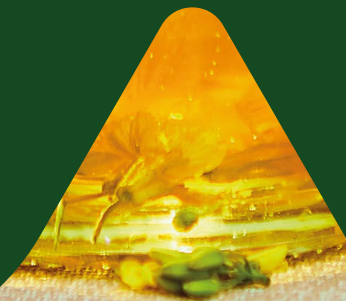
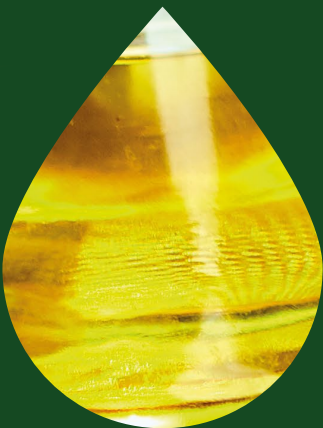




**Sustainable
extraction of
vegetable oils
and plant-based
proteins**

The eco-extraction solution

White Paper - 2021

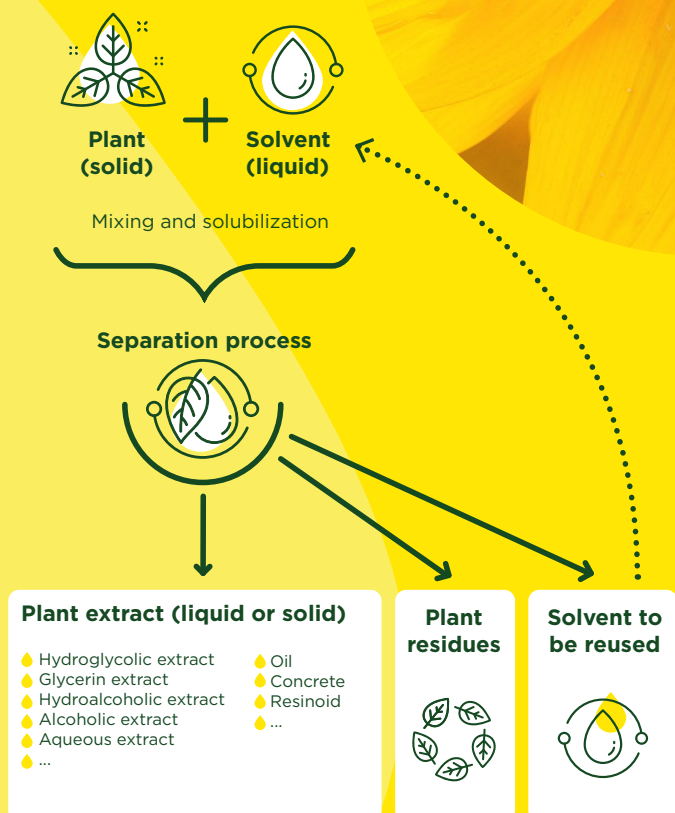


Fractionating plant material using solvent extraction: the basics

Plant extraction fractionates biomass to produce pure substances of interest, such as carbohydrates, lipids, proteins, fibers, bioactives, and pigments or aromatic molecules.

Solvent extraction is the most widely used method. It is a solid/liquid separation operation in which the plant or a (solid) fraction of the plant is placed in contact with a solvent (liquid) whose main function is to **solubilize** the components of interest. This operation is potentially followed by purification stages to isolate the extracted substance and to remove the solvent for reuse.

Solvent extraction process

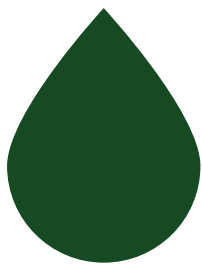


Solvents are found everywhere. **Water** is very **widely used**. Sugar is extracted from beet or sugar cane using water as solvent. It is an efficient solvent for polar molecules and is the universal solvent in nature. Other well-known natural or bio-based solvents, such as ethanol, are widely used in plant extraction processes.

