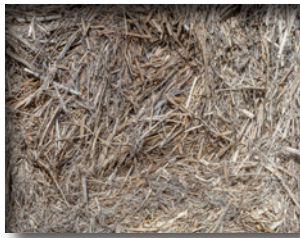
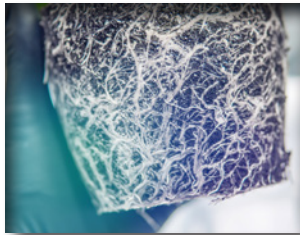


Analytical and Testing Instruments for Hemp & Hemp-Based Products

Complete Solutions for the Industrial Hemp Market: Flower, Stalk, Seed, Leaves & Root



Instruments and Equipment for the Testing and Analysis of Hemp & Hemp-Based Products

Hemp in the United States and worldwide is a hot topic because of its green nature, sustainability, and zero or low carbon footprint. While it appears most of the hemp world has been flower-centric on the health benefits of cannabinoids and terpenes, this is only the tip of the iceberg with respect to applications. The entire plant, including flower, seed, stalk, leaves and root, has 50,000 different uses.¹

According to Canada Hemp Food Ltd.,¹ the seeds may be used for industrial products, foods, and body care items. The stalk can be used for consumer textiles, industrial textiles, paper and building material. The leaves can be used for animal bedding, mulch, and composting. The roots can be used for organic composting, nutrients, and a remedy for other health conditions. For complete information on analysis of the hemp flower for cannabinoids, terpenes and contaminants, see Shimadzu's "Hemp Testing Laboratory Solutions" brochure, which can be downloaded from www.GrowYourLab.com, as well as many other related applications.

This communication will present a limited number of the potential 50,000 different uses. However, Shimadzu is the only worldwide company able to provide analytical instruments, physical testing machines, and X-ray equipment for complete profiling of the hemp plant from development to the final product.

¹Canada Hemp Foods Ltd., <https://canadahempfoods.com/>



Table of Contents

By Application

Flower: QA/QC Testing

- Page 4

Stalk: Textiles

- Page 5

Stalk: Geotextiles & Construction

- Page 8

Stalk: Natural Fiber Composites

- Page 9

Stalk: Paper Products

- Page 11

Stalk: Energy

- Page 12

Seed: Energy

- Page 13

Seed: Foods

- Page 14

Leaves: Food & Compost

- Page 17

Roots: Nutrients & Contaminants

- Page 18

On different pages of this brochure, we have added links to brochures on related topics, including QA/QC testing and analysis of hemp, CFRPs, food development, and greenhouse gases. We encourage you to download these brochures to learn more about our full range of instruments and how we can address your application requirements.

By Instrument/Technique

HPLC/UHPLC

- Pages 4, 12

Physical (Tensile) Testing

- Pages 5, 8, 9, 11

UV-Vis-NIR Spectroscopy

- Page 6

Infrared Spectroscopy

- Page 7

X-Ray Diffraction

- Page 7

Thermal Analysis

- Page 10

Industrial X-Ray Computed Tomography

- Page 10

Particle Size

- Page 11

Balances

- Page 11

GC

- Pages 12, 13, 15, 17

LC-MS

- Page 16

MALDI-TOF MS / Protein Sequencing

- Page 16

AA

- Page 17

GC-MS

- Page 18

EDXRF

- Page 18

Flower: QA/QC Testing

Hemp growers benefit tremendously from testing. Whether meeting state requirements or certifying a product, laboratory testing reduces your risk and ensures delivery of a quality product. And, as medicinal and recreational hemp markets continue to grow, analytical testing will ensure that consumers are receiving accurately labeled products that are free from contamination.

Shimadzu is ready to assist you as you grow your laboratory, providing platforms for the following analyses:

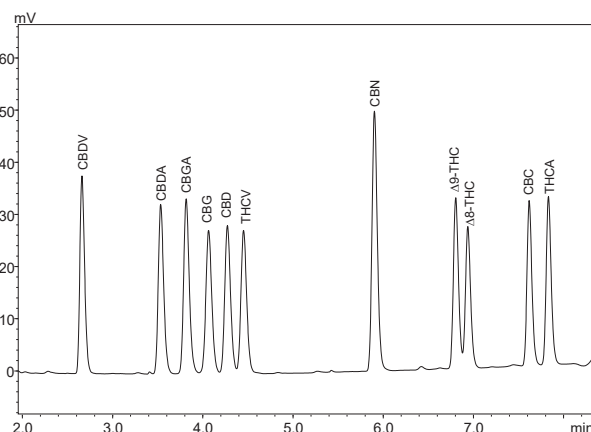
- ▶ Potency Testing
- ▶ Terpene Profiling
- ▶ Pesticide Analysis
- ▶ Mycotoxins Analysis
- ▶ Residual Solvents
- ▶ Heavy Metals
- ▶ Moisture Content
- ▶ Particle Size Testing
- ▶ Research

Potency testing is the starting point for most labs as the Hemp Farming Act of 2018 removes the plant *Cannabis Sativa L.* from the controlled substances act if it contains no more than 0.3% THC on a dry weight basis. Therefore, it is important to accurately distinguish hemp from cannabis using a quantitative analysis of the material. Shimadzu offers numerous options to test potency, including the HPLC-based Hemp Analyzer. A comprehensive package integrating instrument hardware, software, consumables, and analytical workflow, the Hemp Analyzer is ready to use after one day of installation and testing, and requires no time-consuming method development on the part of the analyst.

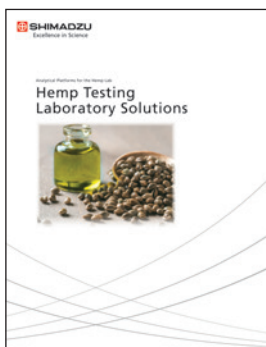


Shown to the right is an example of a separation of CBD, Δ 9-THC, THCv, and 8 other commonly requested cannabinoids in under 10 minutes.

In addition to instruments, Shimadzu offers optional FDA 21 CFR Part 11 compliance software required for labs. LabSolutions DB/CS provides comprehensive features, controls and functionality that assure data integrity in your hemp laboratory. The broad nature of these controls allows a compliant data management environment to be quickly and easily established whether working with a small number of instruments within a single laboratory or with multiple instruments across a large number of laboratories.



[Download](#) our brochure to learn more about our platforms for QA/QC testing, peak harvesting analysis and hemp research.



Stalk: Textiles

The hemp stalk consists of an outer layer called the bast fiber and an inner layer of woody pith. The outer layer is used for textiles while the inner layer is used for fuel, building materials, and animal bedding.

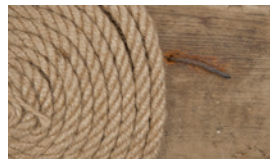
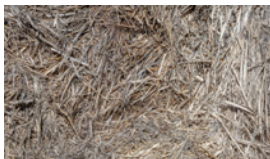
Examples of hemp textiles include woven and knit fabrics, non-woven fiber mats, yarns, and rope. Fabrics can be made of 100% hemp or blended with other fibers such as cotton, flax, or silk. For example, clothing material could be produced from a blend of 30% cotton and 70% hemp fiber. A blended product may be made softer or more durable. There are many advantages of hemp over cotton. Cotton only grows in moderate climates and requires more water and pesticides. One acre of hemp can produce as much fiber as up to three acres of cotton. Hemp is also a stronger fiber and more mildew resistant.

