Activated carbon is used in edible oil bleaching to remove contaminants prior to consumption. Rose Hales looks at how the product is made and activated, who is producing it, and how it works

Activated carbon

Activated carbon or activated charcoal is used during the deodorising and bleaching process of edible oil preparation. It employs physical adsorption as a method to purify vegetable oils and make them suitable for consumption.

Edible oils can be contaminated with natural and anthropogenic compounds, some of which are carcinogenic, including polycyclic aromatic hydrocarbons (PAH), dioxins and polychlorinated biphenyls (PCB), heavy poly neleic aromatics (HPNA), pesticides and herbicides. Oils can become contaminated through environmental pollution, drying with combustion gases, associated smoke drying or contamination of transport containers.

Activated carbon is employed alongside bleaching earths (see *'Salt of the earth', OFI June 2016*) for refining and decolourisation of oil. According to activated carbon producer Cabot Norit Activated Carbon, although activated bleaching earths have improved in quality and are now capable of most of the bleaching, activated carbon is useful for high concentrations of pigments – such as chlorophylls, xanthophylls and carotene – to improve the bleaching effect or support the thermal decomposition of pigments during deodorisation.

Activated carbon is produced from carbonaceous sources, which can include coal, coconuts, nutshells, peat, wood and lignite. The source can be any organic material with a high carbon content.

The organic raw material is physically modified and thermally decomposed in a furnace to produce the activated carbon. The final product is highly porous. One gramme of activated carbon has a surface area of at least 500-1,500m^2, according to activated carbon solutions provider Haycarb. The company says that a single spoon of activated carbon could easily equate to the surface area of a football field.

Contaminants adhere to the carbon's large surface area, removing them from the end product.

Properties

Activated carbon products are characterised by their activity and physical properties. Pore size distribution is an important activity property that indicates the carbon's performance for removing contaminants from a liquid. According to TIGG – a supplier of activated carbon adsorption systems, equipment and media – there are three pore size regions:

- Micropore region – less than 100 angstroms (a unit of length equal to one ten-billionth of a metre)
- Mesopore region – between 100 and 1,000 angstroms
- Macropore region – more than 1,000 angstroms

In addition to this, activated carbons produced from different raw materials have distinctive properties and characteristics that make each suitable for specific types of purification. These characteristics include pore diameter, hardness, density, iodine content and ash content. Table 1 (*following page*) provides examples of the varying properties achieved through using different raw materials.

Pore diameter determines whether a certain kind of activated carbon can be used for general dechlorination and a wide variety of organic contaminants. Such variants include bituminous coal activated carbon. If the carbon has greater microporosity, such as that made from coconut, it may be better suited for removing low concentrations of contaminants. Pore diameter is deduced from the iodine number, ,with a higher number correlating with a larger surface area. A large surface area is more suitable for weakly absorbed organic contaminants. This is the most fundamental consideration when choosing an activated carbon for any application.

Hard carbon may be necessary if the purification process is more vigorous, such as backwashing. Density affects how much carbon can fit into a container or processor, and incorrect use will affect performance. Ash content is mainly important for water treatment, as a high ash content may not be suitable for certain water purification processes where liberated ash will cloud the water. Finally, the molasses efficiency rate measures an activated carbon's aptitude to absorb large molecules.

According to activated carbon producer Haycarb, activated carbon with optimum iodine, methylene blue and molasses figures – with demonstrated colour and smell removal capabilities and consistency – should be used for edible oil applications. The company recommends these properties for oils including coconut, olive, fish, sunflower, rapeseed, palm/palm kernel and soyabean.

How is it activated?

When something has been 'activated', this means it has been processed to increase the internal microporosity of the original material. This is done by removing individual carbon atoms and creating tiny holes in the material, which adsorb unwanted molecules. According to Hugh McLauglin in *Biofuels Digest*, "the key to activated carbon is that it is optimised for a specific adsorption application and the adsorption capacity is packed into as dense a material as possible to minimise the


PHOTO: SHOWCAKE/ADOBE STOCK

volume of adsorbent necessary."

Carbonaceous raw materials are activated either using chemical activation or high temperature steam activated (HTSA)/physical mechanisms.

CHEMICAL

According to B. Viswanathan, P. Indra Neel and T. K. Varadarajan in their book '*Methods of Activation and Specific Applications of Carbon Materials*', chemical activation is a single step process where chemical agents are used to activate organic carbon. The method utilises a solid activating agent (such as an alkali), substances that contain alkaline earth metals, or some acids. The agents used dehydrate the carbon and cause pyrolytic decomposition, which inhibits the formation of tar and enhances the carbon yield.

Chemical activation takes place at a lower temperature than physical activation, which results in a better developed porous structure. However, drawbacks of the method include the need to wash the final product of residual inorganic materials, which can cause pollution problems.

