vessel with 21.64 square feet of heat exchange that is capable of scaling up to a 10-ton per day processing throughput making it a high-capacity terpene collection system for any extraction operation.

Full Spectrum terpenes are completely natural and easy to dilute into formulations. Processing of terpenes earlier, rather than later, is a huge advantage for formulations and aroma engineering. Equipment, training, and standard operation procedures (SOP) for this process are included in our consultation offerings.

¹⁴ Veress, T.; Szanto, J. I.; Leisztner, L. Determination of Cannabinoid Acids by High-Performance Liquid Chromatography of Their Neutral Derivatives Formed by Thermal Decarboxylation. I. Study of the Decarboxylation Process in Open Reactors. *J. Chromatogr. A* **1990**, 520 (C), 339–347. [https://doi.org/10.1016/0021-9673\(90\)85118-F](https://doi.org/10.1016/0021-9673(90)85118-F).

Step 2. Extraction



Figure 3. extraktLAB's E-180

See how the E-180 extraction machine works

(<https://extraktlab.com/supercritical-co2-extractors/co2-extractor-180-product-tour/>)

How to extract hemp oil: Supercritical CO₂ extraction has become the preferred method for extracting THC and pure CBD oils. This extraction method serves consumer markets with the most demanding standards for safety, quality, purity and consistency. Progressive brands are boldly stating “extracted with supercritical CO₂” on package labels. This is due to the fact that CO₂ oil is purer than ethanol derived oil.

Supercritical CO₂ extractors use carbon dioxide (CO₂) at elevated temperatures (40-60°C) and pressures (3000-5000 psi, 206-345 bar) to extract soluble compounds from natural products, leaving behind no chemical residues after extraction. Above 31°C (critical temperature) and 1071 psi, carbon dioxide becomes a supercritical extraction solvent, which has an increased capacity for solubilizing non-polar compounds like

cannabinoids. Extraction machines raise the temperature and pressure of the liquid CO₂, providing highly efficient oil extractions in a short period of time.

The **CBD extraction process** begins by filling the extractor machine with hemp or cannabis. Once the operator and lot of material are scanned in, then the latest calibration and maintenance are checked before operation. Once the extraction method is running, CBD extract or THC extract is produced and harvested hourly.

Step 3. Dewaxing, Distillation, and Isolation

Dewaxing

How to make winterized oil:

Winterization is typically needed to remove extracted heavy waxes; the resulting oil is referred to as dewaxed oil or winterize oil.

Winterizing is usually accomplished by dissolving the extract in a **small amount** of **food grade** ethanol, cooling the ethanolic extract to -20°C, and then filtering. At -20°C, the precipitation of wax in ethanol can take up to 24 hours to complete. However, many operators process materials prepared the day before in a first-in-first-out manner.



Figure 4. extraktLAB's DrainDroyds

Sub-critical CO₂ extraction methods can also be used to remove the need for winterization and is popular for producing terpene rich oils.

Filtration with large filter funnels offers a high throughput means of separating the precipitated wax from the ethanolic oil.

The DrainDroyd is a useful tool for this process as it enables high throughput vacuum filtering to dewax the winterized oil. The equipment is fabricated from polished stainless steel and utilizes certified technical grade filtration papers to catch and separate the waxes from the oil.

Ethanol is then removed and recycled with a **thin film evaporator** or a rotovap. Two advantages of a thin film evaporator are: it is continuous and has a high throughput.