Hemp fabrics can be used for T-shirts, dresses, hoodies, underwear, socks, other forms of apparel, as well as household textiles such as blankets, duvets, towels, tablecloths, and upholstery. Hemp fibers are fine enough to make fabrics with a thread count of 250-300, which is considered percale, a closely woven fine fabric used for sheets. An early harvest will produce a softer fabric. The fabric is very breathable, has high-moisture-wicking abilities, and low heat-retention abilities. The fabrics have a low possibility of pilling where short or broken fibers group together because of abrasion and become tangled in a tiny knot or ball, known as a pill.

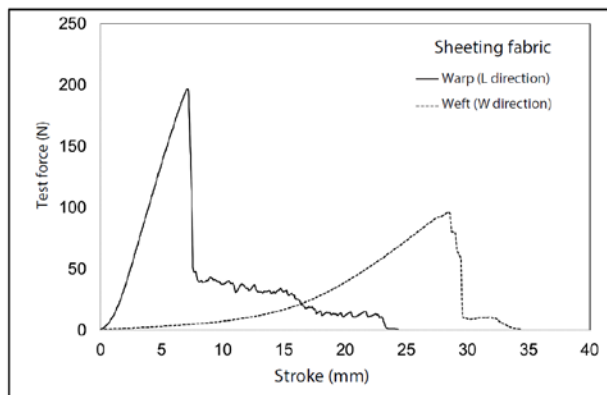
Tensile Testing

Stretchability of Fabrics

Hemp fabrics are considered to have medium stretchability or give. Any of these parameters may be changed by blending with other fibers. Shimadzu's full line of universal tensile testing machines is capable of testing many conventional tests of fabrics or other materials, such as stretchability, strength, and tear resistance.



The physical properties of textiles are an interdependent result of fiber type, yarn spinning method, and fabric construction. A universal test machine, such as the Shimadzu EZ-X, measures force and displacement while deforming a sample. They can be configured with many different types of grips and accessories to evaluate the myriad properties of textile products that determine their feel and function, such as fabric stretchability, tear resistance, burst strength, seam strength, and fiber elongation.



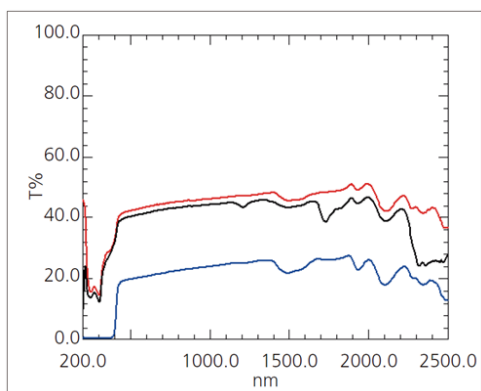
Generally, tensile testing of fabrics occurs in two directions: the warp (length) and the weft (width), also referred to as the woof or fill. Shown is an example of tensile testing of a sheet.

Stalk: Textiles

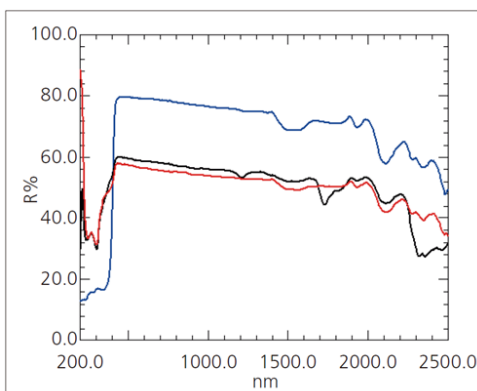
UV-Vis-NIR Spectroscopy

Analysis of Natural Illumination and Thermal Insulation

A variety of functional materials, such as fabrics, are being developed for their thermal insulation properties as well as to provide natural lighting. It can be presumed that increasing transmittance and lowering reflectance produce illuminating properties, while lowering transmittance and increasing reflectance produce thermal insulation properties. Shown are transmission and reflectance spectra of fabrics utilizing Shimadzu's UV-3600i Plus with the ISR-1503 integration sphere.



Transmittance Spectra of Fabrics with UV-3600i
Black & Red: Designed for Natural Illumination
Blue: Designed for Thermal Insulation



Reflectance Spectra of Fabrics with UV-3600i
Black & Red: Designed for Natural Illumination
Blue: Designed for Thermal Insulation

Analysis of Dye Colors

Textile color is an important consideration when selecting and purchasing a product. Shimadzu's full line of UV-Vis-NIR spectrophotometers are useful for analysis of dye colors through final product. Shimadzu's compact UV-2600i (Double-Beam, Single Monochromator) and UV-2700i (Double-Beam, Double Monochromator) are universal, research-grade spectrophotometers that can be used in a wide range of fields for material characterization (solid/liquid), with the capability of measuring very high absorbing samples and expandability to 1400 nm.



Stalk: Textiles

FTIR and Infrared Microscope

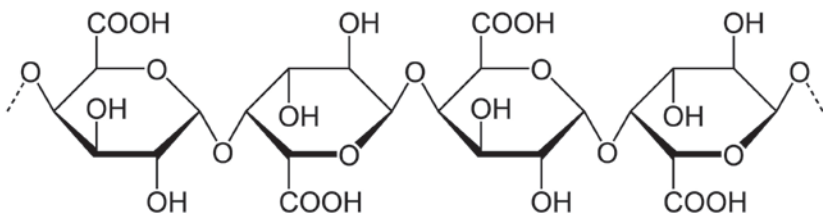
Determination of Pectin Removal Level

Differentiation of Textile Fibers

FTIR spectroscopy may be used to determine the pectin removal level during the purification process by monitoring the functional groups in the transmission mode using the Shimadzu IRTracer-100 FTIR spectrometer (pictured in image on the left). Using the attenuated total reflectance (ATR) accessory for ATR-FTIR the instrument is capable of differentiate textile fibers by their chemical composition, commonly classified by their origin as natural (e.g. hemp, cotton, linen, silk, wool), regenerated (e.g. viscose hemp, cellulose acetate) and synthetic (e.g. polyester, polyacrylic, polyamide).



The AIM-9000 microscope (pictured in image on the right) used in conjunction with FTIR helps identify visible and chemical contaminants, breaks in the fiber, and blends of fibers.



Chemical Structure of Pectin

X-Ray Diffraction (XRD)

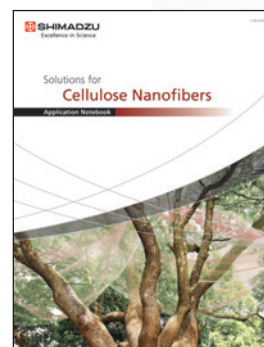
Determination of Crystallinity

During the different stages of chemi-mechanical treatment of the fibers, powder X-ray diffraction (XRD) in transmission mode can be used to determine the crystallinity throughout the process. The goal of the treatment process is to remove amorphous aggregates and increase the crystallinity. Elimination of amorphous compounds, with the increase of crystallinity index, is attributed to the ordered close packing of macromolecules of cellulose in the fibers and strengthening of the hemp fibers.



The following table lists characteristics of individualized cellulose nanofibril samples that are required to be measured or identified, measurement methods, and instruments used.

