Renewable in more ways than one: hemp returns to UK farming

Hemp loves the UK weather, and has a mind-boggling variety of uses. Could this old plant become our new best friend?

Martha Simpson-Holley and Ian Law

National Non-Foods Crop Centre, UK

Title image: *Cannabis sativa* plants growing near Driffield, East Yorkshire. Image credit: NNFCC

Walking through farmland near Driffield in East Yorkshire, fields stretch away in all directions, full of barley, wheat, and cattle. However, tucked away here in the Yorkshire countryside are a few hectares of a crop which, although once grown in the UK by royal mandate, is now a somewhat startling sight.

Cannabis sativa, or hemp, is a tall herbaceous annual, with strong stems, a deep tap root and an abundance of distinctive spiky leaves (Figure 1). The plant forms part of a recent enterprise in UK farming: it is a 'non-food crop'. The non-food crops initiative advocates the cultivation of crops that can be processed into biofuels, construction materials, packaging, speciality chemicals and pharmaceutical products. This allows farmers to diversify their business and make money from expanding markets in these sectors.

In addition, these crops form a crucial part of a renewable and sustainable society: renewable because crops can be harvested and re-sown, and sustainable because the carbon emissions produced during their downstream use are reabsorbed by new plant growth, so the cycle can continue indefinitely. By contrast, non-renewable sources of fuel such as coal and oil are dug up and then burned, thereby throwing all their stored carbon back into the atmosphere.

As a member of the non-food crops portfolio, which includes stalwarts such as oilseed rape and newer crops like miscanthus and borage, hemp is a bit of a star act. The plant seems to embody the expression 'multi-tasking', with each of its physical components having several uses in the non-food crops sector (Figure 2).

The stems of the hemp plant contain cellulose fibres (Figure 1C), which have multiple ancient and modern uses: in textiles, construction, biocomposites and paper manufacture. They were once used to make canvas for the sails of Elizabeth I's Navy, and they now provide horse-bedding in Elizabeth II's stables. Bast fibres are derived from the phloem of the stem - the tissue which transports sugars through the plant. These fibres are stronger than cotton, and can be grown organically: by contrast, around £1.5 billion is spent on pesticides for cotton cultivation worldwide each year (figures from the Pesticides Action Network). When mixed with resins, hemp fibres can be moulded into biocomposite panels used in the doors and roofs of BMWs and Mercedes. These panels are stronger and lighter than their synthetic counterparts.

'Hemp-crete' is a concrete substitute made from hemp hurds (short fibres from the core of the stem) mixed with a lime binder and water: it has significant advantages over concrete. It is breathable, fire resistant and a good insulator, and can be used as a fill around a timber frame, as a finishing plaster, or to build free-standing walls. Concrete manufacture emits 1.3kg CO_2 per kilogram produced. In contrast, hemp plants absorb 1.7kg of atmospheric CO_2 for every kilo of dry hemp material. Therefore, building with hemp-crete reduces atmospheric CO_2.

So far, hemp-crete has been used in the construction of a new distribution centre by Adnams brewery in Suffolk, and a similar material has been successfully used to build houses in a Suffolk Housing Authority project. There is an ongoing research project monitoring the hemp houses alongside conventional homes of the same age and design. The hemp houses show superior thermal properties to the conventional homes: the exterior walls of the conventional homes were 4-6°C warmer than those of the hemp houses, indicating that loss of heat through the conventional brick walls was considerably greater than that through the hemp-crete walls (Figure 3).

The construction of the hemp houses was more expensive: however, this was largely due to a lack of experience of building with this material, and a lack of specialist equipment. In time, economies of scale should significantly reduce costs for hemp-crete construction.

Figure 1. Photographs of hemp plants in the field. A) Finola variety dual-use hemp grows to around 1.5m tall and is used principally for seed production, but can also be used for fibre. B) Fibre hemp varieties grow to between 2 and 4m high. The crop is cut and left on the ground (retted) to free the fibres. C) 'Green' hemp fibres obtained after retting and initial processing of the crop.

Figure 2. Uses of different parts of the *Cannabis sativa* plant.

Hemp and its uses have outlasted civilisations, spanning thousands of years. Artefacts indicating the use of hemp in cloth, buildings and rope have been found which date back to pre-Christian times. During the world wars, hemp was a valuable fibre crop, even prompting a propagandist promotional film, 'Hemp for Victory' (1942) in the USA. More recently hemp has been sidelined, due to legal restrictions on its growth and the use of alternative man-made materials.