High Speed Filtration & Dewaxing

DRAIN DROYD[®]



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Request your quote today at: extraktlab.com/draindroyd-vacuum-filtration/

Solvent Removal

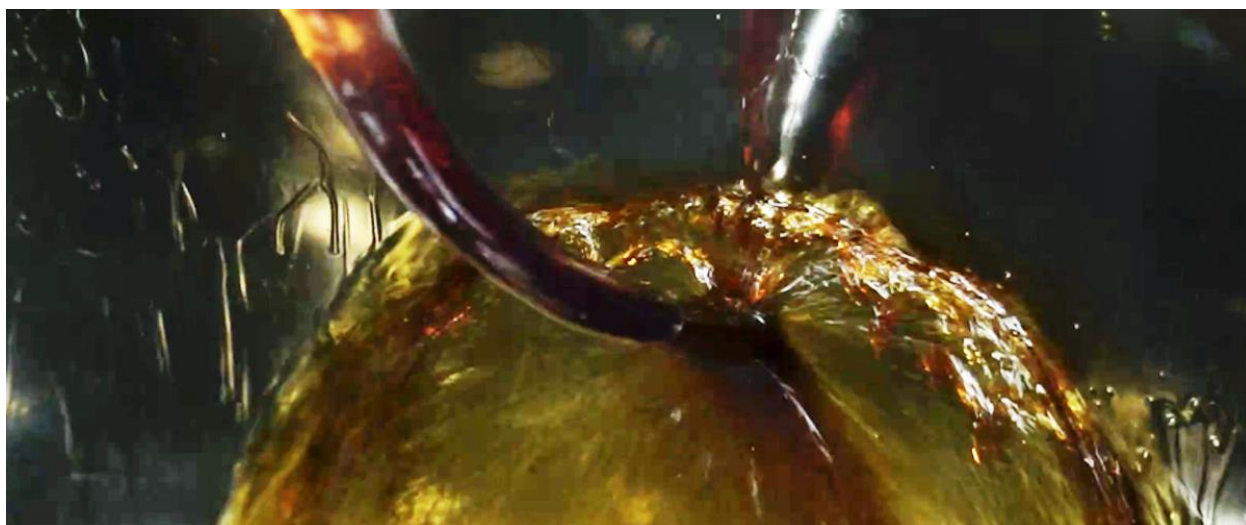


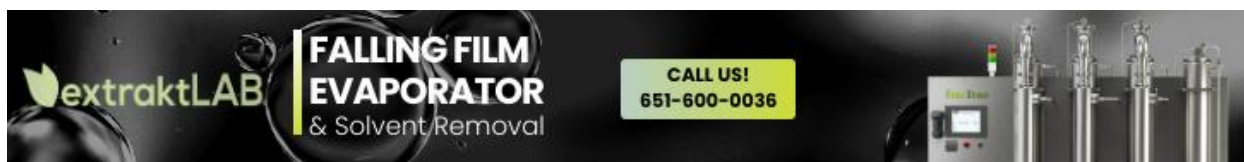
Figure 5. Removing solvents in extraktLAB's fracTron

How to remove solvents from ethanolic extracts: Solvent recovery is necessary to recover or remove solvent from CBD oil after ethanol extraction or winterization. The first step in removing ethanol from an extract is to heat the ethanol to its boiling point where it is evaporated. The ethanol vapor is then transported to a different location where it is condensed back into a liquid. This process is called fractional distillation. To accomplish fractional distillation quickly and with high throughput, solvent recovery systems must be designed that can keep up with the solvent removal demand.

The fracTron efficiently **removes ethanol** from the dewaxed oil, leaving winterized oil. It is also useful for fractional distillation of terpenes for the beneficiation of aroma and flavor. The fracTron **falling film evaporator** is a fully automated three-stage horizontal fractional distillation and evaporation apparatus; removing up to 50 gallons of ethanol per hour from oils – without having to shut it down for refilling or cleaning. It has a clog-free design, enabling easy cleaning. The unit and software are GMP compliant and come with methods and cleaning protocols.

The small amount of ethanol used in the winterization process does not carry the same drawbacks as long as UL, CE, and pure ethanol is used. Additionally, less ethanol is required for winterization compared to extraction. In most cases, occupancy and storage requirements can be managed as a factory industrial (F-2 occupancy).

Solvent sourced contamination is not an issue because a higher grade of ethanol is used and the primary concentration step has already been completed. The use of in-process hoods keeps production areas ventilated below the lower explosive limit (LEL). Our professional hazardous waste and lower explosive limit calculations will help both with insurance and your local fire department.