Characteristics	Measurement Methods	Instrument
Morphology	AFM	SPM-9700HT
Width, height and length	AFM	SPM-9700HT
Optical transmittance	UV-Vis spectrophotometry	UV-2600, UV-1900
Surface functional types	FT-IR	IRTracer-100, IRSpirit
Thermal stability	TGA	TGA-50
Constituent sugar content	HPLC	Nexera Series
Acid-soluble metal content	ICP, ICP-MS	ICPE-9820, ICPMS-2030
Crystal structure	X-ray diffraction	XRD-7000



[Download](#) our "Application Notebook: Solutions for Cellulose Nanofiber" or request a printed version using code C10G-E076.

Stalk: Geotextiles & Construction

Geotextiles

Geotextiles are soil reinforcements used in environmental engineering and construction projects to prevent erosion, aid in drainage, separate structural layers, and improve vegetation establishment. Due to their long fiber length and strength, hemp fibers can be used in geotextiles in the form of fabric, fiber mats, and nets. In contrast to synthetic plastic geotextiles, hemp is renewably sourced and biodegradable, so it does not contaminate the environment at the end of its useful life. Shimadzu's AGS-X Series Universal Electromechanical Test Frames are ideal for testing the strength of geotextiles.



Worker laying geotextile in preparation for new building used for separation and reinforcement



Shimadzu's AGS-X Series Universal Electromechanical Test Frames for geotextiles testing

Construction Materials

Hemp hurd and fibers have found use in several construction materials, including concrete, insulation, and particle board. When hemp hurds are incorporated to lime-based cement, they create a renewably sourced, lightweight, and insulating building material that can replace concrete and synthetic insulation in some applications. Hemp stalk materials are also possible replacements for wood chips in fiberboard and particleboard materials. Typical tests for construction materials include compression and bending tests, and evaluation of changes in physical properties due to environmental exposure. Shimadzu's UH-X hydraulic test frames can achieve the forces required for testing high-strength construction materials, and the software includes the concrete test control software standard.

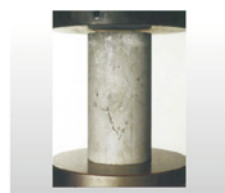


Shimadzu's UH-X hydraulic test frames compression for concrete as well as hempcrete

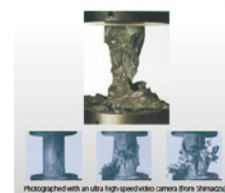


Shimadzu's HyperVision HVP-X2 high-speed video camera enables recording at up to 10 million frames/second for visual compression and tensile monitoring.

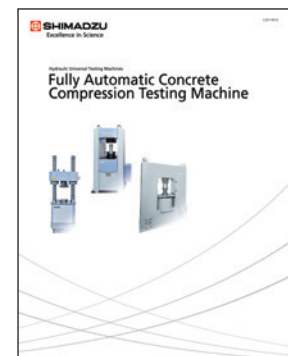
Watch a video of cement exploding at 10,000 frames/second:
<https://www.youtube.com/watch?v=PIZY6vyP0b8>



Compression testing of explosion proof cement



Compression testing of non-explosion proof cement



[Download](#) our brochure for concrete, also useful for hempcrete, or request a printed copy using code C221-E012.

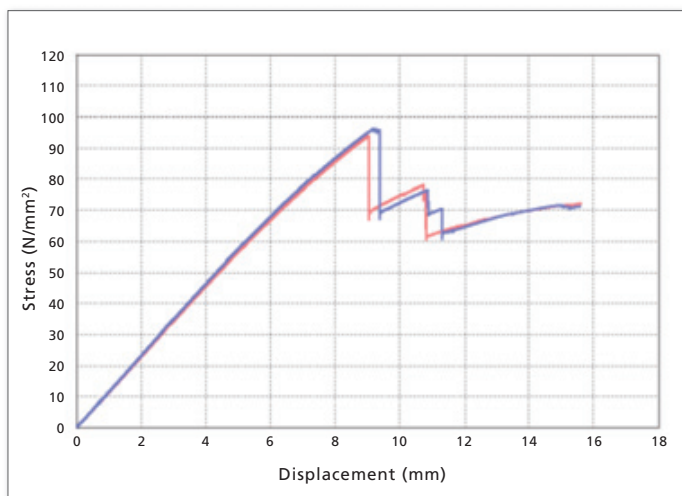
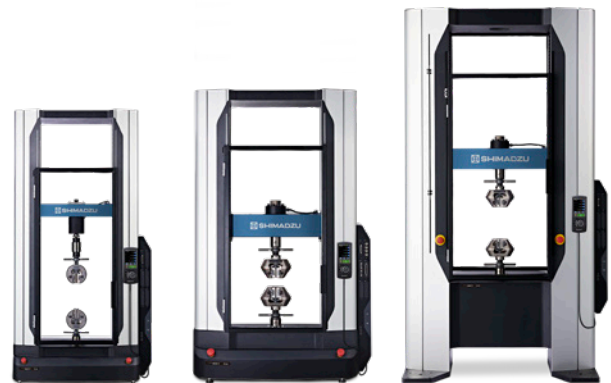
Stalk: Natural Fiber Composites

Tensile Testing

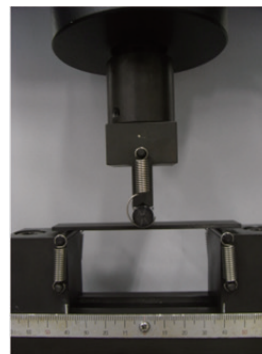
Natural fiber composites combine plant fibers, such as hemp, with a polymer matrix to create materials with improved rigidity and strength and decreased weight. Composites made with natural fibers have potential advantages over glass and carbon fiber reinforcements in many applications due to the right balance of weight, cost, and performance in addition to generally having a much lower energy of production.

They are already widely used in the automotive industry for interior panels such as doors and trunk liners and are expected to be incorporated into more components as their properties are improved. Bending and shear testing are important because composite strength can vary depending on the direction that force is applied. Natural fiber composites may also be more sensitive to humidity and temperature, so performing physical testing in thermal chambers is necessary.

The AGX-V universal test frame offers the highest precision and control for accurate evaluation of composite mechanical properties. Specialized shear jigs are available to test the force required to separate the fibers and layers within the composites. Bending tests, performed on either a 3 or 4-point bend fixture, measure the rigidity of a material and induce both tensile and compressive forces to determine the force that causes a material to rupture. For high-force testing of cement, high-capacity hydraulic test frames are available.



The image above shows the results of a 3-point bending test performed on a composite material to determine flexural modulus.



