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Current and Potential Market Opportunities for Hempseed and Fibre in Scotland

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Final Report

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Executive Summary

Hemp is one of the world's oldest economic plants. Industrial hemp, by law, must contain no more than 0.2 per cent of Δ^9 THC on a dry weight basis in the UK. The crop originated from central Asia and its cultivation can be dated as far back as 3000 years ago. In Scotland, direct and surrogate evidence shows that hemp cultivation can be traced as far back as the eleventh century. It was widely used in the UK until the 20th Century, when cheap and abundant jute and cotton made hemp uncompetitive. Each part of the plant has economic value; the flower/leaves, stem, seeds, and roots.

With the exception of a few countries, cultivation of industrial hemp is illegal. The United Nations comprehensive "Single Convention" of 1961 classifies industrial hemp under illicit drugs. In Europe, hemp extract (i.e. Cannabidiol or CBD) is not harmonized under the European Union (EU) law and it is classified under novel foods. In Scotland (UK), the Misuse of Drugs Act 1971, makes it unlawful to possess, import, export, supply, and cultivate any plant of the genus Cannabis except under the Home Office license.

This report is part of a Scottish Environment, Food and Agriculture Research Institutes (SEFARI) fellowship scheme aiming to identify current and potential market opportunities and describe the supply chain for hempseed and fibre in Scotland. By adopting desk-based research, primary and secondary data analysis, the first part of the report aims to summarize, collate, and synthesize results from existing research on hemp production worldwide. It gathers online data from published scientific and grey literature, and government published data such as FAOSTATS, EUROSTAT, and HMRC data. The second part of the report relies on secondary data from the Global New Product Database (GNPD) which contains information on hemp-based products launched by major retail supermarkets and manufacturers from 1997 to 2021 in Europe and North America. This information was used to assess trends in new

product development in the hemp market. The final part of the report analyses the supply chains for hempseed and fibre in Scotland using primary data collect from farmers in Aberdeen, Aberdeenshire, and along the Scottish borders. The information obtained was used to assess the strength, weakness, opportunities and threats faced by the sector. The report concluded with strong and time bound recommendations necessary to advance the Scottish hemp sector.

Our findings show that world production of industrial hemp has been on the decline since the 1960s due to an unfavourable political climate regarding the cultivation and use of the crop. For instance, the production of hemp fibre fell from 368 thousand tonnes (highest) in 1966 to 83 thousand tonnes (lowest) in 1990 and rose again to 305 thousand tonnes in 2017. Also, the production of hempseed fell from 103 thousand tonnes (highest) in 1966 to 2.9 thousand tonnes (lowest) in 2014.

Globally, China, France, Netherlands, and Poland are the biggest producers of hemp fibre whilst Russia, Chile, Ukraine and Iran are the biggest producers of hempseed. Similarly, Europe, France, Poland, and Netherlands are the biggest producers of hemp in terms of tonnage and area allocated to hemp production. There are no official statistics on hemp production in the UK or Scotland. However, the HMRC has trade data which shows that the UK is a net importer of hempseed and hemp fibre. Major suppliers of hempseed to the UK are the Netherlands, France, Spain, and China whilst major countries importing UK produced hempseeds are France, Germany, India and Netherlands. Also, major suppliers of hemp fibre to the UK are Lithuania, Netherlands, Australia, and Senegal. The UK also supplies hemp fibre to France, Australia, France and UAE.

The potential markets for both hempseed and fibre have the possibility to be important for Scotland while also providing environmental and health benefits. Hemp can sequester more carbon dioxide than is emitted during the production process; having a long tap root, it is able

to loosen the soil and improve biodiversity of soil making it an important crop to include in rotational cropping; and it performs well in contaminated soils and can extract toxins from soil through phytoremediation. Hemp provides an eco-friendly insecticide and pesticide for use in agriculture and performs well with limited nutrient and pesticide inputs and can grow on more marginal lands. Hempseed is high in protein, fibre and micronutrient vitamins and minerals, as well a range of bioactive phytochemicals. The oil from hempseed has a good ratio of omega-3 and omega-6 fatty acids making it an essential ingredient in human and animal feed. The fibre can also be used for composites for manufacturing of car parts, furniture and as a sustainable building material. The hemp oil is considered to be good for the skin and has been used in cosmetology to produce a range of products. Hemp can also be used to produce biofuel and it is a good substitute for biofuel derived from corn and soybean. Hemp can be used to produce a paper that is biodegradable and recyclable and used in eco-friendly and allergen-free textiles and fabrics.

In the food and drinks sector, more than 4,076 hemp-based products have been launched in worldwide. Hemp-based products became popular after 2012 leading to exponential growth in the number of products launched. The UK is among the top five countries launching hemp-based products in the world. The USA is the country with the biggest number of hemp-based products, followed by Germany, Canada, the UK, and France. The majority of the products launched are in the following product categories: snacks, nutritional drinks and beverages, health care, breakfast cereals and bakery.

Hemp-based products with claims concerning health and nutrition, demographic (products targeted at certain demographic groups) and sustainability are the most dominant in the retail market. The topic five claims associated with hemp-based products are low, no or reduced allergens, vegan, gluten-free, organic and vegetarian.

The supply chain for Scottish grown hemp is still under development. Currently, there are no well-established market routes for farmers. However, the hempseed supply chain is better integrated than the supply chain for hemp fibre because only a few farmers grow the latter. The supply chain is exposed to many threats limiting its development, including no established market routes, low profitability, lack of technical support, weather limitation, lack of financial assistance, etc. However, the potential benefits and opportunities for the crop outweigh the current threats and weaknesses found in the sector.

Some important and time bound recommendations have been made to eliminates the threats and advance the opportunities for hemp production and processing in Scotland. First, there is the need for regular extension services to educate on the agronomic requirements of the crop. Second, a review of the licensing system may enable new or existing farmers to better benefit from the environmental advantages offered by the crop. Third, restrictions on where hemp can be grown, threshold of THC, and destructions of the hemp flowers/leaves could be reconsidered by learning from countries like the USA, Canada and France (Government of Canada, 2020; Vanderbilt University, 2018). In addition, the time to obtain licence and licence cost could be reduced to encourage new entrants into the sector. Fifth, strong horizontal and vertical linkages are required to ensure a resilient hemp supply chain. All supply chain agents in the hemp sector are required to play a conscious role to achieve the goal. Finally, although current oil seed rape facililties can be adapted to hempseed oil processing, there is the need for the Scottish Hemp Association to consider establishing permanent hemp processing facilities and seed production sites to ensure a sustainable hemp sector is developed.

I. Introduction

Hemp is one of the world's oldest economic plants that was developed from wild cannabis plants. Though there is still some uncertainty, it is believed to have originated from Central Asia over 3,000 years ago (Clarke, 1999). From Central Asia, the plant was carried throughout East Asia, South Asia, and Europe.

The industrial hemp/cannabis plant has many economic benefits, but fibre, food, and drugs are historically the primary benefits derived from the plant. The use of the cannabis plant differs between cultures. While Europeans, northern Asians and eastern Asians use cannabis as fibre and seed plant, those in Africa, the Middle East, South Asia and Southeast Asia used the plant primarily for its psychoactive benefit and secondarily as fibre and seed plant (Clarke, 1999).

Western Europe and East Asia are the main origins for the dispersal of hemp fibre varieties to the New World. The dispersal from Europe and East Asia (China and Japan) began during the 1960s and early 1900s, respectively. Also, intensive breeding of fibre varieties of hemp continued in the US from the late 1800s into 1930. Hemp is now cultivated worldwide with different varieties under study in Europe.

Cannabis has been used to produce a myriad of necessities such as cordage, cloth, lighting oil and medicine before 1000 B.C. until the late 1800s. Industrial/cannabis hemp is noted for producing strong and durable natural fibres. It is also used for the manufacturing of fine cloth, rope, twine, canvas, and sacking. Hemp was widely used for textile until the invention of the cotton gin - a machine that quickly and easily separates cotton fibers from their seeds. Also, the invention of petrochemical fibres and acid-process pulp paper reduced the economic importance of industrial hemp. Soon kerosene replaced cannabis seed as a source of lighting oil. Though cannabis was recommended in the treatment of diverse medical conditions for over 3000 years, the medicinal importance of cannabis began to disappear following the prohibition of cannabis drugs and cultivation in many countries (Clarke, 1999).

Industrial hemp (Cannabis sativa L.) is different from sunn hemp, waterhemp, hemp sesbania or hemp dogbane, but it is in the same family and species as marijuana. The main difference is based on the concentration of delta-9-tetrahydrocannabinol (Δ^9 THC) in both species. By law, the threshold of Δ^9 THC in industrial hemp is 0.2 per cent on a dry weight basis for the UK (Home Office, 2022), while in the US the threshold is pegged at 0.3 per cent Δ^9 THC on a dry weight basis (Arnall et al., 2019).