Some of the legal restraints on the growth of industrial hemp have been relaxed in Europe and Canada (although not in the USA). Cultivation of low-THC hemp varieties in the UK requires a home office licence. Proof of the seed type planted must be sent to Defra's Rural Payments Agency and plants from 20% of the area grown may be tested for THC (delta-9-tetrahydrocannabinol, the main psychoactive substance found in hemp). EC legislation specifies that flowers from industrial hemp must contain less than 0.2% THC.

Cannabis as a drug was reclassified in the UK from Class B (which includes, for example, amphetamines) to Class C (which includes drugs such as Valium) in January 2004. Thus, although the cannabis drug remains an illegal substance, the cultivation of the *Cannabis sativa* plant is no longer necessarily an illegal activity. Hemp can help to fulfil the current demand for sustainable, renewable materials in multiple sectors. If supply chains can be developed, hemp may soon return to mainstream agriculture.

The agronomy of the hemp crop favours modern farming methods: hemp can be grown with minimal pesticides, and its large canopy and rapid growth make it difficult for weeds to thrive. Hemp plants are frost tolerant and the tap root can help to condition heavy soils. Industrial hemp varieties require fairly high nitrogen inputs in the form of fertilisers in order to reach their substantial heights (2-4m, Figure 1B-C). However, Finola, a new dual-use variety bred by Springdale Crop Synergies (based in Driffield, East Yorkshire), is shorter and therefore has a lower demand for fertiliser and can be harvested using a conventional combine harvester (Figure 1A). The Finola crop can be grown for both seed and fibre applications.

Pharmaceutical uses of *Cannabis sativa* extracts

Cannabis sativa contains a range of compounds called cannabinoids, many of which are pharmacologically active (Di Marzo and De Petrocellis, 2006). In industrial varieties of hemp, the pharmacologically active cannabinoids are expressed at extremely low levels (~0.05%). The most abundant cannabinoid in marijuana varieties of hemp is delta-9-tetrahydrocannabinol (THC), which is the main psychotropic agent in marijuana. The molecular structure of THC was determined in 1964, allowing THC to be synthesised and its binding sites to be found in the brain.

Binding studies showed that THC localises to the basal ganglia and cerebellum, regions of the brain which govern movement, as well as the cerebral cortex, which plays a central role in many brain functions. Neurons in these regions express a THC receptor, CB1, on their surface. CB1 receptors are clustered on the membrane of neurons just before the synaptic bulb, the site where neurons connect with one another via chemical neurotransmitters. When THC binds to CB1, a G-protein-mediated signalling cascade is triggered inside the cell. This prevents the neuron from releasing neurotransmitters across the synaptic cleft to its neighbour. Without the release of these chemical messengers, neuronal signals are stopped in their tracks. So THC binding to CB1 changes the ability of neurons in the brain to talk to one another.

In China in the first century AD, marijuana was recommended for over 100 ailments. However, the approval and use of any drug in modern society requires that it be scientifically defined and tested in clinical trials. The discovery of THC and its receptor CB1 allowed this process to begin for cannabinoids. A UK company, GW Pharmaceuticals, has developed a pharmaceutical-grade *Cannabis sativa* extract consisting of two cannabinoids, THC and cannabidiol (CBD), dissolved in an ethanol-based medium. The drug, Sativex®, is not yet licensed in Europe but has an 'approval with conditions' in Canada for use as an adjunctive treatment for the symptomatic relief of neuropathic pain in Multiple Sclerosis (MS). GW Pharmaceuticals has also filed a regulatory submission in selected European countries for Sativex®, to be used for the symptomatic relief of spasticity in people with MS.

It is of note that the drug is not synthetic, but a standardised pharmaceutical extract of the active components of the *Cannabis* plant. There is evidence that CBD acts synergistically with THC, abrogating side effects such as feelings of anxiety and intoxication: therefore the plant extract, which contains both cannabinoids, is preferable to THC alone. The drug is administered as an oro-mucosal spray. Clinical trials are being conducted for the use of the drug in the treatment of other conditions, including neuropathic pain and cancer pain. In all clinical trials to date, the side effects of Sativex® have been found to be minor, and intoxication from the drug has not been found to be significant at doses required for its therapeutic effects. Although not a miracle cure, the Company considers that Sativex® could provide a user-friendly, versatile source of relief for a range of neuropathological symptoms.