3-point bending on a Shimadzu Universal Testing Machine

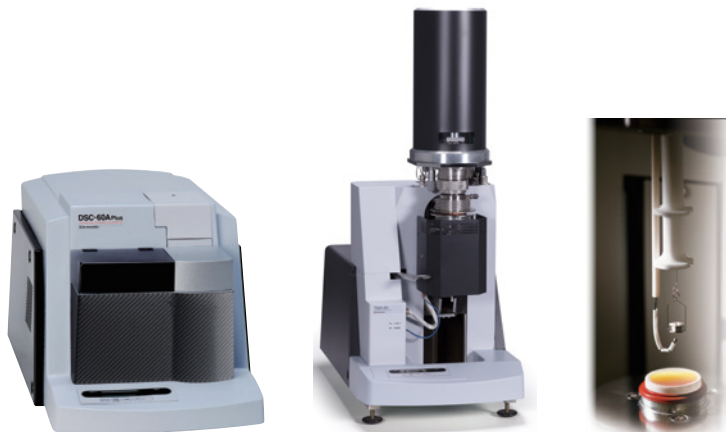
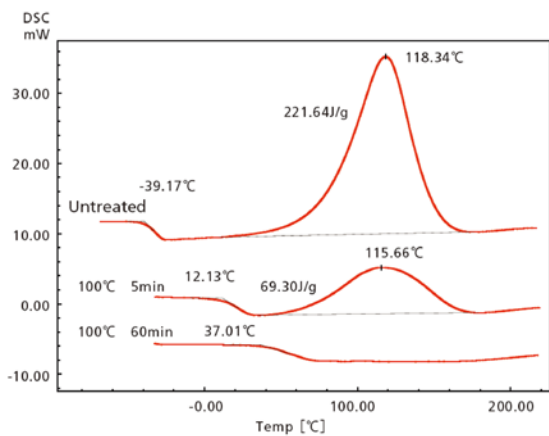


Stalk: Natural Fiber Composites

Thermal Analysis

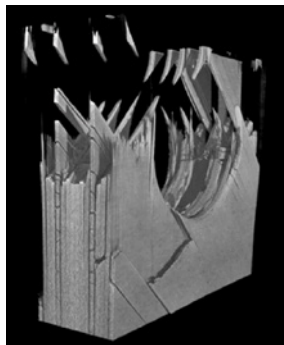
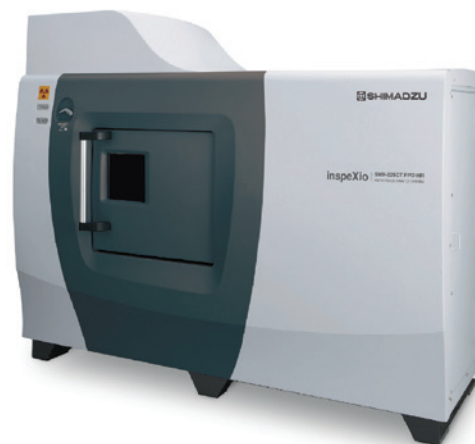
A variety of thermal properties of composite resins and industrial chemicals can be determined using Shimadzu thermal analysis instruments (TGA, DSC, TMA, and DTG) and Capillary Flow Technology (CFT), such as glass transition temperature, degradation or melting temperature, purity analysis, and curing behavior.

Shown below is a DSC measurement of a hardening reaction of an epoxy resin at various points of heat treatment. As the reaction progresses, the glass transition temperature increases and the enthalpy of reaction decreases.

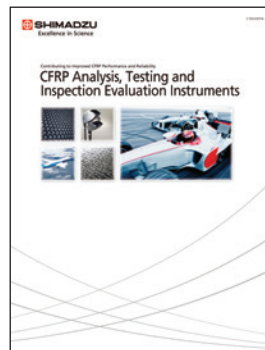


Industrial X-Ray Computed Tomography (CT)

Industrial X-Ray CT systems provide detailed visualization of the internal structure and features of an object. Scanning composites can identify fiber position and alignment, calculate volume fraction of different components, and identify the size and distribution of pores. Powerful color processing software enables observation and statistical calculations of different internal regions. CT scanning is also a useful tool for identifying cracks, voids, and disconnections for failure analysis.



This CT scan of the fracture area of a fiber composite illustrates areas of delamination and cracking.



[Download](#) our brochure for more solutions to fiber reinforced plastics using additional instruments and applications or request a printed copy using code C10G-E037A.

Stalk: Paper Products

Hemp paper from the stalk can be used for printing, newsprint, packaging, cardboard, and other paper products. Paper products can be made of the long bast fiber or the hurd (or pulp). The different parts of the stalk may have different applications. The fiber bast paper has been reported to be thin, tough, brittle, and rough while the hurd has been reported to be thicker, easier to make, not as strong, with more daily applications. Depending on the source of information, dried hemp has been reported to have between 50-85% cellulose, the main ingredient in paper, while trees are in the 30-50% range. Therefore, the other 50-70% of chemical compounds from trees are required to be removed. Relatedly, hemp has lower concentrations of lignin, which must be removed during the process of making paper products. The lignin concentrations are 5-24% and 20-35% for hemp and trees, respectively. Hemp paper can be bleached with hydrogen peroxide instead of toxic chlorine or dioxin chemicals used with paper from trees.

Hemp reaches maturity in 3-4 months while trees require 20-80 years and has four times more fiber than a forest using the same land mass. Thus, hemp paper can be produced at a much faster rate. It also has been reported that hemp paper products can be recycled eight times, while tree products can only be recycled less than half the number of times.

While on-line sensors may be available to measure some production parameters, lab scale method development may require laboratory instruments. Some parameters measured are weight, moisture profile, ash content, color, brightness, smoothness, gloss, coat weight, formation, porosity, fiber orientation, surface properties, tear strength, and opacity. For example, Shimadzu's EZ-X could be used for determination of breaking strength, breaking length, tearing strength on the long and short side, elongation, fold resistance and more. Shimadzu offers analytical, top loading and moisture balances for weight and moisture profiles.

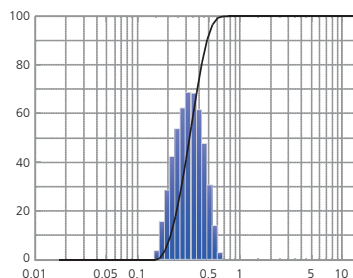
In the paper industry, coatings, fibers, fillers, sizing agents and other items affect a paper's properties, such as brightness, color, gloss, and opacity. Shimadzu's SALD-2300 particle size analyzer is ideal for this application with a measurement range of 17 nanometers to 2500 microns.



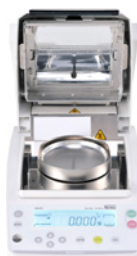
Shimadzu EZ-X Universal Tester tearing paper



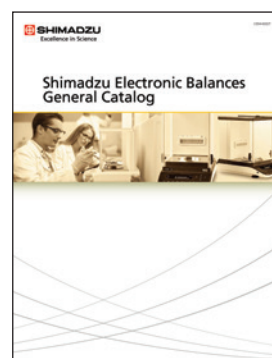
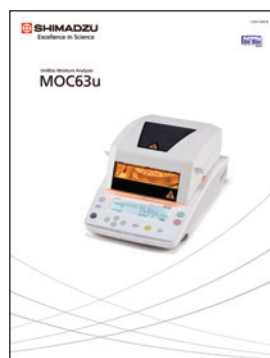
SALD-2300 Particle Size Analyzer



Example of particle size distribution (um)



Shimadzu MOC63 Moisture Balance.
[Download](#) the brochure or request a printed copy using code C054-E067B.



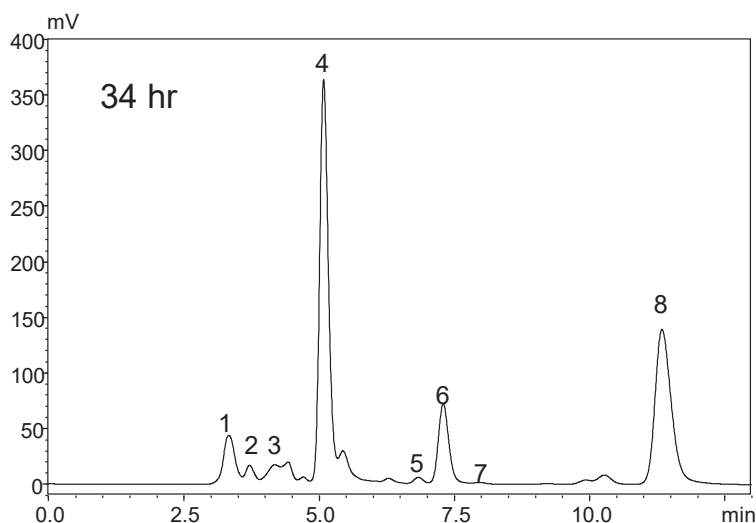
General Balance Brochure.
[Download](#) the brochure or request a printed copy using code C054-E032T.