To see the more information about the fracTron: extraktlab.com/falling-film-evaporator

Distillation



Figure 6. Distillate

How to make distillate: Distillation can be accomplished with short path distillation equipment or **wiped film evaporation equipment**. A distillation machine is typically used to improve the potency and color of the extract. Potency is typically improved 10-30% while the color of the oil is converted from an opaque dark amber – to a light amber – then to a clear light yellow.

Our clearSTILL wiped film evaporation equipment is the perfect solution for evaporation or short path distillation.

clearSTILL is a two-stage unit. The first stage evaporates volatiles from the oil; the second stage is used in a short path distillation mode. Alternatively, both stages can run in distillation mode. The unit is fully automatable and offers all of the track and trace capabilities required for GMP operation.

Chromatography

Chromatography is a separations method necessary for the remediation and isolation of various compounds into their individual components. This is essential for remediating THC from CBD products, identifying and removing unwanted materials, and isolating cannabinoids for specific downstream product formulations. ekstraktLAB's **pure99** is an automated, high performance liquid chromatography solution designed for

highly efficient separation and purification of hemp and cannabis compounds for precise, safe, and efficient product formulations.



Figure 7. extraktLAB's pure99

The throughput of the pure99 is roughly 2-6kg of broad-spectrum extract per hour and depends on a variety of factors, one of which is the issue of solvent loss. Solvent loss can be a key contributor to high operating costs and throughput efficiency if the solvent becomes entrained with the product during the chromatography process, however, this is not the case with the pure99. The pure99 chromatography system incorporates a falling film solvent recovery system, to avoid the hassle of having to do an extremely large amount of solvent recovery.

In the hemp and cannabis extraction industry, chromatography allows manufacturers to distinguish a list of compounds in the cannabis plant and create a specifically formulated product that's both legal and tailored to the marketplace demands. Chromatography is also effective at identifying and removing unwanted pesticides, and other residual chemicals. These are essential factors in creating a healthy, safe, desirable product for the end user making supercritical chromatography an essential part of your production.

CBD Crystals or THC Crystals

How to make isolate: CBD crystals are made by precipitation in a nonpolar solvent, which involves dissolving distillate into the solvent, cooling the solvent down to induce precipitation of CBD, washing the crystals, and then removal of the nonpolar solvent. When using jacketed stirred reactors, crystallization and precipitation processes can be used to produce several hundreds of kg of crystal CBD isolate.



Figure 8. Isolate

Just like in the winterization process, the amount of solvent used is less than when compared to the solvent required for extraction. Crystal production rooms can be designated as separate control areas, making the amount of solvent in the room and building more manageable.

THC crystals are made by similar precipitation. Typically, an ethanolic extract is subjected to very low temperatures thus causing precipitation of the crystals. Just like CBD crystals, they're washed and then the solvent is removed.



What Equipment & Facility Specifications are Needed?

If you are planning to start an extraction facility or are looking to scale up, the first thing your architect should require is a detailed list of equipment.

The following table is an equipment summary for each process:

Table 1. Simple equipment list by process.

Process	Equipment
Drying	Dehumidifier or dry room or cold air, rotary kiln, cyclones.
Bucking Machine	shuckNbuck bucking machines plus cyclone.
Grinding	Hammer mill, cone mill, cyclone.
Decarboxylation	Vacuum oven with vacuums and terpTRAP condensing units.
Extraction	extraktLAB Supercritical CO₂ Machines , CO ₂ Cage, Pump Cart, Chillers, Bulk CO₂ Supply , DrainDroyd condenser for CO ₂ gas.
Winterization	Freezers, DrainDroyd , Jacketed collector, ETOH collector.
Solvent Removal	fracTron , rotovaps
Distillation	clearSTILL , jacketed reactor.
Chromatography	pure99
Crystal Production	Jacketed reactors, chiller heaters, DrainDroyd , Grinder, vacuum ovens.
Quality and Manufacturing Software & Equipment	igwLAB .