However, not all molecules can be extracted efficiently using water or ethanol. Particularly, oils and fats are not soluble in water. That is why choosing the right solvent – based mainly on its polarity and chemical properties – is critical to efficiently **dissolving the desired compounds of interest**.

Today, “solvents” are often perceived negatively because of the harsh chemical solvents used in paints, inks and cleaning products.

Did you know? Plant extraction is a widely used process. For example, vegetable oils are mainly extracted from oilseeds (e.g. sunflower, soybean, etc.), or fruit (e.g. olive, palm). Active ingredients used to make medicines or personal care products are often extracted from plants in the pharmaceutical, cosmetics and nutraceutical industries. In our daily life, **brewing tea or coffee** is also an accessible solid-liquid plant extraction process.



From past to present: some history of plant extraction

One of the most ancient processes with modern applications

Plant extraction has existed since the dawn of time in all civilizations. Our ancestors soon realized that plants had valuable properties: medicinal, nutritional, spiritual, aphrodisiac, esthetic or for well-being. And history shows that all populations have used plant extracts **to feed, heal and perfume** themselves.

Nowadays, plant extraction tends to be associated with industrial and chemical techniques. And with the **development of the petrochemical-based economy**, extraction processes have become less environmentally responsible, with the emergence of energy-intensive processes.

Fortunately, the awareness of consumers has changed how we develop and assess plant extraction processes.

Eco-extraction, a growing expectation among industrial players and consumers

Today, consumers take a closer look at **where** the products they consume come from, their composition, and **how** they are produced. We are all increasingly aware of the impact of our consumption patterns on our health and on the environment.



Some key numbers to support this:

- **57%** of consumers world-wide would change their purchasing habits to help decrease environmental impact (IBM Institute for Business Value, 2020);
- **60%** of consumers world-wide are interested in knowing where their food comes from (Innova Market Insights, 2020);
- Knowing what is in food is of major importance for **85%** of consumers world-wide (Innova Market Insight, 2021).

A growing appreciation of the value of **naturalness** is a force for innovation and creativity in the nutrition and personal care industries. The **clean-label** approach is key and **transparency** is the new leitmotiv.

Whole value chains are involved, from ingredient sourcing to packaging design. Industrial players need to move towards more eco-responsible processing solutions to meet new consumers expectations

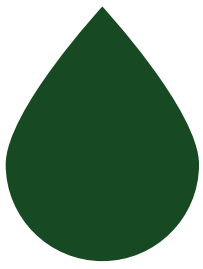
The plant eco-extraction trend was born from this observation, aiming to be healthier and more respectful of the planet and people.

Advantages of eco-extraction



Eco-extraction is the result of extraction processes designed to reduce energy consumption using non-petrochemical solvents and renewable plant resources.

- No petrochemicals - only renewable raw materials
- Use bio-based solvents manufactured from biomass
- Creation of co-products instead of waste
- Reduction of energy consumption
- Reduction of the number of process unit operations
- Naturalness



Extraction of vegetable oils and plant-based proteins: commonly used methods

Mechanical extraction and solvent extraction

A **sufficient and reliable food supply** is a basic need of mankind. **Oilseeds** such as soybean, sunflower, rapeseed are major sources of plant proteins and vegetable oils in our modern world.

This abundant resource is largely processed using a **solvent extraction technique** to separate the high-protein meal solids from the vegetable oil.

Seeds such as sunflower and rapeseed that contain high amounts of oil are usually first pressed mechanically to extract part of the oil. More than half of the oil can easily be extracted from a seed in this way, but the solid residue will still be 6 – 20% oil.

In comparison, solvent extraction with hexane (the main solvent used worldwide by the oilseed industry) extracts almost all the oil: **only about 0.5-1% of residual oil** remains. Maximizing the extracted oil yield is the main benefit of solvent extraction. It also allows the production of low-fat feed meal that stores well unaffected by oxidation of fat. This protects the quality of plant proteins. In addition, solvent extraction uses less energy, and requires less maintenance and use of machines than mechanical pressing.