Stalk: Energy

The 2007 federal legislation that encouraged production of biodiesel in the United States has also increased production of ethanol in an effort to offset dependence on fossil fuels and reduce carbon dioxide emissions. The cellulosic material in hemp can be converted into sugars and fermented into ethanol to be used as a supplement in gasoline, much as has been done with corn and soybean biomass.

High Performance Liquid Chromatography (HPLC)

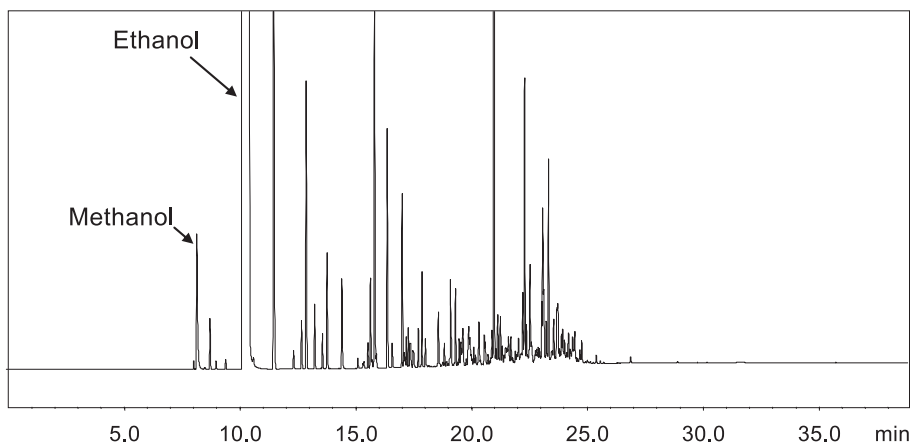
Careful attention must be paid to the fermentation process to guarantee its efficiency and the purity of the final ethanol product. High performance liquid chromatography (HPLC) is an ideal method for monitoring the conversion of sugars to alcohol during fermentation. The Shimadzu Bioethanol Analyzer is a turnkey analyzer, well suited to plug-and-play operation for this application.



HPLC chromatogram showing conversion of sugars to ethanol during fermentation 34 hours after the process began. Peaks are 1) DP4+ (oligosaccharides with ≥ 4 degrees of polymerization), 2) DP3 (oligosaccharides with 3 degrees of polymerization), 3) Maltose, 4) Glucose, 5) Lactic acid, 6) Glycerol, 7) Acetic acid, 8) Ethanol

Gas Chromatography (GC)

After fermentation is complete, the produced ethanol must be denatured to ensure that it is not taxed nor used for human consumption. Following test methods such as ASTM D5501, which specifies GC-FID, allows for the determination of the ethanol content in ethanol denatured with methanol or gasoline.



GC-FID chromatogram methanol and ethanol content in a fuel ethanol denatured with gasoline by ASTM method D5501.

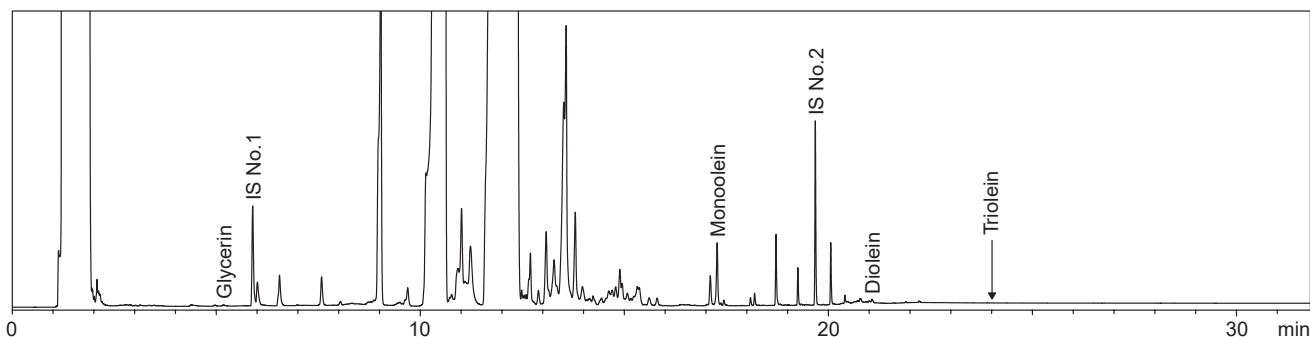


Seed: Energy

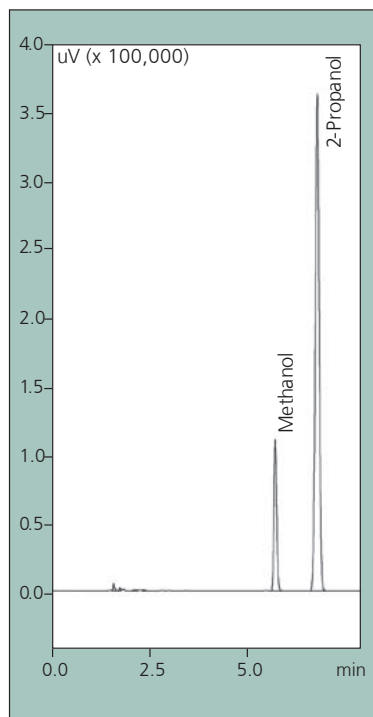
With the passage of federal legislation in 2007, production of biofuels, such as biodiesel and ethanol, in the United States has increased in an effort to further energy independence and combat carbon dioxide emissions. Much like soybeans, the oil within hemp seeds can be extracted and converted into biodiesel through a process called transesterification. Because hemp can be cultivated on less fertile land with less human intervention, it is thought that hemp-based biodiesel may offset the demand for soybean-based biodiesel.

Any biodiesel and biodiesel blend must meet stringent regulations to ensure that it functions safely and efficiently as a fuel, such as those laid out in ASTM D6751 for B100, or 100% biodiesel, and D7467 for B6-B20, or 6-20%, biodiesel blended with conventional petrodiesel.

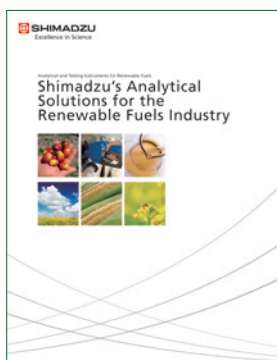
Various properties of the biodiesel, including glyceride content, metals content, and assessment for residual methanol used during fuel production, must be met. These factors relate to the combustion and lubricating properties of the biodiesel as well as the stability of the fuel itself once produced. Such regulation guarantees that biodiesel and biodiesel blends are safe and effective to use in properly equipped vehicles.



GC-FID analysis of biodiesel for total glycerides according to ASTM D6584



HS-GC-FID chromatogram for residual methanol in biodiesel according to EN 14110



[Download](#) our brochure to learn about more analytical solutions for the renewable fuels industry.