In addition to an equipment list, the architect will require specifications for the production rooms and the adjoining materials and personnel corridors. Each room specification needs to include the following information:

- Electrical requirements (volts, amps, frequency, phase) and locations,

- Heat loads (in kw),
- Footprint, weight of the equipment, and special handling requirements,
- Arrangement of equipment,
- Process piping and connection requirements (P&ID),
- Humidity and temperature requirements,
- Venting requirements and air exchange calculations,
- HVAC pressurization requirements,
- Air quality requirements and sensors for each room,
- Hazard storage specification and occupancy calculations,
- Certifications,
- Control areas designated,
- Amounts of chemicals in storage, open use, and closed use,
- Process notes for installation.

This process can be time consuming for most startups. Startups can leverage the experience of our firm to reduce the time spent gathering this data, providing a better time to market.



Good Manufacturing Practices for Equipment & Processes

Good Manufacturing Practice (cGMP) regulations are important for cannabis and hemp companies required to comply with federal regulations for food, pharmaceuticals, or cosmetic products. Each country has its own GMP standards affecting equipment use and the production facilities. It is important to **evaluate compliancy before building** or purchasing equipment.

International GMPs should be considered when the goal is to export your products. The following table summarizes common GMP requirements relating to our equipment offering:



Figure 9. extraktLAB's igwLAB

Table 2. Brief summary of GMP requirements and extraktLAB solutions.

Description	Applies To	extraktLAB Solutions
Buildings and Facilities	Design, construction, HVAC, plumbing, electrical, sanitation.	Design Consulting Hazardous Materials Consulting
Equipment	User requirements document, contact materials, data integrity, spare parts.	Contact Materials Certificates, Calibrations, Design, Software, Data Integrity
Control of Components, Containers, and Closures	Receipt, storage, testing, quarantine, rejection.	igwLAB, SOPs, Training
Production and Process Controls	Standard operating procedures for all quality facing processes.	igwLAB, SOPs, Training
Laboratory Controls	Sampling, quality control	igwLAB, SOPs, Training
Records and Reports	Batch records, master batch records, calibration records, training records, cleaning records.	igwLAB, SOPs, Training
Holding and Distribution		igwLAB, SOPs, Training

igwLAB helps automate quality, manufacturing execution, and laboratory information. This master batch record system was built specifically for the cannabis and hemp industries.

The igwLAB is built on GAMP5 and 21 CFR Part 11 standards, and is set up to track material movement GMP SOP, GMP training records, quality, and information flow through the manufacturing facility. The system interfaces with popular seed-to-sale software and compliance software METRC. Custom APIs can be developed for your ERP system.

This software/hardware combination accomplishes tracking via barcode input of data. Some of the data scanned includes: user, method, equipment, sampling events, training events, calibration events, expiration dates, maintenance events, batch records, yield tracking, material movement tracking, quality designation, and metadata. The software comes with SOPs and methods customizable to your workflow.

On-Site and Third-Party Analytical Laboratory Testing

Hemp and cannabis production facilities should have their own internal laboratory for measuring potency, purity and identity of in-process samples. Testing capability enables the quality data feedback to track cannabinoid yields with better accuracy.

When conducting routine potency analysis, it is important to recognize results will depend highly on the sample prep method you use and the matrix of the sample. Test validation must be conducted in the matrix of the analyte for results to be valid.

We have designed advanced laboratories with a wide variety of analytical equipment and methods. These include ICP MS for heavy metals, GCMS for solvents and terpenes, LC/MS/MS for pesticides, LC/FI for toxins, clean benches and incubators for microbials

Every lot is usually tested by an external analytical laboratory. It is a good idea to establish a relationship with an external laboratory early in your business cycle.



What Yield Can I Expect?