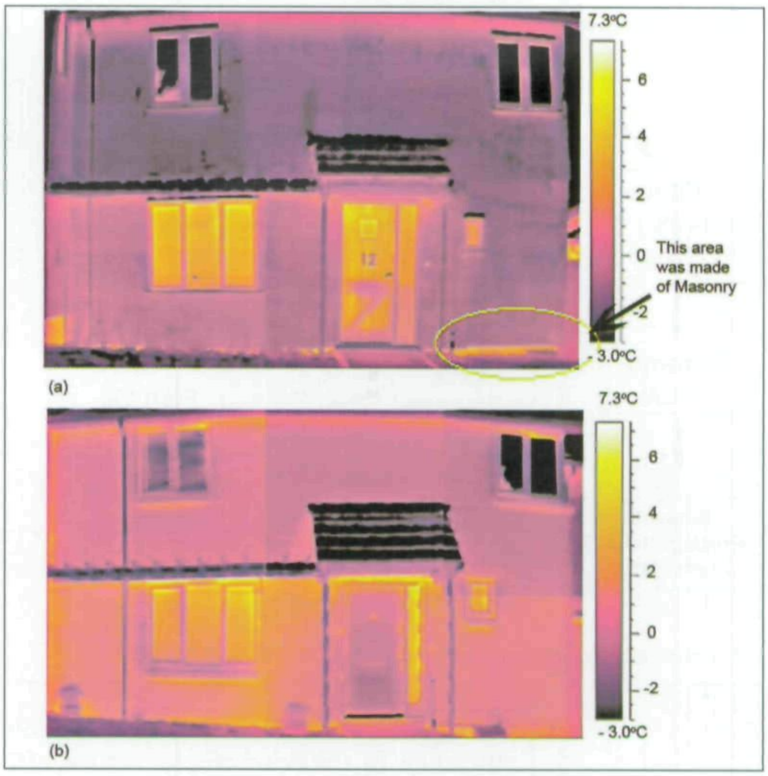


Figure 3. Thermographic images taken of houses built of a) hemp-crete and b) brick masonry. The darker purple colour of the hemp house indicates 3-5 °C less heat loss than the brick house. Source: www.suffolkhousing.org/pixs/Thermo%20report.pdf.

Hemp in nutrition

Hemp seeds contain an edible oil, rich in essential polyunsaturated fatty acids (PUFAs) and Vitamin E, and low in saturated fats. PUFAs are fatty acids which contain multiple double carbon-carbon bonds, and are better for health than the saturated acids found in animal fats. There are two principal families of PUFAs, classified by the position of the first double bond: omega-6 and omega-3. Omega-3 oils have recently been associated with a range of beneficial health effects (DeFilippis and Sperling, 2006).

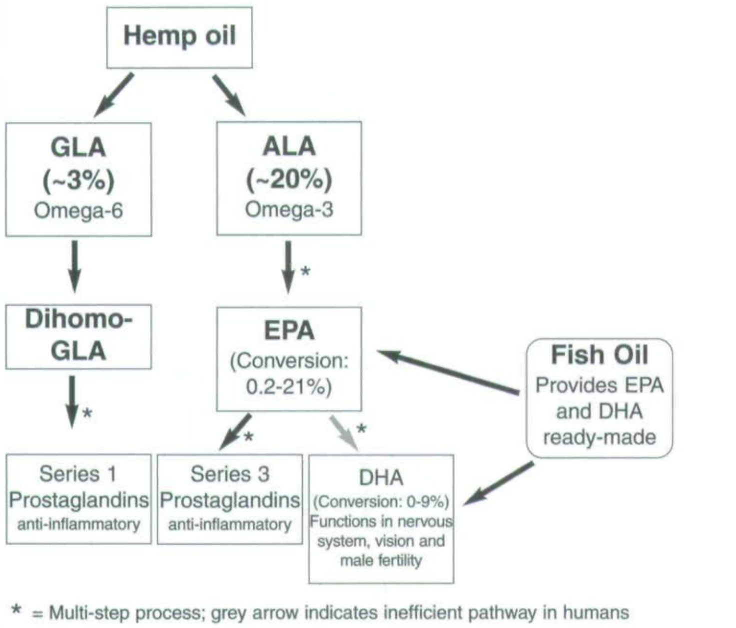
There is a huge amount of publicity surrounding these health benefits, and hemp oil, which contains around 20% α-Linolenic acid (ALA) – an omega-3 PUFA – is marketed both as a culinary oil and a nutritional supplement. Hemp oil also contains ~3% γ-Linolenic acid (GLA), which is also found in higher proportions in evening primrose oil (~9%) and borage oil (~23%). GLA is an omega-6 PUFA, and is associated with a further set of beneficial effects on human health.