Seed: Foods

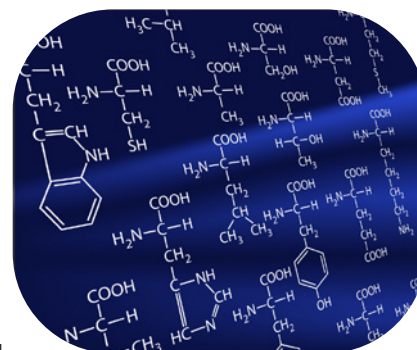
Hemp seeds are an excellent source of nutrition and, thus, are very beneficial to human health. They are high in fiber, protein, vitamins, and the “good fats”, like Omega-3 and Omega-6 fatty acids.



Hemp seeds contain all nine essential amino acids, and important vitamins (A, B, C, and and minerals (Ca, Mg, K, P). As a bonus, there are no known food allergens in hemp seeds.

According to the USDA National Nutrient Database, a two-tablespoon serving of hemp seeds weighing 20 g contains 6.3 g protein, 9.8 g fat, and 1.7 g carbohydrates (incl. 0.8 g fiber).

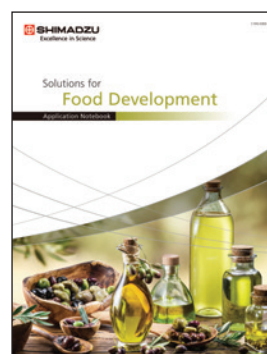
The US FDA has classified hemp seeds as GRAS (Generally Recognized As Safe), indicating that hemp seeds are safe in foods and won't require further approval. This FDA approval clears the way for hemp seeds and hemp seed oil to become part of mainstream cuisine.



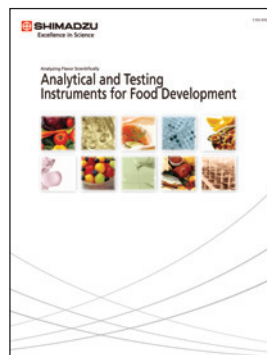
Currently, there are no official methods for hemp seed and hemp seed oil as food. Methods released on hemp analysis are primarily focused on cannabinoids (mostly CBD and THC).

For nutritional analysis of hemp seeds and hemp seed oil, methods from other, similar seeds and oils can be used, e.g., soy, chia, and castor. Shimadzu's Advanced Food Solutions provide the analytical tools to identify and quantify the nutritional characteristics of hemp seeds.

As hemp seeds find their way into our kitchen more frequently, more methods for hemp seeds analysis will be developed. And Shimadzu, with decades of experience serving the food sciences industry, can provide all the advanced and innovative analytical tools needed to fully characterize this superfood.



[Download](#) our brochure for our guide to instrumental analysis in Food Development or request a printed version using code C10G-E060.



[Download](#) our brochure to learn more about the full portfolio of food testing instruments from Shimadzu or request a printed version using code C10G-E052.



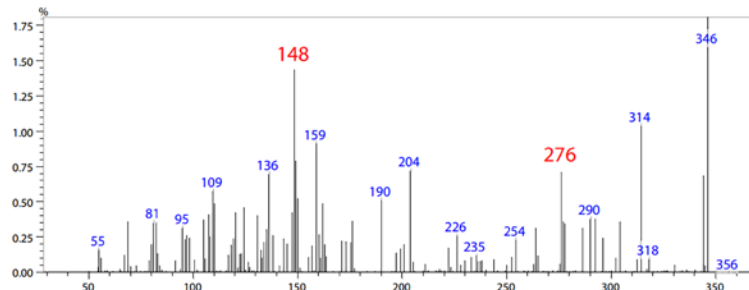
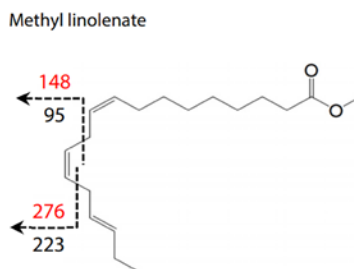
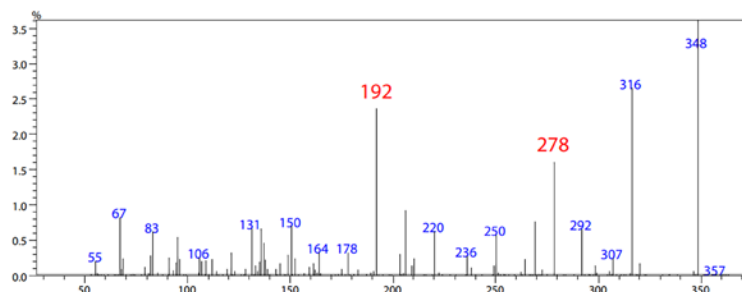
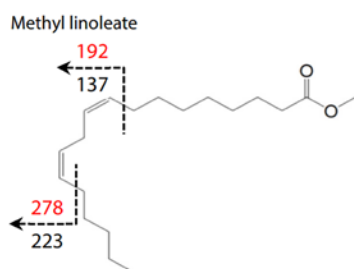
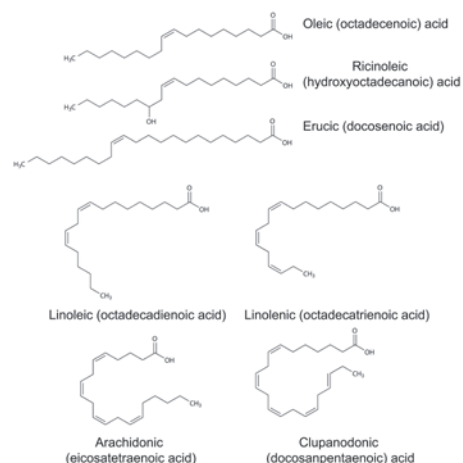
Seed: Foods

Gas Chromatography

Analysis of Fatty Acids

Analysis using Gas Chromatography (GC) is a suitable measurement technique, as GC has a high separation capability. In this technique, the fatty acids are first derivatized by methyl esterification to produce fatty acid methyl esters (FAME) with sufficient volatility. However, localization of the double bond position in unsaturated FAMES is difficult, even when using mass spectrometry.

To overcome this difficulty, a new analysis technique was developed: Solvent Mediated Chemical Ionization (SMCI). It is a soft ionization method using an organic solvent. The new Shimadzu SMCI unit makes it possible to introduce acetonitrile, which is necessary in this double bond localization technique, into the analytical instrument.