Hemp was dispersed to the British isle through European Celts and Picts. Its presence in the UK has been traced back to 343 BC (Gibson, 2006). Hemp was mandated in the British isles and as far back as 1175, it was listed as a commodity subject to tithe by the council of Westminster (Macpherson & Anderson, 1805). In the late 1500s, Thomas Fella advised the sowing of hemp for its use as fibre, food, medicinal properties, and oil. This led to the growth of the hemp industry in Britain. To meet the domestic demand for sailcloth and cordage, hemp was imported from Baltic states and Italy which supplied the finest grades. In 1781, the British government granted a bounty for hemp and flax to encourage farmers to grow it. Production of hemp was not only encouraged in Britain but also in British colonies. The British Isles– Lincolnshire, Norfolk, Suffolk, Dorset and Kent were the main growing counties due to the high demand and profitability of hemp production (Gibson, 2006).

In Scotland, hemp cultivation is documented as far back as the eleventh century (Whittington & Edwards, 1990). Direct evidence suggests the cultivation of hemp in Scottish areas such as Dumfriesshire (Sinclair, 1793) in the eighteenth century, Lewis (McKay, 1980), Islay (Sinclair, 1814), and Galloway (Kirk Session Minutes, 1724). According to Whittington & Edwards, (1990) surrogate evidence such as placename suggest the cultivation of hemp in the following areas in Scotland: “Hemphill (Kilmarnock parish, Ayrshire), Hempland (Torthorwald, Dumfriesshire), Hempriggs (Wick, Caithness) and Hempy Shot (Oldhamstocks, East Lothian). The earliest occurrences traced include Hemp-buttis (from 1556 in Auchtermuchty, Fife),

Hempriggis (from 1571 in Alves, Morayshire), Hempisfield (from 1642 in Plenderleith, Roxburghshire) and Hempshaugh (from 1663 in Selkirk)."

Industrial hemp was widely used in the UK until the 20th Century when cheap and abundant jute and cotton made hemp uncompetitive. The decline in the industrial use of hemp was gradually replaced by the misuse of hemp as a psychoactive agent. This resulted in European and North American countries banning the cultivation of cannabis. In 1928, an act was passed that finally prohibited hemp cultivation in the UK (Mackinnon et al., 2001).

In recent years, there has been growing demand for products containing hemp ingredients and the hemp plant. Moreover, the launch/relaunch of new products containing hemp ingredients has increased exponentially over the years. This is driven by the demand for nutritional and healthy products as well as the environmental benefits of growing the crop. There are significant market opportunities associated with industrial hemp cultivation – fibre, seed, flower and leaves, and stem or roots. As a result, many countries in Europe and North America are changing their legislation to support the revamp of industrial hemp industry. Scotland as well as the UK could learn from these countries to develop its hemp sector. A Scottish Environment, Food and Agriculture Research Institute (SEFARI) Fellowship was established in partnership with Scottish Agricultural Organisation Society (SAOS) Ltd and The Scottish Hemp Association with the goal of providing objective insights about the current and potential market opportunities to support hemp production in Scotland.

The report, developed with project partners SOAS and the Scottish Hemp Association describes the economic importance of the crop and potential uses of each part of the crop. It then reviews the global trends in hempseed and fibre production and who are the major producers. This is followed by a brief review on the trade of hempseed and fibre in the UK (no

data for Scotland) by taking a keen interest in the import and exports as well as major trading partners. The next section reviews the profitability of hemp production from empirical studies in the US, Canada, Europe, and Africa. This is followed by a section that discusses the trends in new product development in the global and the UK hemp product market. The final section of the report looks at the supply chain map of hempseed and fibre in Scotland, the Strength, Weaknesses, Opportunities and Threats in the Scottish hemp sector and concludes with recommendations to develop a strong and resilient hemp sector.

II. Method of Analysis

This report is based on three main analyses, which are a literature review, secondary data analysis, and a SWOT analysis.

Literature review

The review of the recent work on hempseed and fiber was a desk-based exercise. The main goal is to summarize, collate and synthesize results from existing research on the production of hemp worldwide. The desk research gathered online data on published literature and government published data such as FAOSTATS, EUROSTATS, and HMRC data. The literature search includes studies on the trends, economic value, uses, cost and returns for hempseed and hemp fiber cultivation in the UK and elsewhere. The search focused on articles published in English only. We used various combinations of the terms 'industrial hemp', 'cannabis plant', 'market potential', 'hempseed', 'hemp fiber', 'uses of industrial hemp', and 'economics of hemp' (and closely related variants of these terms). The searches were not limited to academic journals but also 'grey literature' such as government reports, newspaper articles, and market research reports. The main search trawl used to solicit literature was Google Scholar, as well as key government reports such as Defra.

Data analysis

Two data analysis were carried out: 1) based on Global New Product Database (GNPD) which contains information on hemp-based products launched by major retail supermarkets and manufacturers between 1997 and 2021. The data is based on products launched in Europe and North America. Each product contains information on the date and country it was first launched, product category, the manufacturing company, the brand name, positioning claims, prices, package size, the brand, product description, storage type etc. This information was used to assess trends in new product development in the hemp market.

2) based on primary data collected from Scottish farmers in Angus, Aberdeenshire and along the Scottish border. The data collected information on barriers, opportunities, weakness, and threats that the Scottish hemp supply chain is exposed to. Also, data on the motivations and potential market routs for hemp fibre and hempseed were gather. The results were presented in figures and tables. These allowed us to formulate recommendations that will assist in developing a strong Scottish hemp sector.

SWOT analysis

Teoli et al., (2019) defines SWOT analysis as a strategic tool used by an organisation to assess their performance against their competitors. In supply chain analysis, Görener et al., (2012) defined the concept as a systematic approach and support system for studying both internal and external factors of the supply chain. These internal and external factors are divided into four parts: Strengths, Weakness, Opportunities and Threats (SWOT). The procedure used in carrying out the SWOT analysis for the Scottish Hemp sector is described in the figure 1 below. Interview Questions answered by farmers were structured to illicit the SWOT of the hemp sector.

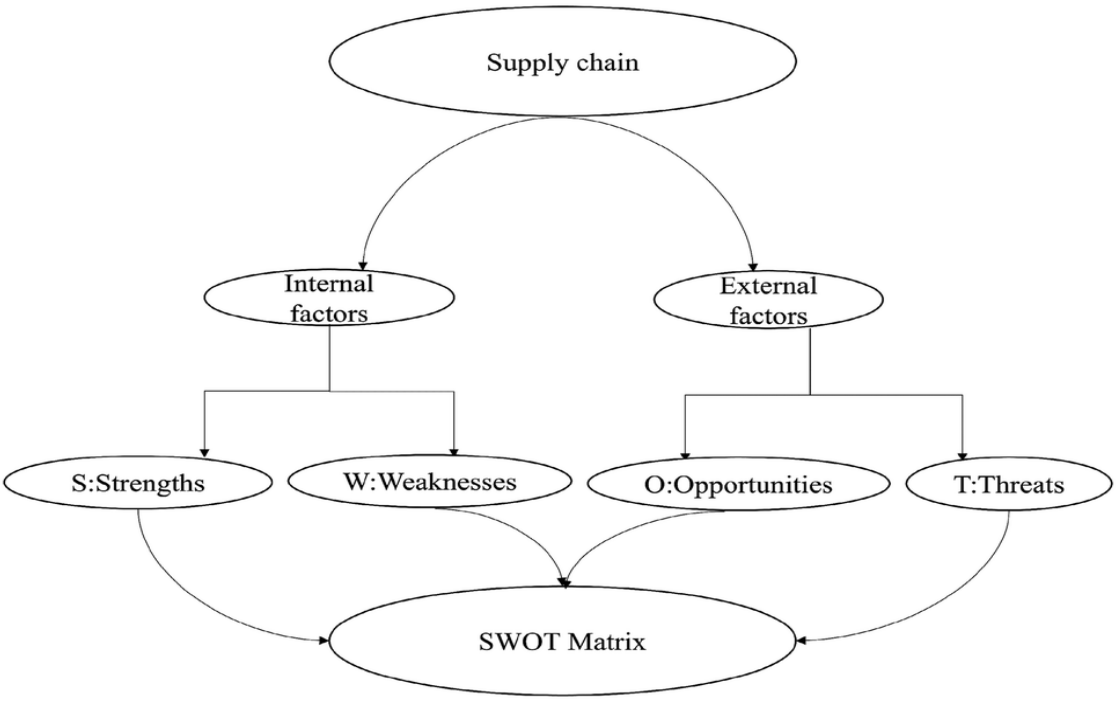

Figure 1: The procedure used in carrying out the SWOT analysis. Source: Meena et al., (2019)

III. Findings

The Market Potential for Industrial Hemp

The market potential of industrial hemp in Scotland is a critical consideration in assessing the long-term feasibility of developing domestic industry. Every part of the hemp plant can be used for different end-uses making the plant unique (Rehman et al., 2021). Industrial benefits from hemp can be derived from 1) flower and leaves, 2) stem or stalk, and 3) seed. Cannabis seeds are not controlled; however, their cultivation requires a Home Office Licence. The leaves and flowers of the cannabis or industrial hemp plant is considered controlled drug material in the UK (Cosmetic, Toiletry and Perfumery Association (CTPA) 2019).