Therefore, solvent extraction can be considered as **the most efficient and reliable method** for separating large volumes of oil from protein meal.

Why do we still use hexane?

The standard solvent used in the oilseeds industry is hexane due to its low cost and high efficiency. From a purely technical point of view, hexane is a stable product presenting a high solubilizing power and high selectivity towards lipids, as well as appropriate chemical properties enabling straightforward recycling.

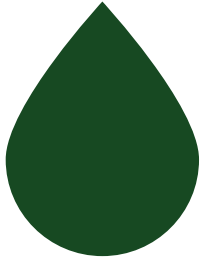
5 things to know about hexane

- 1 Commercial-grade hexane for extraction is a mixture of n-hexane and its isomers
- 2 It is a **petrochemical**
- 3 **1 million tonnes are consumed each year** worldwide in the food industry as an extraction agent
- 4 Hexane is widely recognized as a **neurotoxic** substance, is classified as a **reproductive toxicant** and is toxic for the aquatic environment. It is also suspected to be an endocrine disruptor
- 5 Even if the solvent is recycled after oilseed extraction, unavoidable residues are found in all foodstuffs containing vegetable oils and plant-based proteins, leading to **hexane exposure in the general population**

Despite the known harmful effects of hexane on the environment and human health, it must be noted that hexane extraction is today essential to feed the world as the global production of vegetable oil and plant proteins relies on this technique which has been optimized since the 1950s in large industrial processing facilities.

Removing hexane from the food chain with minimal costs for the industry requires alternative solvents that can be used in the existing industrial infrastructure.





Eco-extraction techniques

Eco-extraction techniques are being developed to bring **new, safe and environmental-friendly alternatives** to hexane, while demonstrating similarly high efficiency in oil extraction performance.

Supercritical CO₂

- The use of supercritical fluids as solvents to extract vegetable oil is generally described in the literature.
- Supercritical CO₂ is a commonly used eco-extraction method to separate various high value components from a plant using carbon dioxide - a natural and food-grade gas that is found in soft drinks for example.
- Because it needs high pressure conditions, supercritical CO₂ extraction does not operate in continuous mode and is used for specific extraction processes such as tea decaffeination or hop processing.

Aqueous extraction and enzyme-assisted processing

- Aqueous extraction processing has been widely investigated during the past decade as an environmentally-friendly approach for extracting oil from oilseeds.
- This technique is less efficient in achieving high oil yields due to the very low affinity of water with lipids. Performances can be improved by using specific enzymes to increase oil recovery, but operating costs are higher as a result.
- This method is suitable for extracting lipidic ingredients for high added-value applications (cosmetics,...) but has no future in the processing of commodity oilseeds as protein meals cannot be fully commercialized due to stability issues.



Bio-based solvents

- **Safer solvents derived from renewable biomass**, such as ethanol or isopropanol, have been tested to replace hexane. But alcohols do not dissolve lipids well.
- **The bio-solvent 2-methyloxolane** is safe alternative to hexane. This innovative extraction solvent is made from agricultural waste (sugar cane bagasse) and marketed as **EcoXtract®**. Compared to hexane, it has a higher affinity for triglycerides, phospholipids, tocopherols and sterols.



Most important, EcoXtract® can be used in existing commercial-scale hexane extraction units using the same extraction and solvent recovery equipment. It appears to be the most suitable alternative solvent for changing the game in large-scale in oilseeds processing.

EcoXtract®:

The only scalable solution
for the eco-extraction of vegetable
oils and plant-based proteins

EcoXtract® consistently delivers outstanding performance in oil extraction. It has demonstrated similar extraction yields to hexane in the laboratory and at pilot and small commercial scales. EcoXtract® technology is now operating at industrial scale and **blazes the trail for the replacement of petrochemicals in the extraction of vegetable oil and plant-based proteins.**



- The biomass is prepared and mixed with EcoXtract®. With its high affinity for lipids, the bio-based solvent **solubilizes** the lipids in a fluid called miscella (liquid containing EcoXtract® and crude oil).
- The miscella is then heated to 71-80 °C to separate EcoXtract® from the crude oil by simple evaporation.
- The remaining biomass is filtered out, desolventized and further processed into plant proteins for food or feed applications.
- EcoXtract® is then recovered for reuse.