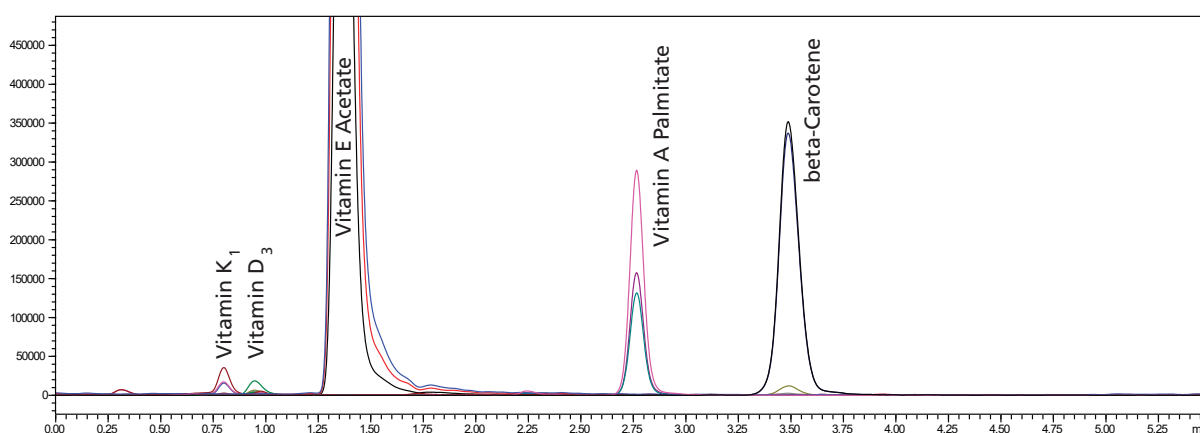


Seed: Foods

Liquid Chromatography / Mass Spectrometry

Analysis of Vitamins

Though many AOAC Official Methods for vitamins employ microbiological assays or LC with fluorescence detection, use of LC-MS/MS techniques in this field is rising because they offer advantages over these other methods, including specificity, speed, ability to detect impurities, and broad applicability. The Shimadzu LCMS-8040 with the Nexera UHPLC provides excellent instrumentation for fat-soluble vitamin analysis.



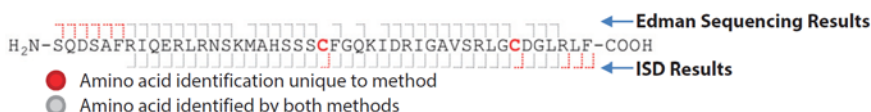
MALDI-TOF MS / Protein Sequencing

Protein Analysis

Traditional Edman sequencing avoids mass dependency and the use of databases by analyzing each amino acid from the N-terminus one at a time in sequence. Unfortunately, Edman has its own limitations in providing high sequence coverage. Mass spectrometry has become an indispensable tool for researchers looking to sequence peptides. Although effective in many cases, sequencing by In Source Decay (ISD) faces a few challenges, e.g., its ability to provide reliable sequence information including isobaric amino acids, database dependency, and low molecular weight interferences.



Combining the powerful capabilities of MALDI-TOF MS (MALDI-8020) and Edman sequencing (PPSQ™-50A Gradient System) provides a more accurate and complete N-terminal sequence of peptides.



Leaves: Food and Compost

Concentrated at the top of the hemp plant are the leaves, which can be used for food, animal bedding, mulch, and compost. Hemp leaves are edible and can be used in raw leafy vegetables in salads because they are rich in digestible proteins. In fact, the hemp leaf has been reported to have five times more protein than lettuce. The leaves are rich in omega-3 and omega-6 fatty acids, as described in the “Seed: Food” section of this brochure.

In addition, the leaves are rich in polyphenols, acting as powerful antioxidants. Our bodies get these micronutrients through some plant-based foods. There are health properties for fighting against cardiovascular disease, diabetes, and digestive issues. Antioxidants have been referred to as “free-radical scavengers” and protect against cancer and other diseases. Polyphenol extracts have been measured in many foods by various instruments, including UV, FTIR, LC, LC-MS(/MS) and GC-MS(/MS). See the “Seed: Food” section of this brochure.



The leaves, which contain levels of iron and magnesium comparable to kale, can also be pressed to make juices. The elements can be measured by Atomic Absorption (AA), Inductively Coupled Plasma (ICP), ICP with a mass spectrometer (ICP-MS), and EDXRF, a technique described in the “Roots” Nutrients...” section of this brochure.



The Shimadzu Atomic Absorption AA-7000 with ASC-7000 autosampler is used for measuring elemental nutrients.

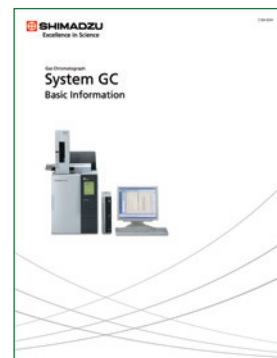


Hemp leaves are also used in meat dishes for refreshing flavor and replacing parsley and mint. Hemp leaves can be thought of as a superfood, just as the hemp seed. The leaves contain trace or no cannabinoids. If the leaves contain cannabinoids, they would be in the acidic form as Cannabidiolic acid (CBDA) and Δ 9-Tetrahydrocannabinolic acid (THCA); the latter form would not induce the so-called “high” like THC. The leaves also contain beneficial terpenes as described in the “Flower: QA/QC Testing” section of this brochure.

Hemp leaves can be made into mulch and compost. Compost helps plant growth when added to soil because of organic material. The EPA has reported that 28% of what is thrown away could be composted. Recycling the hemp leaves helps prevent methane and other greenhouse gases from being produced in landfills. In summary, compost enriches soil, suppresses plant disease, reduces pesticides, produces beneficial bacteria and fungi, and reduces greenhouse gases, thus lowering carbon footprint.



[Download](#) our brochure to learn more about our system for analysis of greenhouse gases or request a printed version using code C184-E041.