Human food

Hempseed is beneficial for animals and humans alike. The hemp seed contains about 320 – 380 g/kg of oil (Hullar et al., 1999). Research has shown that the use of hempseed in food products, beverages or as a nutritional supplement is gradually becoming important, especially in counties like Canada, the USA, France, Germany and the UK (Callaway, 2004; Crini et al., 2020c; Pihlanto et al., 2017; Wang & Xiong, 2019). The hemp seed is also a good source of protein. Research shows that 2-3 tablespoons of Hemp seeds can supply about 11g of protein (Rehman et al., 2021).

Other studies suggest that Hemp seeds contain 20–25% proteins of biological value equivalent to hen's egg white (Mikulec et al., 2019), 25–35% of lipids, 20–30% carbohydrates, 10–15% insoluble fibres and minerals such as phosphorus, potassium, sodium, magnesium, sulphur, calcium, iron, and zinc (Callaway, 2004; Deferne & Pate, 1996). It also contains essential amino acids such as methionine, lysine and cysteine (Dunford, 2015). The seed flour also is devoid of gluten and does not contain allergens making it a useful bakery for people with celiac diseases (Kolodziejczyk et al., 2012).

The growing interest in the nutritional value of hempseed can be attributed to growing interest in the valorisation of agri-food products, the search for new sources of protein and the production of bioproducts, concerns for food allergies, animal welfare issues associated with animal-derived proteins, and a better environment (Pihlanto et al., 2017). For instance, a study by Multari et al. (2016) and Neacsu et al. (2022) showed that hemp is a valuable source of dietary amino acids, beneficially modulating gastrointestinal hormones and promoting satiety in healthy volunteers.

In the UK, Good hemp is the leading producer of hemp-based foods and beverages. Hemp products sold in the UK include hemp oil, hemp milk, shampoo, etc. According to Crini et al., (2020c) hemp seed oil is the most expensive product from the hemp seed. Animal feed which is made from the whole seed is the cheapest.

Animal feed

In agriculture, the hemp crop can be used as 1) mulch and animal bedding, 2) eco-friendly insecticides/herbicides, 3) biofertilizers, and 4) animal feed, or bird seeds. For the latter, hemp is a good source of animal feedstuffs. The hemp seed contains approximately 30% protein, 25% starch and 30% oil. The pressed seed produces oil that contains more than 90% of polyunsaturated fatty acids (Crini et al., 2020c; Galasso et al., 2016). Four main products can be derived from the hemp plant for animal feedstuffs; these are hemp seed cake/meal, hemp seed oil, hemp seed and the whole plant. The seed and seed cake can be used as feedstuff for all types of animal species (Bouloc, 2013).

Hempseed is also used in aquaculture to feed fish. The aquaculture industry is projected to play a crucial role in the next decades (Brugère & Ridler, 2004) by growing at a rate of 3.9 per cent from 2020 – to 2027 (Research Dive, 2021). This suggests a potential increase in the demand for aquafeed and hence for hempseed.

Composites and furniture

The hemp stalk provides the raw material for both traditional and industrial applications. Hemp can also be used for the production of bio-composites in the automotive industry (Crini et al., 2020c). Bio-composite materials may consist of natural fibres and a polymer matrix (Pernevan et al., 2012). Hemp scraps have a compact structure with low density and good mechanical strength making them suitable to be used as reinforcing materials in bio-composite materials. Moreover, recent interest in sustainability has led to research into natural fibre-based bio-composite materials, like those based on bast fibres like flax, hemp, jute kenaf and ramie (Bos, 2004). Bast fibres have many advantages over synthetic ones, such as good mechanical and thermal insulating properties. In addition, they have low energy requirements and costs during production. Hemp fibre is an excellent substitute for glass fibres in terms of their strength and stiffness when used as reinforcement elements in composites.

For instance, a study by Karus et al suggests that hemp-based plastic was used by Henry Food to build car doors and fenders in 1941. This gave the car the ability to withstand ten times the impact of an equivalent metal panel. However, the car did not make it to the market due to prevailing economic limitations. Currently, Germany is cited as the leader in using natural fibres in composite materials for automobile applications. The use of natural fibres as automotive composite is estimated to have doubled from 9,600 tons in 1999 to 19,000 tons in 2005; hemp fibre constitutes 10 per cent (Karus et al., 2006). Hemp can also be processed into different forms to be used in the automotive interior and exterior applications, e.g. as trunks, head-liners, spare wheel covers, parcel trays, car door panels, boot trims, rear shelf and roof liner panels, dashboards, pillar trims, seat shells, underbodies and other applications(Crini et al., 2020b).

Studies on the use of hemp fibre for reinforced thermoplastic show that thermoplastic has many advantages over thermosets polymers. For instance, a study by Wambua, Ivens, and Verpoest (2003) comparing the mechanical properties of natural fibre/PP composites, using kenaf, coir,

sisal, jute, and hemp fibres, all at 40% fibre weight fraction suggest that the latter showed the highest tensile strength of 52 MPa while coir showed the lowest (10 MPa). Another study by Khoathane et al., (2008) studied the mechanical and thermal properties of hemp fibre reinforced 1-pentene/PP copolymer composites. The thermal stability of the composites was found to be better than that of the fibres or the matrix as individual entities.

Another valuable field is the manufacture of biodegradable and non-toxic plastics based on hemp, referred to as bioplastics. From the environmental perspective, Shahzad (2012) suggests that hemp fibre can be used to reinforced biodegradable polymers and concludes that natural fibres reinforced with biodegradable polymers result in completely "green" composites.

Industrial hemp can be used to reinforced bio-composites to produce green composites, bio-composites, plastic composites, Nanomaterials and the furniture industry (Faruk et al., 2012). A study by Lamberti and Sarkar (2017) compared and contrasted the performance characteristics of 100 per cent woven cotton and 100% woven hemp fabrics for furnishing applications and concluded that hemp is a viable fibre for use in furnishing applications.

Insecticides/Pesticides

Hemp has been used as a natural replacement for synthetic pesticides/insecticides due to the latter's high cost, and environmental and human damage. For instance, Mukhtar, Kayani, and Hussain (2013) assessed the effectiveness of aqueous extracts of industrial hemp and Zanthoxylum alatum on hatching, mortality and infectivity of Meloidogyne incognita, root-knot nematodes, at different concentrations. They concluded that hemp extract is more effective than Zanthoxylum alatum and possess high potential for the control of root-knot nematodes and could be the best possible replacement for synthetic nematicides. In addition, Benelli et al. (2018) studied the use of essential oil from monoecious hemp cv. Felina 32 against mosquitoes, the peach-potato aphid, the housefly and the tobacco cutworm. They concluded that monoecious hemp cv. Felina 32 represent valuable sources of green insecticides. Hemp essential oils have also been tested against a wide range of arthropods pest. For instance, Bedini

et al. (2016) studied the chemical composition of essential oils from industrial hemp, *C. Sativa* and hop, *H. lupulus* and their acute toxicity against the Asian tiger mosquito *Aedes albopictus (Skuse)* and, the freshwater bladder snail *Physella acuta*. They concluded that hemp essential oil was more effective than that of the hop, killing 100 per cent of both invasive mosquitoes and freshwater snails. Also, the rapid development of insecticides resistance to malaria vectors has necessitated research into the use of essential oils of industrial hemp leaf as an alternative insecticide. Abé et al., (2018) studied the insecticidal activity of terpenes and aliphatic compounds in industrial hemp leaf essential oil on the malaria vector Anopheles gambiae s.l (Giles). The authors concluded that the compound proved to be effective against Anopheles gambiae s.l (Giles) larvae and adults.

These studies confirm the huge market potential for industrial hemp as a good green or natural replacement for synthetic insecticides/pesticides.

Cosmetology

Hemp essential oils are considered a niche high value product with promising market potential (Mediavilla & Steinemann, 1997; Thomas et al., 2000). It can be used for cosmetic products such as essential oils, body oils, body lotions, shampoos, bath gels, soaps, anti-microbe, and hand soaps (Crini et al., 2020b). For instance, Bertoli et al. (2010) studied the use of ten hemp fibre varieties for the production of essential oils in Italy. The fresh plant inflorescences were hydro-distilled, and the essential oils were characterized by gas chromatography–mass spectrometry (GC–MS). In addition, the composition of the aroma emitted spontaneously was analysed by solid-phase microextraction gas chromatography–mass spectrometry (SPME-GC–MS). The study concluded that hemp fibre inflorescences can be used to produce essential oils as a natural flavour and fragrance additives. Ionescu et al. (2015) also studied the pharmaco-cosmetic potential of four bioactive vegetable oils including hemp essential oil. The authors

concluded that hemp oil presents the best advantage for the application in the dermato-cosmetic industry, due to its optimal omega:omega 3 ratio.