The roles of essential PUFAs such as ALA and GLA and their metabolites are diverse: they are building blocks for cell membranes, and have important roles in the nervous and immune systems. These roles are not yet fully understood, but clinical studies have suggested that ALA and GLA can have beneficial effects in the treatment of several chronic diseases (DeFilippis and Sperling, 2006). Such clinical findings should be interpreted with caution, especially in the current climate in which nutritional supplements are aggressively promoted and are increasingly self-prescribed by health conscious consumers.

α-Linolenic Acid

ALA stands at the head of a metabolic pathway shown in a simplified form in Box 1. Following consumption, ALA can be converted into eicosapentaenoic acid (EPA), a long chain omega-3 fatty acid. EPA can subsequently be converted to docosahexaenoic acid (DHA): however, in the majority of studies this conversion has

Box 1: Metabolism of ALA and GLA.



been found to take place with negligible efficiency. In the scientific literature, efficiencies of conversion of between 0.2-21% (ALA to EPA) and 0-9% (ALA to DHA) have been recorded (DeFilippis and Sperling, 2006). Intake of ALA above 4.5g/day leads to increases in EPA of 33-370%, and the relationship between ALA intake and EPA levels is a linear one. Thus, dietary ALA can provide significant amounts of EPA (Burdge and Calder, 2005). By contrast, in studies using elevated dietary ALA, DHA levels consistently fail to increase: ALA is therefore not considered to be a significant dietary precursor for DHA.

The downstream products of the ALA pathway are numerous, and have roles in the immune system, nervous system and in the functioning of cell membranes. EPA is a precursor for the prostaglandin 3 series of molecules, which have anti-inflammatory activity. It is important to note that these metabolic pathways exist as part of a large network which is governed by the levels and activities of many different fatty acids, enzymes, and other regulatory molecules. Some pathways are pro-inflammatory, others are anti-inflammatory, and others can have either effect. It is not possible to flick a switch by consuming more of one type of molecule, but the accumulating data on omega-3 fatty acids imply that pathways can be up- and down-regulated by the presence of differing levels of ALA or EPA+DHA.

An important alternative source of omega-3 fatty acids is fish oil, derived from the tissues of fish such as salmon, mackerel and tuna. Fish oil contains EPA and DHA 'ready-made', and therefore provides the most effective way of directly influencing levels of these molecules. Given the low conversion rate of ALA to DHA, fish appears to be the only significant source of DHA in the human diet, and cannot be substituted by hemp oil or other plant oils. An alternative source of DHA is marine algae, which can be taken as a nutritional supplement.

Increased ALA levels have been correlated with a reduced incidence of cardiac disease (coronary artery disease, myocardial infarction) and stroke (Kris-Etherton *et al*, 2002). Fish oil supplementation has been used more frequently than ALA in clinical studies, and is associated with a significant reduction in cardiac arrest and coronary artery disease. Fish oil is also beneficially linked to other conditions including arthritis and stroke. Low DHA levels have been correlated with increased incidences of Alzheimer's disease, depression and bipolar disorder. In animal studies, reduction of dietary DHA led to impaired vision and mental development in early life (Burdge and Calder, 2005).

In most cases, the evidence for omega-3-associated health effects requires confirmation through large scale randomised controlled trials. In addition, the amount of evidence for the beneficial effects of EPA and DHA derived from fish oil make hemp oil a relatively ineffective substitute for fish oil, at the quantities used in nutritional supplements. However, such supplements may be useful in cases in which consumers or patients are opposed to the use of fish. As a dietary component, hemp oil can provide a significant source of ALA and can lead to a significant increase in EPA levels. Extrapolating from published conversion rates of ALA to EPA, replacement of vegetable oils with hemp oil in an average Western diet could lead to the production of more daily EPA than is found in many fish oil supplements (see Appendix). It is worth noting that fish stocks are in some cases becoming depleted, and therefore finding a sustainable source of EPA and DHA is of interest, with DHA providing the greatest challenge.

γ-Linolenic Acid (GLA)

In addition to omega-3 fatty acids, hemp seed oil contains ~3% GLA, an omega-6 PUFA with claimed anti-inflammatory effects (Fan and Chapkin, 1998, Box 1). GLA is found in higher concentrations in a few other seed oils, notably evening primrose (*Oenothera* spp.) and borage (*Borago officinalis* L.). GLA can be produced in the body from linoleic acid, an omega-6 fatty acid which is abundant in the Western diet. However, the enzyme responsible for the production of GLA from linoleic acid is rate-limiting, and consumption of GLA is therefore desirable to obtain anti-inflammatory effects. The enzyme involved is also required for ALA metabolism to EPA, perhaps explaining the limited conversion observed in most studies. In addition to the GLA pathway shown in Box 1, further processing of GLA can lead to the production of arachidonic acid (AA), which is a precursor for various pro-inflammatory molecules. These pathways are not shown here since there is no evidence that GLA ingestion upregulates the inflammatory response when ingested as part of a Western diet.