Exactly accurate calculations for yield are mythical because of the reality of processing a natural product. Input material varies considerably within a batch, so the outputs will also vary on yield, waste, and even the presence of contaminants. The best anyone can do is provide estimates and ranges on yield for each process which will give a range of results. To get a better understanding of yield sensitivity and set the right expectations in your business, model both high and low results.

Table 3. Process yield and key parameters affecting yield.

Process	Yield Range % (w/w)	Key Yield Factor
Drying	60-80%	Yield is affected primarily by moisture content.
Bucking Machine	10-30%	Yield is affected primarily by stem and stock content.
Grinding	90-95%	Yield is affected by stem and stock and seed loss and grinder type.
Decarboxylation	80-90% + terpenes	Yield is affected by residual moisture content and terpene content.
Extraction	10-25% Cannabis 3-15% Hemp	Yield is affected by particle size, pressure, temperature, time, molecular state of cannabinoids, and flow rate. Roughly follows biomass potency.
Winterization	60-80%	Yield is <i>highly</i> affected by strain. Some strains have more wax than others.
Distillation	50-70%	Yield is <i>highly</i> affected by distillation method parameters and number of passes.
Crystal Production	70-90%	Yield is affected primarily by precipitation efficiency. <i>Some distillate is impossible to crystallize to a high purity.</i>

An example: 1000 kg of dry, ground, decarboxylated material with an average 12.5% +/- 2.5% CBD content distributed across 10 totes. The material will yield 100-150 kg of crude extract. Winterization will yield 60-120 kg of winterized crude. Distillation will yield 30-84 kg of distillate. Isolate process could yield 21 to 76 kg. This operation is often

standardized based on the equipment, strain, and methods; which narrows the yield range.

Rely on Extraction Experts to Scale Your Operation





The key consideration for any large-scale ethanol system or supercritical CO₂ extraction workflow is to make sure all equipment will work together. This will eliminate the bottlenecks in workflow. It is also important to consider the scalability of your solutions.

For newly licensed producers in the cannabis industry, we highly recommend a Crawl-Walk-Run approach to manufacturing capacity planning. This approach provides the flexibility needed to migrate toward the most profitable customer and market segments, while delivering maximum utilization of your manufacturing equipment investment. The following consulting options allow you to leapfrog over hundreds of hours of research and work:

- growLAB
- Facility layout and process design.
- Scale up defined for equipment and infrastructure.
- All processing equipment, including 3rd party products matched for quality and capacity.
- Documented Standard Operating Procedures (SOP) for all processing steps.
- Equipment installation and training of your labor force.
- Manufacturing line commissioning to verify oil output quality.
- Formulations consulting, methods, testing protocols, and training.
- Ongoing service and support.



Summary

-  Supercritical CO₂ produces superior extracts.
-  Ethanol extraction methods produce extracts with questionably “safe” levels of chemical residuals. These chemical residues are avoidable with CO₂ extraction methods.
-  extraktLAB’s product platform provides unlimited scalability to any capacity size, and in any increment for maximum flexibility.
-  extraktLAB’s team members are experts across the entire cannabis extraction and manufacturing process. We help you research what solutions are right for your business and help get your operation moving forward.

A promotional graphic for a 'CBD Jam Session'. On the left, a hand holds a smartphone with various icons (laptop, globe, mail, etc.) floating around it. The text 'CBD Jam Session' is in large blue font, followed by '20 min free jam session to figure out your next steps.' in a smaller, italicized font. A dark blue button with white text says 'FREE Schedule today!'. At the bottom, the 'extraktLAB' logo is shown in green, followed by the phone number '651.600.0036'.

CBD Jam Session
20 min free jam session to figure out your next steps.

FREE
Schedule today!

extraktLAB 651.600.0036

To schedule a CBD Jam Session: extraktlab.com/cbdjamsession



Glossary

Important Terms and Definitions You Must Know

All of the interchanging terms can be confusing, even for an experienced practitioner. This section provides simple definitions for commonly used terminology along with commentary.