In the UK, there is a variety of hemp-based cosmetic products in retail shops including shampoo and hair conditioners from well-known brand ranges.

Biofuels in the Bioenergy sector

The demand for sustainable energy has led to research into avenues to reduce the global reliance on fossil fuels such as coal, gas and oil-based energy (Rehman et al., 2021). The part of the hemp plant used for energy is either the whole plant or its shives (Burczyk et al., 2008). Two main types of biofuels can be derived from the hemp plant (Das et al. 2017; Rehman et al. 2013), biodiesel made from the oil of the pressed seed and bioethanol and methanol made from the fermented stalk. The forms of biofuel include boiler fuel (solid and pellets), biodiesel (bioethanol and methanol), biogas (methane and biohydrogen) and electricity. Ahmad et al., (2011) investigated the use of hemp as a potential source of biodiesel based on detailed physico-chemical analysis. The authors concluded that hemp oil biodiesel was found to be clean, environmentally friendly, and exhibit fuel properties within the range of American Standard for Testing Material. Another feasibility study was carried out by Li et al., (2010) on converting hemp oil into biodiesel through base-catalysed transesterification. They found a conversion factor greater than 99.5 per cent and a biodiesel yield of 97 per cent.

Hemp also presents an alternative avenue for the production of ethanol. Empirical studies by Sipos et al. (2010) showed that ethanol can be produced from steam pre-treatment of dry and ensiled industrial hemp. In addition, Kreuger et al. (2011) investigated the conversion of industrial hemp to ethanol and methane using stream pre-treatment and co-production and concluded that co-production of ethanol and methane from steam pre-treated stems gave a high yield of transportation fuel.

Industrial hemp presents market opportunities to obtain green and cheaper biofuels as it does not produce sulphur emissions, either when burnt directly or converted into liquid fuels such as bioethanol. In addition, Industrial hemp has high biomass and energy yields per hectare when compared to wheat, corn, sugar beets and sugarcane.

Hemp as building materials

The construction sector contributes significantly to global environmental pollution due to the use of energy and carbon-intensive raw materials. To ensure the construction of sustainable buildings, it is an imperative to replace carbon and energy-intensive resources with new low environmental impact ones (Ingrao et al., 2015). In building construction, hemp fibre can be used as insulation material, hemp wool, panelling, fiberboard, concrete, cement block and mortar. The use of hemp in concrete buildings has the added benefits of carbon sequestration apart from low embodied energy and renewability. Unlike synthetic fibre materials, the use of industrial hemp fibres represents a sustainable solution in building constructions. Hemp fibre can be processed into a variety of more durable commercial products that resemble concrete, wood and thermoplastic (Crini et al., 2020c). A big advantage of using hemp fibre over synthetic ones is that they are durable, lightweight, affordable to produce, water-proof, fire-proof, self-insulating, resistant to mould, moisture-proof, highly breathable, and resistant to pests, and have good heat retention in wintertime and cool in summer (Cigasova et al., 2015; Shahzad, 2012). Arnaud (2000) showed that concretes of lime and hemp made using the central porous part of the hemp stalk or shives has strong thermal and acoustic insulation properties. In addition, it can regulate the humidity inside buildings by absorbing and releasing moisture depending on the air conditions. Pretot et al. (2014) performed a life cycle assessment of hemp concrete walls and concluded that compared to traditional construction materials, hemp concrete has a low impact on the environment. Finally, Moujalled et al., (2018) performed an

experimental and numerical evaluation of the hygrothermal performance of hemp-lime concrete buildings. They concluded that hemp-lime concrete helps to maintain a good hygrothermal comfort level in winter and summer making it an excellent building material.

In Scotland, IndiNature, which is the first natural insulation factory in the UK uses hemp to produce natural fibre construction insulation for homes.

Hemp in the paper industry

The pulp and paper industry are a major contributor to environmental pollution due to the high consumption of energy and chemicals. Paper can be produced from the long bast fibres of hemp stem (Crini et al., 2020a). This makes it an excellent replacement for the traditional sources of raw materials for pulp and paper. Industrial hemp is useful for papermaking due to its high yield of hemp (Miao et al., 2014). In addition, hemp paper requires fewer chemicals for treatment into pulp paper (Malachowska et al., 2015). It is also useful for producing high-quality papers (Barberà et al., 2011). Furthermore, hemp paper is stronger, fine and does not turn yellow as conventional paper when bleached (Crini et al., 2020a). It can also be used for tea bags and coffee filters (Dutt et al., 2007), wax match paper (Dutt et al., 2002), cigarette papers (Jeyasingam, 1994; Yao et al., 2017)), electrical insulation papers (Dutt et al., 2003), glassine and greaseproof papers, condenser papers (Dutt et al., 2004), technical filters, banknotes, bible paper, dielectric, and medical paper (Callaway, 2004).

An empirical study on the use of hemp root bast paper for oil/air filtration for automobile engine oil concluded that hemp papers have better oil/air filtration properties than cotton paper in practical application (Jianyong & Jianchun, 2015).

Uses of hemp by the textile industry

Textile production from hemp has been displaced by imports of cotton and synthetics which are intensive and heavily dependent on inputs of pesticides, fertilisers and water (Riddlestone,

1996). Hemp bast fibre is a more sustainable replacement for the traditional natural and synthetic fibres in the textile industry (Amaducci & Gusovius, 2010). Hemp fibre textiles offer excellent protection from ultraviolet rays (Kocić et al., 2019; Zhang et al., 2016). Furthermore, hemp fibres are useful for textiles because they have a good thermal conductivity which is necessary for heat transfer in summer and retaining heat in winter (Stanković et al., 2019). Also, hemp fibre textiles have been proven to be suitable for people prone to allergies and sensitive skin (Kostic et al., 2008). Moreover, hemp bast fibres are stronger, can hold their shape and stretches less than other natural fibres (Muzyczek, 2020).

Environmental benefits of hemp

Hemp presents a new perspective and possibilities to mitigate climate change. Hemp fibre is considered a low input and low environmental impact crop (Smith-Heisters, 2008). The crop contains about 45 per cent of atmospheric carbon taken up during photosynthesis. In addition, hemp straw produced by 1 ha of land can store approximately 3.06 t of carbon (van der Werf, 2013).

Hemp planted for fibre require a high planting density and grows rapidly allowing it to crowd out weeds, resulting in little to no herbicides usage. However, these potential benefits disappear when hemp is planted for seed instead of fibres due to the lower planting density required.

Hemp has been used in soil cleaning through phytoremediation and phytoextraction processes. Hemp grown for fibre can be used as a renewable resource to decontaminate pollutants such as metals, radioactive elements, organics including pesticides and fertilizers, oils and solvents from soils (Linger et al., 2002). According to Small and Marcus (2002), hemp has been used in land reclamation in the oil and gas industry in Alberta. An empirical study by Pejic et al. (2009) showed that short hemp fibre is capable of adsorbing metal ions (Pb^{2+}, Cd^{2+} and Zn^{2+}) from single as well as ternary metal ion solutions. Also, Vukcevic et al. (2014) studied the use

of short hemp fibres, acquired as a waste from the textile industry, as bio-sorbent for the removal of zinc ions from polluted water. They concluded that short hemp fibres are efficient bio-sorbent for the removal of zinc ions from polluted water. Another study by Bugnet et al. (2017) also assessed the use of hemp materials (loose fibre and felted fibre) to decontaminate poly-metallic aqueous solution containing aluminium, Cobalt, Chromium, Copper, Nickel, and Zinc. They concluded that both loose and felted fibre has 99 per cent removal efficiency. The study was replicated and confirmed by Loiacono et al. (2017).

Hemp fibre also presents new opportunities for water and wastewater treatment. For instance, Vukčević et al., (2015) showed that carbonisation and activation of waste hemp fibre present an efficient alternative for the removal (adsorption) of pesticides for water purification. Similarly, Zou et al. (2012) studied the use of a zeolite-hemp fibre composite for green removal of aromatic organic pollutants (benzene, toluene and chlorobenzene) from aqueous solutions and concluded that the zeolite-hemp composite exhibited a high degree of removal (above 80 per cent) for the pollutants. This makes the composite an environmentally friendly alternative for water purification.

Industrial hemp has both environmental and biodiversity benefits. Products made from industrial hemp are biodegradable and are able to meet the demand for ecologically friendly products (Iványi & Izsáki, 2007). Figure 2 shows the crude mean evaluation of biodiversity-friendly of different crops including hemp for fibre and oil. Tobacco had the worst score for biodiversity friendliness whilst alfalfa has the highest biodiversity friendliness. Major annual crops like wheat, rapeseed, and barley are grown in Scotland were found to have negative biodiversity friendliness (Montford and Small, 1999). Fibre cannabis (hemp fibre and oil) was found to have a positive biodiversity friendliness compared to flax which had a negative biodiversity friendliness. Though both crops have similar uses, hemp could be considered

attractive for its biodiversity benefit. It was suggested (Omnes, 2021) that the cultivation of hemp before wheat leaves a clean and loose soil and helps to maintain the soil's biodiversity. Most studies suggest that the main strength in the use of hemp-based materials comes from the production phase because of the "green" origin of these materials, mainly associated with the carbon sequestration during plantation growth (Ingrao et al., 2015).