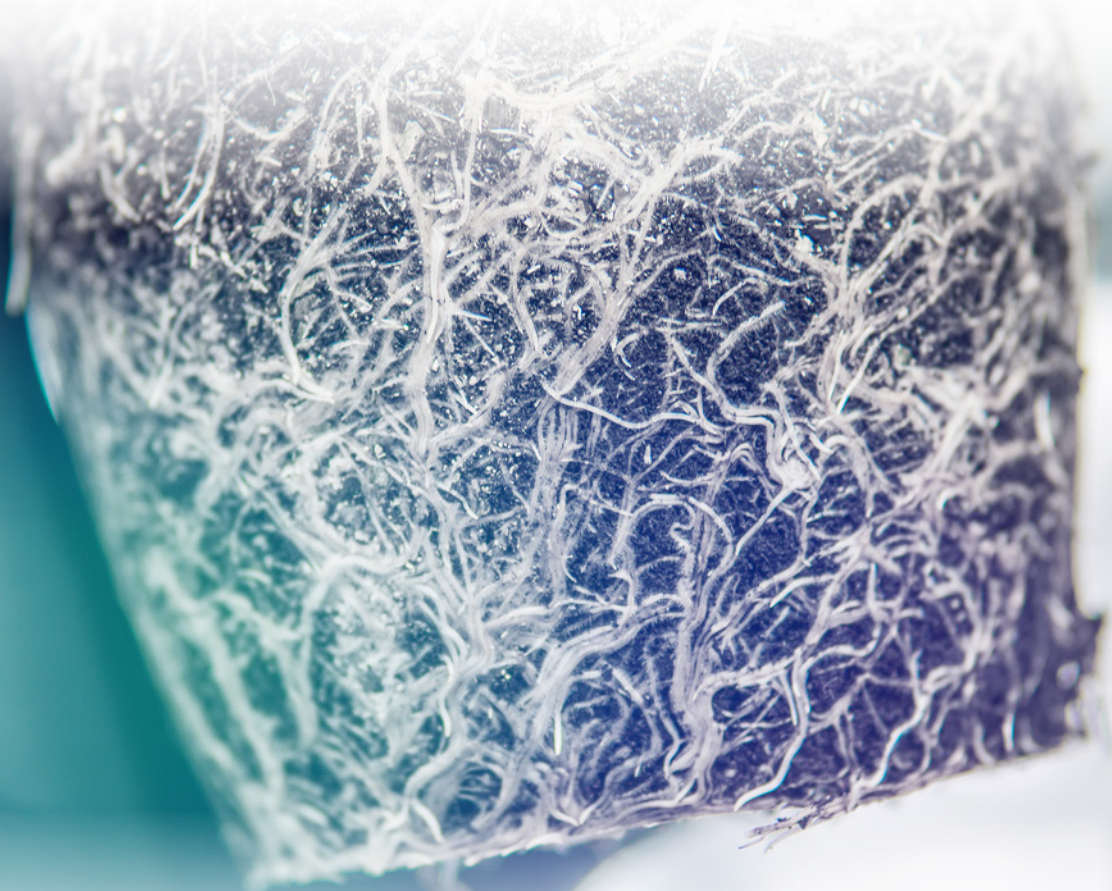
Roots: Nutrients & Contaminants

Gas Chromatography / Mass Spectrometry

Determination of Triterpenes

Hemp roots can be used for organic composting, nutrients, and as remedies for health conditions. The hemp root contains little to no cannabinoids and no THC, which produces the so-called "high". *Cannabis Therapy** reported that the oldest Chinese Herbal Atlas describes hemp root as being used as a painkiller and to help stop bleeding during difficult births. Ancient Romans used the root for cramps, joint pain, and arthritis. Hemp root tea has been reported to relax muscles, assist with digestion, and remove elemental contaminants. The hemp root has been reported to have anticancer properties because of the triterpenoid chemicals: friedelin and epifriedelanol.

The determination of triterpenes is performed by Gas Chromatography-Mass Spectrometry (GC-MS). To the right is Shimadzu's GCMS-QP2020 NX with AOC-6000 Plus autosampler for liquid injection, headspace sampling, and solid phase micro extraction (SPME).



Roots: Nutrients & Contaminants

Energy Dispersive X-Ray Fluorescence Spectrometry (EDXRF)

Quantitative (%) Analysis of Nutrients & Heavy Metals

The health of the hemp plant is determined by environmental conditions such as soil, water, and air, as well as additives for plant health and growth. There are twenty essential macronutrients and micronutrients for the plant to grow properly. In the “Flower: QA/QC Testing” section of this brochure, the flower is tested for contaminants such as arsenic (As), cadmium (Cd), lead (Pb), mercury (Hg), other heavy metals and nutrients by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) because hemp plants are bio-accumulators. The soil, roots and plant’s health and growth products can also be tested by ICP-MS, but there is a time-consuming sample preparation step requiring dissolving the sample by acid-assisted microwave oven digestion.



With Shimadzu’s Energy Dispersive X-Ray Fluorescence Spectrometer (EDX-7000), there is little or no sample preparation with analysis complete in a few minutes. Once the EDX-7000 has been programmed, it may be operated by a layperson.

Shown in the table are the quantitative testing results of eight samples of plant additives in the liquid and powder forms as well as soil for 27 elements, including nutrients and contaminants by EDXRF. The <DL is for data below the instrument detection limits. There are noticeable differences between the elements and concentrations for similar matrices.

Matrix	Liquids				Powder	Soils		
Sample ID	A	B	C	D	E	F	G	H
Ag	<DL	0.142	<DL	<DL	<DL	<DL	<DL	<DL
Al	<DL	<DL	<DL	<DL	<DL	9.855	9.948	17.372
As	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
Ba	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
Br	<DL	<DL	0.179	0.390	<DL	<DL	<DL	<DL
Ca	36.438	44.795	16.059	10.563	6.057	11.677	12.665	5.815
Cr	<DL	<DL	<DL	<DL	<DL	0.045	0.041	0.118
Cu	0.214	0.176	0.284	0.478	0.045	0.055	0.065	0.082
Fe	1.828	1.656	1.255	0.674	5.964	8.371	9.370	14.327
Hf	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
Ir	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
K	27.591	31.681	68.730	66.311	5.864	6.215	7.000	4.480
Mn	0.425	0.504	<DL	<DL	0.268	0.471	0.538	0.279
Mo	0.036	0.022	<DL	<DL	<DL	<DL	<DL	<DL
Ni	<DL	<DL	<DL	<DL	<DL	<DL	<DL	0.032
P	21.212	10.568	8.597	15.113	<DL	0.147	0.348	<DL
Pb	<DL	<DL	<DL	<DL	0.049	<DL	<DL	0.038
Pd	<DL	<DL	<DL	<DL	<DL	<DL	<DL	0.071
Rb	<DL	<DL	<DL	<DL	0.029	0.018	0.021	<DL
S	10.007	9.910	4.540	6.269	1.570	1.975	<DL	0.223
Si	1.535	<DL	<DL	<DL	72.626	60.126	56.838	54.725
Sr	0.460	0.331	<DL	0.196	0.045	0.091	0.970	0.080
Ti	<DL	<DL	<DL	<DL	<DL	0.893	0.878	1.488
V	<DL	<DL	<DL	<DL	0.024	0.030	0.037	0.072
Zn	0.254	0.018	<DL	<DL	0.024	0.070	0.091	0.759
Zr	<DL	<DL	<DL	<DL	<DL	0.016	0.035	0.037
Y	<DL	<DL	<DL	<DL	0.006	<DL	<DL	<DL

List of Analytical and Testing Instruments for Industrial Hemp and Associated Markets



	Industrial Hemp	Hemp Flower QA/QC Testing	Food Test	Nanofiber	CFRPs
AA/ICP/ICPMS	✓	✓		✓	✓
GC, GC-MS(/MS)	✓	✓	✓		✓
HPLC/UHPLC	✓	✓	✓	✓	
SFE/SFC		✓			
IC					✓
LC-MS(/MS)/Q-TOF	✓	✓	✓		✓
UV-Vis	✓		✓	✓	
FTIR	✓		✓	✓	✓
MALDI-TOF MS	✓	✓			
Protein Sequencing	✓				
DSC/TGA/TMA/DTG	✓			✓	✓
Particle Size	✓	✓	✓	✓	✓
X-Ray CT	✓				✓
XRD	✓			✓	
EDXRF	✓				
Universal Testing	✓		✓	✓	✓
Flow Testing				✓	✓
Compression Testing	✓				✓
Fatigue Testing					✓
Impact Testing					✓
High-Speed Video Camera	✓				✓
SPM				✓	✓
fNIRS			✓		
Balances	✓	✓	✓	✓	✓
Software Compliance	✓	✓	✓	✓	✓

www.GrowYourLab.com



Shimadzu Corporation
www.shimadzu.com/an/

Shimadzu Scientific Instruments
 7102 Riverwood Drive, Columbia, Maryland 21046, U.S.A.
 Phone: 800-477-1227/410-381-1227, Fax: 410-381-1222
www.ssi.shimadzu.com

For Research Use Only. Not intended for diagnostic procedures.

These statements have not been evaluated by the Food and Drug Administration. We makes no claims meant to diagnose, treat, or cure any disease or medical condition. Please consult your doctor before starting ANY medical treatment or before using any medical product during pregnancy or if you have a serious medical condition.

Company names, product/service names and logos used in this publication are trademarks and trade names of Shimadzu Corporation or its affiliates, whether or not they are used with trademark symbol "TM" or "®". Third-party trademarks and trade names may be used in this publication to refer to either the entities or their products/services. Shimadzu disclaims any proprietary interest in trademarks and trade names other than its own.

The contents of this publication are provided to you "as is" without warranty of any kind, and are subject to change without notice. Shimadzu does not assume any responsibility or liability for any damage, whether direct or indirect, relating to the use of this publication.