Biomass selection

Commodities

- ♦ Rapeseed
- ♦ Soybean
- ♦ Sunflower

Specialties

- ♦ Almond
- ♦ Grapeseed
- ♦ Linseed



Preparation

Prepared Biomass

EcoXtract®



Eco-extraction

Plant proteins

Crude oil

EcoXtract®

Oil-based ingredients
(lecithins, polyphenols...)

Refined oil

EcoXtract® provides a hexane-free processing solution:



Food

Edible oils

Soy-based proteins (soybean flour, white flakes, isolates, concentrates)

Plant-based proteins from canola, sunflower, hemp, linseed,...

Lecithins, tocopherols, polyphenols...



Feed

Soybean, rapeseed or sunflower meal (low-fat <1%)

Feed meals from various oilseeds

Protein concentrates (SPC,...)

Vegetable oils



Personal care

Vegetable oils

Marine/algal oils

Lecithins, tocopherols, polyphenols...

Lipophilic bio-actives compounds



Why choose EcoXtract®?



Innovative bio-based solution

Sustainable sourcing

- EcoXtract® is derived from hemicellulose contained in sugarcane bagasse, a by-product of sugar production. EcoXtract® upcycles low-value **agricultural co-product** from the food industry and so its production does not require the cultivation of additional agricultural land.
- EcoXtract® is certified as a 100% bio-based product by the USDA BioPreferred scheme.
- EcoXtract® is **naturally** present in edible plants. It is also produced *in vivo* by a yeast present on our skin: *Malassezia furfur*.



Providing undisputable market differentiation

- The removal of hexane from the processing pipeline while maintaining a high-level of performance extraction and affordability of final products is a large opportunity for innovation and differentiation in the production of edible oils and related plant-based proteins.
- There is growing demand for clean-label products and some food manufacturers are starting to claim the hexane-free properties of their products.
- EcoXtract® allows the efficient, safe and sustainable production of **hexane-free** ingredients for food, feed and personal care applications.



A safe solution reducing carbon footprint of extraction processes

For human and animal health

- Scientifically proven as safe for humans and animals: its residue has no impact on health. Toxicologists have concluded that EcoXtract® is a low toxicity product, in the same category as ethanol according to pharmaceutical guidelines.
- It protects the **health of the workers in the factories** as it does not cause occupational diseases (which is the main issue of hexane).

For the environment

- EcoXtract® is an eco-responsible solution fully aligned with the circular economy system. It is **recyclable** without loss of properties and directly **reusable** without loss of function.
- It is 100% biodegradable and reduces carbon footprint of processes.
- EcoXtract® manufacturing process shows a carbon footprint reduction of 90% (cradle-to-gate) compared to standard petrochemical solvents.



Efficiency and Competitiveness

- EcoXtract® **maximises oil extraction yield**. The level of residual oil remaining in the meal after extraction is equivalent to or even lower than hexane-based extraction.
- EcoXtract® appears to be **competitive** when compared with all existing solutions that do not involve petrochemical solvents as it can be implemented directly in existing oilseeds processing units using hexane.



Compatible with a CSR policy

EcoXtract® is an **ethical** product. From sourcing to the final product, it respects human welfare, animals and the environment. EcoXtract® has recently obtained the **Solar Impulse Label** selecting efficient, clean and profitable solutions with a positive impact on environment and quality of life.



About Pennakem

The development of EcoXtract® technical innovation is supported by Minafin Group, in particular through the expertise and capabilities of its subsidiary Pennakem in **sustainable and renewable chemistry**.



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