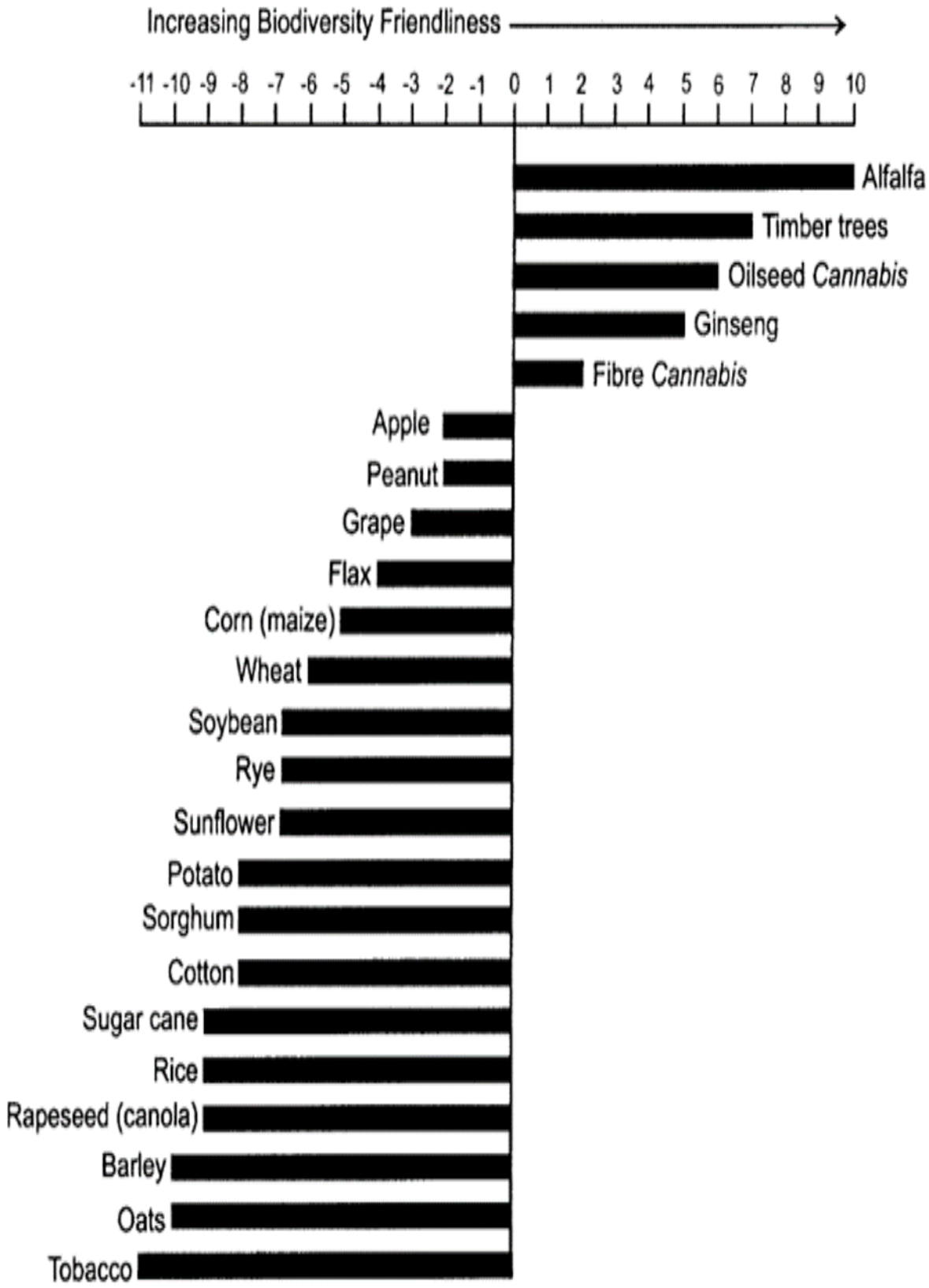

Figure 2: Crude mean evaluation of biodiversity friendliness of selected major crops and fibre and oilseed *Cannabis*, based on a scoring system. Source: Montford and Small (1999)

The Hemp Industry

Global trends

Figure 3 shows the trends in land allocated to hemp fibre and hempseed production since 1961. Land allocated to hempseed and hemp tow waste has been on the decline since 1961. The largest land area allocated to hemp fibre production was 581 K ha in 1965. Similarly, the largest land area allocated to hempseed production was 390 thousand ha in 1966. The continuous sharp decline in land allocated to hempseed and fibre production over the years are likely attribute to unfavourable government policies and the presence of cheaper plant alternatives. In 2020, land allocated area to hempseed and hemp tow waste were 10 thousand ha and 76 thousand ha, respectively. There is the need to reverse this trend to take advantage of both the environmental and health benefits that industrial hemp produces.

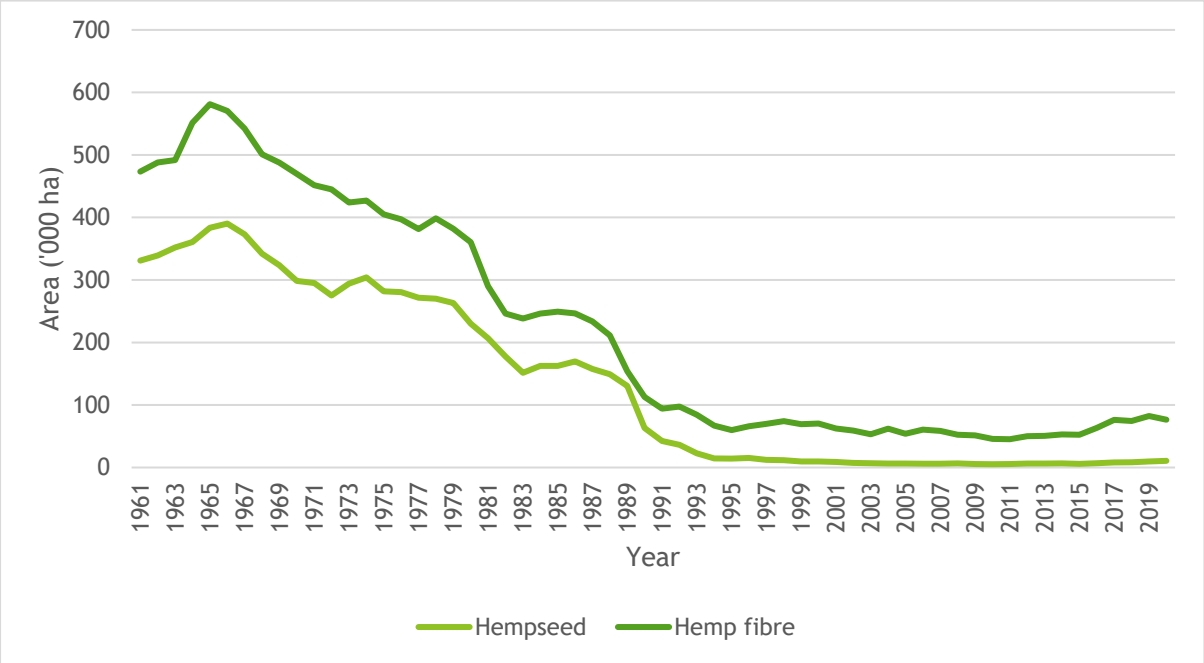

Figure 3: Trends in land allocated to hemp fibre and hempseed production from 1961 to 2020. Source: Own computation based on FAOSTAT

Figure 4 shows the trends in the global production of hemp tow waste and hempseed from 1961 to 2022. Hempseed production follows the same trend as the land allocated to its production. Production has been on the decline since 1961. In 2020, 5K tonnes of hempseed were produced globally compared to 79K tonnes produced in 1961; a reduction of about 74 per cent. For hemp

tow waste, production has been cyclical, the highest quantity of 368K was produced in 1966 whilst the lowest quantity (83K) was produced in 1990. After 1990, hemp tow waste production increased significantly in 2017 but this could not be sustained. In 2020, about 245K tonnes of hemp tow waste was produced. The Figure suggests that hemp tow waste has a larger market and currently performs better than the hempseed subsector.