GLA has been shown experimentally to be effective in the reduction of various symptoms associated with rheumatoid arthritis (Fan and Chapkin, 1998). There is also some evidence of beneficial effects in the treatment of pre-menstrual syndrome, atopic eczema, osteoporosis, cardiovascular disease and asthma. Evening primrose oil was licensed in the UK for the treatment of mastalgia (an aspect of PMS) and atopic eczema, but was withdrawn following an accumulation of evidence indicating insufficient efficacy. GLA has also been shown experimentally to have anti-proliferative properties, reducing motility and invasiveness of colon carcinoma cells *in vitro*, and preventing cancer progression in several animal models (Fan and Chapkin, 1998).

Growing the future

In terms of its versatility and agronomy, hemp is an outstanding example of a useful non-food crop. Its functions are being exploited by companies from the pharmaceuticals, construction, textiles, animal bedding and nutritional sectors. However, it is not widely grown in the UK and will have to overcome economic, legal and strategic challenges to become a widespread crop. These can be overcome in ways which are common to other non-food crops and their applications.

First, legislation which encourages the use of renewable resources can help to establish markets for non-food crop applications. Second, consumer demand can stimulate the use of renewable materials. Public awareness campaigns and advertising therefore play an important role, as can the adoption of non-food crop products by major high street outlets. There is significant consumer demand for organic fibres and nutritional supplements, and the market for local, rurally-sourced UK products is also growing. With the right combination of legislation, investment and public awareness, hemp could become a more common sight in the British rural landscape. For now though it remains an attractive – though perhaps surprising – sight in Yorkshire.

Acknowledgements

The authors would like to acknowledge Dr Peter Lapinskas for helpful discussions regarding the nutritional benefits of hemp, and GW Pharmaceuticals for useful advice regarding the pharmaceutical properties of *Cannabis sativa*.

References

Burdge G C and Calder P C (2005) Conversion of α-Linolenic acid to longer chain polyunsaturated fatty acids in human adults. *Reproduction Nutrition Development*, **45**, 581-597

DeFilippis A P and Sperling L S (2006) Understanding omega-3's. *American Heart Journal*, **151**, 564-570

Di Marzo V and De Petrocellis L (2006) Plant, synthetic and endogenous cannabinoids in medicine. *Annual Review of Medicine*, **57**, 553-574

Fan Y and Chapkin R S (1998) Importance of dietary γ-Linolenic acid in human health and nutrition. *Journal of Nutrition*, **128**, 1411-1414

Kris-Etherton P M, Harris W S and Appel L J (2002) Fish consumption, fish oil, omega-3 fatty acids and cardiovascular disease. *Circulation*, **106**, 2747-2757

Further reading

National Non-Food Crops Centre Hemp fact sheet: www.nnfcc.co.uk

GW Pharmaceuticals: www.gwpharm.com

Medline Plus: Information on Omega 3 fatty acids. www.nlm.nih.gov/medlineplus/druginfo/natural/patient-fishoil.html

Springdale Crop Synergies: www.springdale-group.com

Hemp-crete: www.lhoist.co.uk/tradical/hemp-lime.html, www.limetechnology.co.uk

Hemp-crete homes project: www.suffolkhousing.org/pages/hempage.html

Martha Simpson-Holley is a technical science writer for the National Non-Food Crops Centre, and has a background in academic biological research. **Ian Law** is a technology transfer manager for the National Non-Food Crops Centre and has a background in the pharmaceutical and nutriceuticals industry. Email: i.law@nnfcc.co.uk NNFCC, Biocentre, York Science Park, Innovation Way, Heslington, York, YO10 5DG.

Appendix: Provision of EPA by dietary hemp oil

- Average vegetable oil consumption per capita, 2000 (USA): 15.9kg (cooking and salad oils, source: www.usda.gov).
- If 50% is used for low temperature applications (pouring, spreads, salad dressings), replacement with hemp oil will lead to 7.9kg consumption/annum: 21.6g/day
- Assuming average content of 20% ALA in hemp oil: 4.32g/day
- Assuming average conversion of 15% to EPA: 648mg/day
- Typical super-strength daily fish oil supplement contains 330mg EPA/day