Condensation: *The process of changing a vapor or gas into a liquid. The liquid in this case is called a **condensate**. The term thin film is also applied to a condenser because as condensable vapor gas encounters a cold condenser, a thin condensate film will form automatically. Careful engineering of the condensation path is a key aspect to the overall distillation process. The thin condensate film is typically removed by gravity.*

*Condensers are typically situated in two positions relative to the evaporator. The first position is in close proximity to the evaporator. This is called a **short path**. In the second position, the condenser equipment is located remote from the evaporator.*

Distillation: *Refers to the thermal process of evaporation of a volatile from a fluid and condensation of that volatile to produce a separation between the components that are not evaporated and the components that are condensed.*

Evaporation of a liquid will produce a gas. That gas then travels (called diffusion) to a condenser where it cools and condenses back to a liquid. This is typically accomplished under the power of a vacuum pump.

Distillation systems and distillation equipment: *Typically incorporates both an evaporator and a condenser so as to provide a separation between the evaporated fluid and condensate.*

Evaporator: *A piece of equipment designed to remove selected volatile components from a fluid. Selectively removing solvents from fluids is accomplished by controlling temperature and pressure of the fluid.*

Evaporation: *Evaporation refers to the thermal process of a liquid changing to a gas under a pressure or thermal influence. This change is also known as a "phase change". This happens when water boils and makes water vapor. In the case of cannabis processing, evaporation refers to two different processes. First, a phase change of cannabinoids like CBD from the liquid state evaporating to a gas at a high temperature and vacuum. This change happens at the evaporator surface. Second, evaporation refers to the phase*

change of a solvent such as ethanol as it is being removed from the oil. An evaporator typically has an external condenser.

Evaporator equipment is typically designed to produce a **thin film** on a heated surface so that solvents will volatilize quickly and efficiently.

Falling Film: Falling film refers to a film that spreads over an evaporative surface by gravity. The fluid in this case must have low viscosity at the evaporator temperature so that it can flow and evaporate.

Fractional Distillation: Fractional Distillation refers to the ability to start distilling at a low temperature and ramp up the temperature to sequentially boil the components. The components are also sequentially condensed thus allowing separate fractions to be collected.

Molecular Distillation: Molecular distillation refers to distillation under high vacuum pressure that reduces the probability or frequency of one evaporated molecule encountering another. Under high vacuum, evaporation of cannabinoids from oil purportedly migrate unimpeded from the evaporator to the condenser. However, the conditions for true molecular distillation do not occur in the case of cannabis or hemp oils as there are always other compounds that co-distill with the cannabinoids.

Rotary Evaporators (Rotovaps): May be the most common way to accomplish solvent removal in the hemp and cannabis industries. A form of short path distillation equipment using a spinning round bottom flask, a vacuum pump, a heating bath, and a chilled condenser, to evaporate and collect volatile fluids into a receiving flask.

Short Path: Short Path refers to the distance that the evaporated liquid vapor travels from the evaporation surface to reach the condenser. In practice, “short path” describes the location of the condenser in relation to the evaporator. Short path has an internal condenser (**clearSTILL**) whereas an evaporator has an external condenser (**fracTron**).

Still: Still refers to an apparatus where distillation (evaporation and condensation) are taking place independent of whether the still is short path, falling film, molecular, or wiped film.

Thin Film: The process of coating the solution to be evaporated into a thin film on a heated surface. Wiped film apparatus used in hemp and cannabis distillation are not usually fixed distance but typically use “comb” shaped wipers to mix the oil on the surface of the oil while simultaneously creating a thin film at the surface. A thin film is important so efficient evaporation can occur.

Thin Film also applies to a condenser because as condensable vapor gas encounters a cold condenser, a thin condensate film will form automatically and is typically removed by gravity.

Wiped Film: *Wiped film refers to the existence of a wiper to wipe a fluid over a hot evaporation surface. Wiped film evaporation refers to evaporation from the hot surface as the wiper creates a thin film on the evaporation surface.*



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