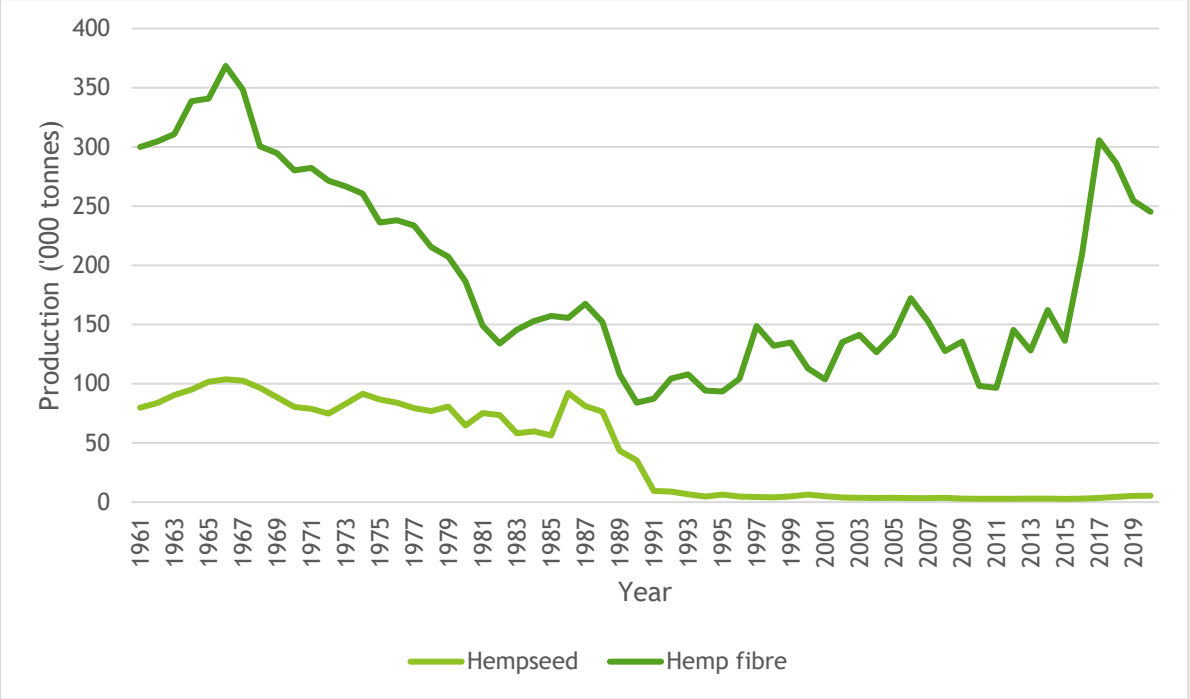

Figure 4: World Production of Industrial Hemp from 1961 - 2020. Note: This underestimates total global hemp production as FAO does not appear to report production data for some newer producers, including Canada and some Western European countries. While the data above is incomplete, there does not currently appear to be aggregated, reliable data on worldwide production at the current time. Source: FAO, FAOSTAT

Figure 5 below shows the top world producers of hempseed and hemp tow waste in 2020. Since 1991, FAO has not recorded any official data for hempseed production by China. From the data available, Russia is the largest producer of hempseed (57 per cent), followed by Chile (28 per cent), Ukraine (11 per cent) and Iran (4 per cent). For hemp tow waste, France is the largest producer, producing 47 per cent of the total world production in 2020. This is followed by China which produces 29 per cent of the global production. Korea, Poland and the Netherlands produce a total of 17 per cent, with the remainder by the rest of the world (RoW).

Unfortunately, the UK including Scotland is not among the leading producers of hemp tow waste and hempseed, suggesting that most of the hemp fibre and seed raw materials are imported.

Figure 5: World top producers and others (Rest of the World (RoW)) for hempseed and hemp tow waste in 2020. Source: FAO, FAOSTAT

Figure 6 shows the countries producing hemp in Europe. The EU does not have consistent data on hemp production data from 2000 to 2021. However, data gathered in 2020 suggests that France is the largest producer of hemp in Europe, accounting for 67 per cent of the total hemp production in 2020. Poland was the second largest producer of hemp, followed by the Netherlands, Austria, and Italy. The top five countries produce 94 per cent of the total EU production.

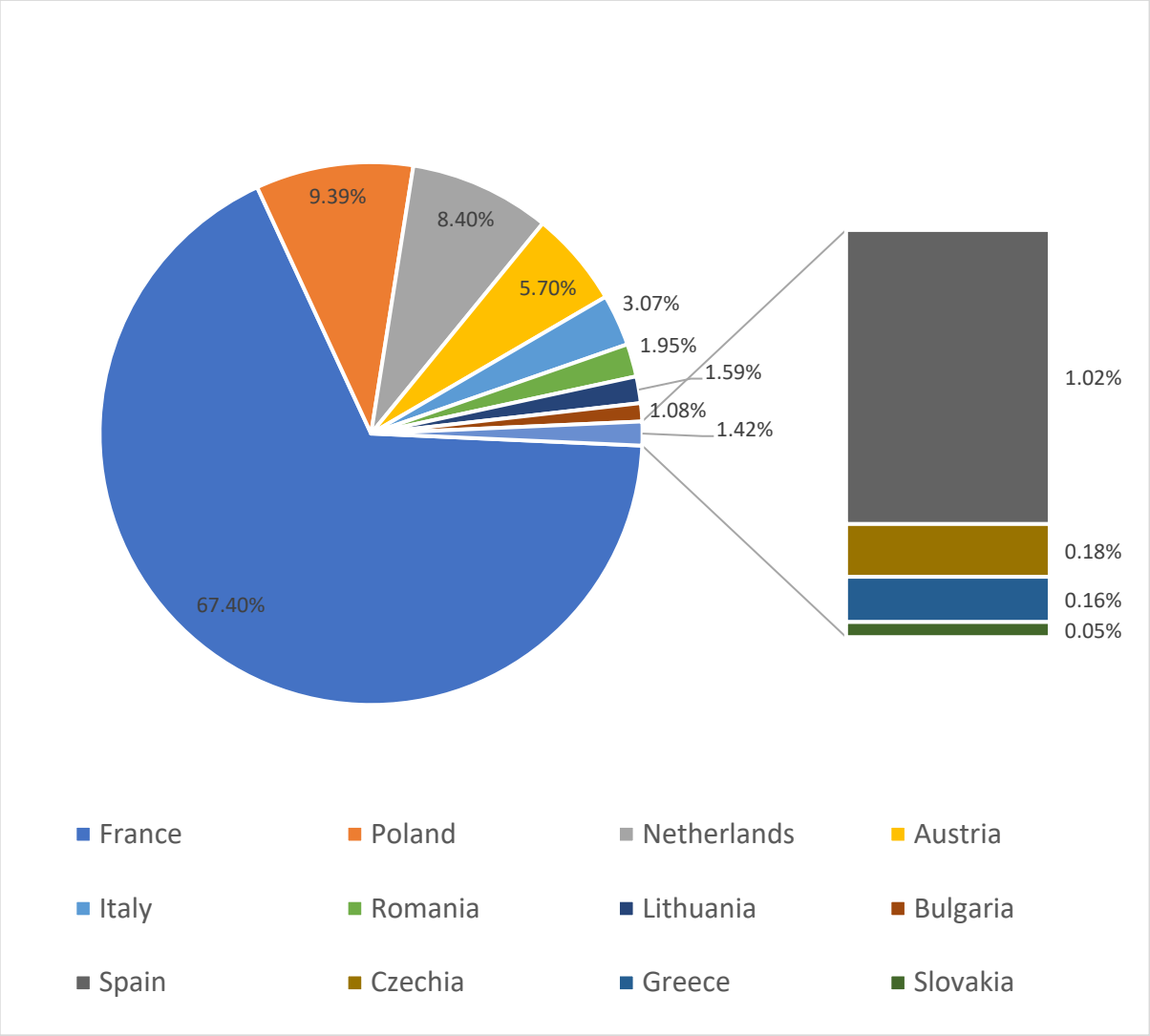

Figure 6: Production of hemp in Europe in 2020. Source: EUROSTATS (2022)

Figure 7 shows the total land in 1000 ha allocated to hemp production in the EU. In 2020, 33 thousand hectares of land was allocated to hemp production. Out of this, 50 per cent, representing 16.88 thousand hectares was planted by France. Slovakia has the lowest area of land allocated to hemp farming (0.07 thousand ha or 0.21 per cent). Germany, Poland,

Lithuania and Austria planted 4.50 ha, 2.37 ha, 2.25 and 2.14 ha, respectively. The UK's land allocated to hemp production has not been reported since 2006, as the data is unavailable. As a result, there is no data for hemp production in Scotland and the UK.