PHYSICAL

In the same book, '*Methods of Activation and Specific Applications of Carbon Materials*', the authors describe how physical activation is a two-step process.

This involves carbonising the raw material in an inert atmosphere and then activating the resulting char with a carbon gasification reactant, such as CO_2, steam or air.

The physical activation reaction happens between the carbon atom and the oxidising gas, which causes the creation of pores as different parts of the char structure react faster than others.

The process uses gaseous activation agents and therefore does not produce wastewater. For this reason, it is considered to be environmentally friendly. However, due to the length of time and energy needed, the method is not ideal. In addition, a large quantity of the internal carbon mass is destroyed to obtain the pore structure, so the yields are limited, especially in comparison to chemical activation.

Physically and chemically activated carbons are available in three forms: granular (GAC), powdered (PAC) and extruded carbon.

- GAC: irregularly shaped, formed through milling and sieving. Sizes range in diameter between 0.2mm to 5mm. They are hard and longlasting, clean to handle and purify large quantities of oil or gas to a consistent quality. GAC can be reactivated and reused.
- PAC: have a particle size distribution between 5-150 angstroms. PAC have relatively low processing costs and can be used flexibly as the dosage can easily be increased or decreased. Edible oils are mainly purified using PAC and always alongside bleaching earths (apart from fish oils). PAC cannot be reactivated.
- Extruded: cylindrical pellets used in heavy-duty applications.

How does it work?

Activated carbon removes contaminants from liquid oil through the process of physical adsorption. According to John Sherbondy and John Mickler at TIGG, activated carbon's large surface area works through several forces to attract other molecules inside it. Sherbondy and Mickler compare this to the gravitational force: "Contaminants ... are adsorbed to the surface of the carbon from a solution as a result of differences in adsorbate concentration in the solution and in the carbon pores".

All molecules apply attraction forces, and these forces are even greater on the surface of a solid – which the internal porousness of activated carbon utilises to its advantage. Contaminants in the solution being purified adhere to the carbon because the attraction forces on the surface of the carbon are stronger than those that keep them suspended within the solution.

TABLE 1: TYPICAL ACTIVATED CARBON PROPERTIES FROM DIFFERENT RAW MATERIALS

	Coconut	Bituminous	Lignite
Iodine number	1,100	950	600
Abrasion number	85	75	60
Bulk density as packed in column ibs/ft3	25	25	23
Ash %	3.0	6.7	20.1

SOURCE: TRIGG

Companies

Cabot Norit Activated Carbon says it is the world's largest and most experienced producer of activated carbon. It purchased Norit NV (previously the largest producer) in July 2012 and formed Cabot Norit Activated Carbon, based in Amersfoort in the Netherlands (although Carb Corp is headquartered in the USA).

An article in *Chemie Magazine* in February 2016 quoted Cabot Norit Activated Carbon's director of global technology and marketing, Jim Makuc, as saying: "On the one hand we are conducting research into new resources, to convert them into activated carbon. On the other hand we are developing products for customers with exactly the right pore structure and we supply the usage data." The future is looking bright for the company as it extends its range of activated carbon products.

Jacobi Carbons says it is one of the world's three largest activated carbon companies and ships over 100,000 tonnes of activated carbon per year. It is also the largest manufacturer of coconut shell-based activated carbon. It has 20 carbon manufacturing facilities and five carbon reactivation plants worldwide.

Haycarb PLC is a leading player in coconut-shell activated carbon and global industry. It has six manufacturing plants acorss three countries, and an annual production capacity of 40,000 tonnes. It had an annual turnover of US$80M in 2015/16. Haycarb markets activated carbon directly to European consumers through its subsidiary Eurocarb.

The Activated Carbon Producers Association (ACPA) represents the European activated carbon industry and in June 2016 it was composed of 10 members. These are CarboTech AC, CECA, Chemviron Carbon, Desotect, Donau Carbon, Eurocarb, Cabot Norit Activated Carbon, Jacobi, SICAV and Silcarbon. Chemviron Carbon purchased CECA at the end of 2016, bringing the member companies down to nine.

Overview of the market

The activated carbon market is mature and around 1M tonnes is produced annually, according to Hugh McLaughlin, writing for *Biofuels Digest* in October last year. It has been growing steadily for the past 50 years, as specific purification processes have been developed in some industries. Most production of the material takes place in tropical and Asian countries. The majority of the product is then exported to Europe and North America. According to McLaughlin, the market is dominated by a relatively small number of international companies with both production and marketing capabilities.

A report published by Ceskaa, titled '*Global Activated Carbon Market: 2016-2021*', projects that the global value market will grow from US$2.7bn in 2015 to US$2.9bn in 2016. The market's growth is expected to continue, and in 2021 it will be worth approximately US$5.1bn. This estimate covers the whole activated carbon market, of which activated carbon for the removal of impurities from edible oil is one part. ●

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