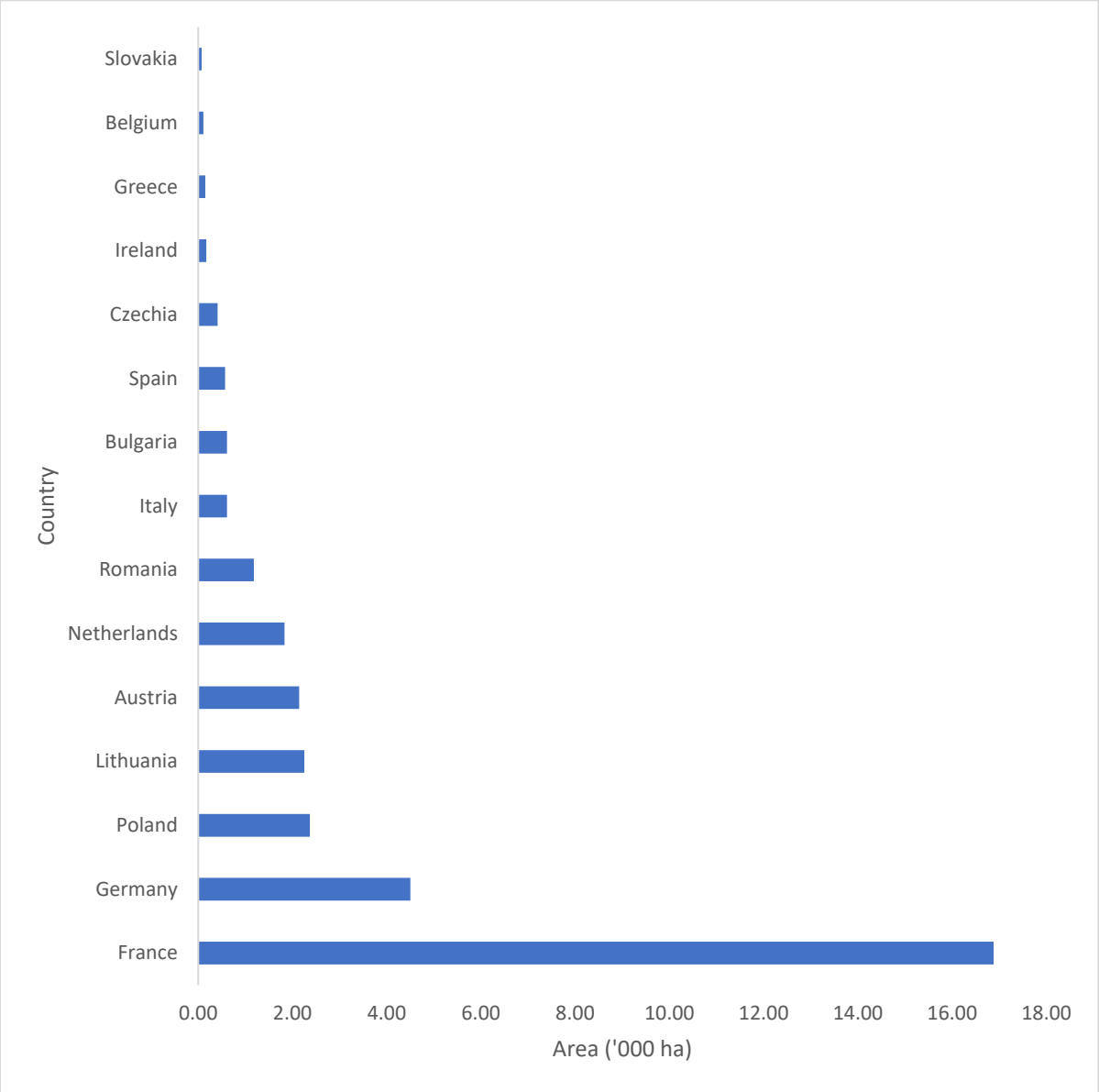

Figure 7: Land allocated to industrial hemp production in Europe in 2020. EUROSTATS (2022)

The UK Hemp trade

Imports and exports trends

There is currently no commercial production of industrial hemp in Scotland. The motivation for the legalisation of commercial production in Scotland is driven by the numerous uses of the

hemp leaves/flower, stem, fibre and seed. Figure 8 shows the evolution of import and export value and volume for hemp fibre[1] in the UK. Between the periods 2002 and 2006, and 2009 and 2012, the UK was a net exporter of hemp fibre. However, since 2014 the UK has been a net importer of hemp fibre to meet its domestic production. According to the HMRC trade data, the value of industrial hemp fibre exported from the UK in 2021 was about £107,000 and represented a decrease of over 57 per cent from the previous year. The total volume of hemp fibre imported in 2021 was 99,000 kilograms whilst the volume of export was 29,000 kilograms; a trade deficit of 70,000 kilograms. This deficit presents potential market opportunity for local producers.

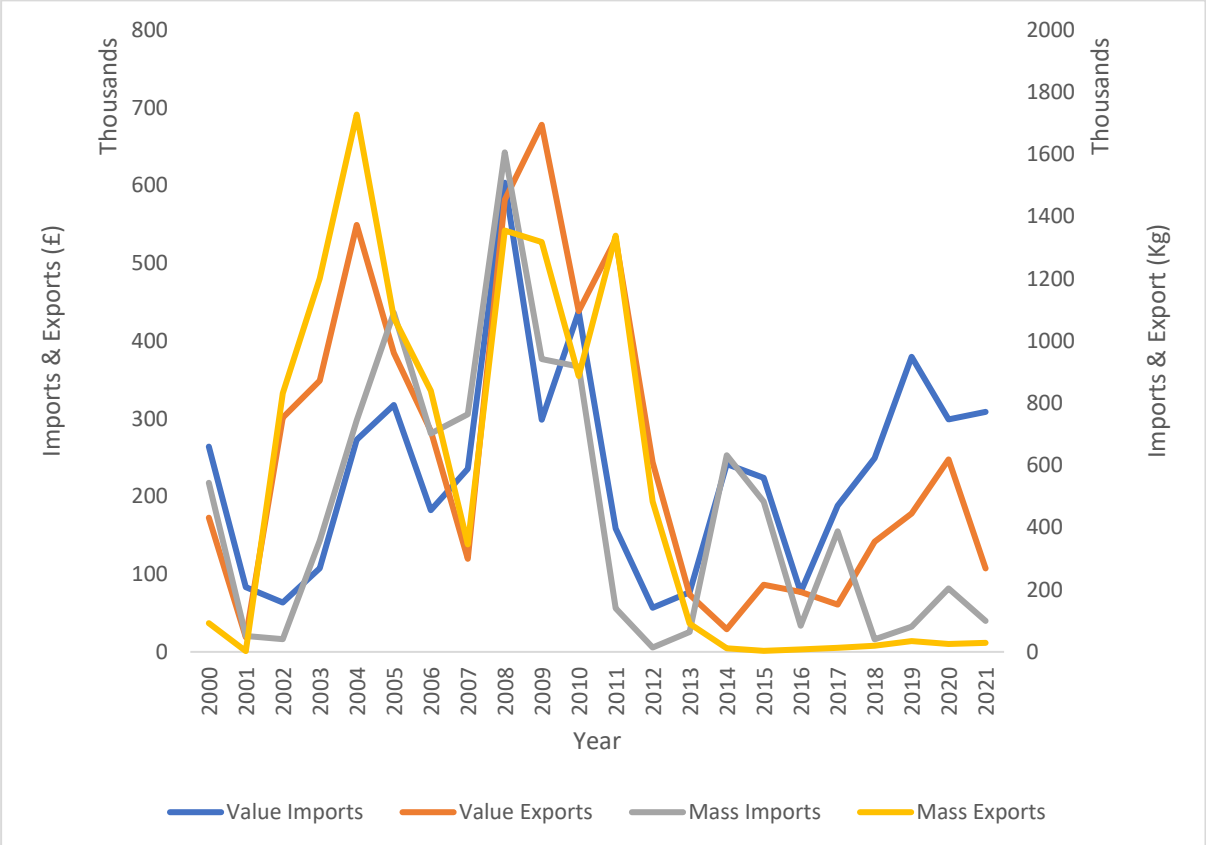

Figure 8: Volume and value of hemp fibre imported and exported by the UK from 2000-2020. Source: Own computation based on HMRC data 2021

[1] 5302 True hemp "Cannabis sativa L.", raw or processed, but not spun; tow and waste of true hemp, incl. yarn waste and garnetted stock

Figure 9 shows the import and export value and volume of hempseed[2] for the UK. Currently, there is no separate data for Scotland. The UK is a net importer of hempseed. Imports of hempseed rose to a record high in 2013 with an estimated value of £7 million (equivalent to 1.8 million kilograms). In 2021, the UK imported £3 million (1.2 million kilograms) worth of hempseed but exported only £396 thousand (37 thousand kilograms) of hemp seed. Also, the huge trade gap suggests a potential market opportunity of about £2.5 million for which domestic hempseed growers.

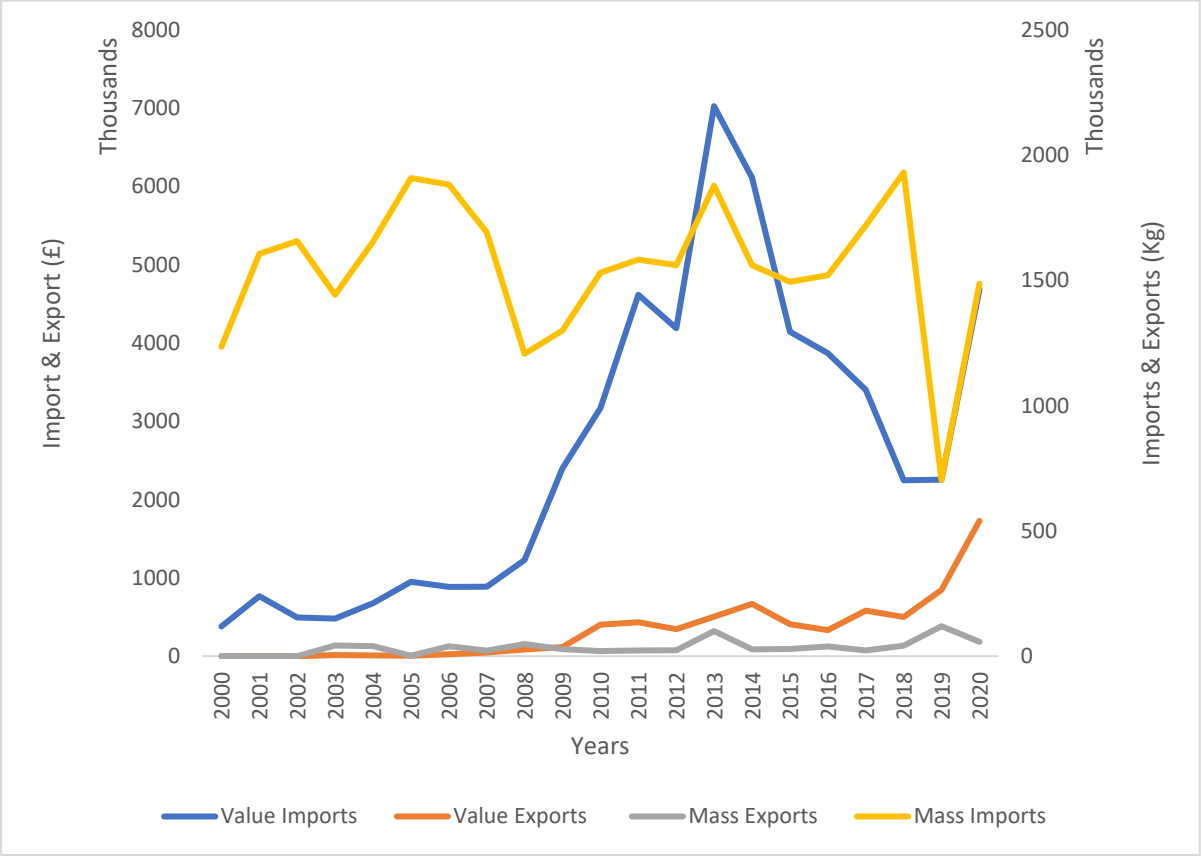

Figure 9: Volume and Value of hempseed imported and exported by the UK from 2000 – 2020.
Source: Own computation based on HMRC data 2021

Table 1 shows the list of companies importing and exporting hempseed and hemp fibre in the UK. Currently, there are ten UK based companies importing hempseed and thirteen exporting companies. According to the HMRC, Hemp fibre is imported and exported by nine and six companies, respectively, in the UK

[2] 12079991 Hemp seeds, whether or not broken (excl. for sowing)

Table 1: List of importers and Exporters of hempseed and hemp fibre in the UK

	Importers	**Exporters**
Hempseed	A Poortman (London) Ltd	Braham And Murray Ltd
	Berrico Foodcompany BV	Essential Trading Co-Operative Ltd
	Dawngreen Limited	F D Copeland & Sons Ltd
	Global Grains And Ingredients Ltd	Holland And Barrett Retail Ltd
	Glynis Patricia Murray Henry Richard Paul Braham	Hsnf Limited
	Hunt's Foodservice Limited	John Woods (Lisglyn) Ltd
	John Woods (Lisglyn) Ltd	Majid Al Futtaim Sourcing Uk Limited
	Kinetic Enterprises Limited	Nutrisure Ltd
	Millenis Sas	Palmer Harcourt Ltd
	T Futter Commodities Ltd	Rawcreation Limited
		Sandfields Farms Limited
		Sensible Gifts Ltd
		Sun & Seed Ltd
Hemp fibre for textile	Afrigen Biologics Pty Limited	Absolute Electronics Limited
	Belcher Stuart	B & K Universal Ltd
	Colefax Group Plc	Freshworld Handling Limited
	Highend Accessories Ltd	Industrial Nature Ltd
	Nkuku Limited	The Wool Packaging Company Ltd
	Rokshaw Ltd	Tissus D'helene Ltd
	Tildenet Ltd	
	Zoetic International Plc	

Source: Own computation based on HMRC data 2021

Hempseed

Figure 10 shows the top five countries supplying hempseed to the UK. These supply about 81 per cent of the total volume of hempseed imported. The Netherlands is the biggest supplier of

hempseed to the UK, supplying a total of about 33 per cent of the hempseed in 2021. France, the second largest supplier, supplies 17 per cent, followed by Spain (15 per cent), China (14 per cent), and Canada (12 per cent). The remaining 9 per cent was supplied by the rest of the world which includes the Czech Republic, Lebanon, Germany, Italy, Ireland, Lithuania, Portugal, Paraguay, Benin, United States and Poland.

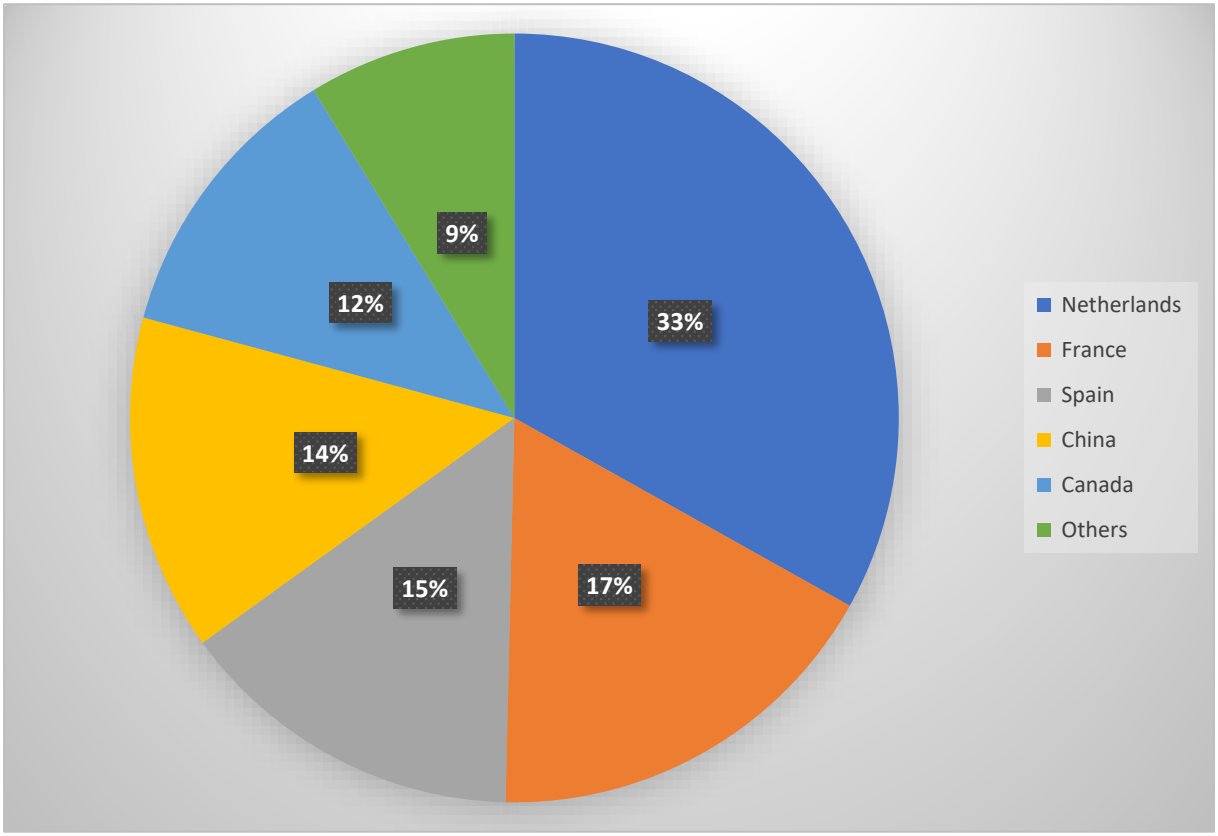

Figure 10: Top five countries the UK imported hempseed from in 2021. Source: Own computation based on HMRC data 2021

Figure 11 shows the top five export markets for UK hemp fibre. In 2021, the UK exported 27 per cent of hempseed to Lithuania, the largest importer of the UK's hempseed. The Netherlands imported 13 per cent whilst both Senegal and Australia imported 10 per cent of the UK's hempseed. Israel and Macedonia imported 8 and 6 per cent, respectively. The remaining 26 per cent were sold to the rest of the world which includes Lesotho, Spain, Ireland, Greece, Germany, Norway, Canada, Portugal, France, Sweden, Oman, Vietnam, Azerbaijan, Slovenia and Japan.

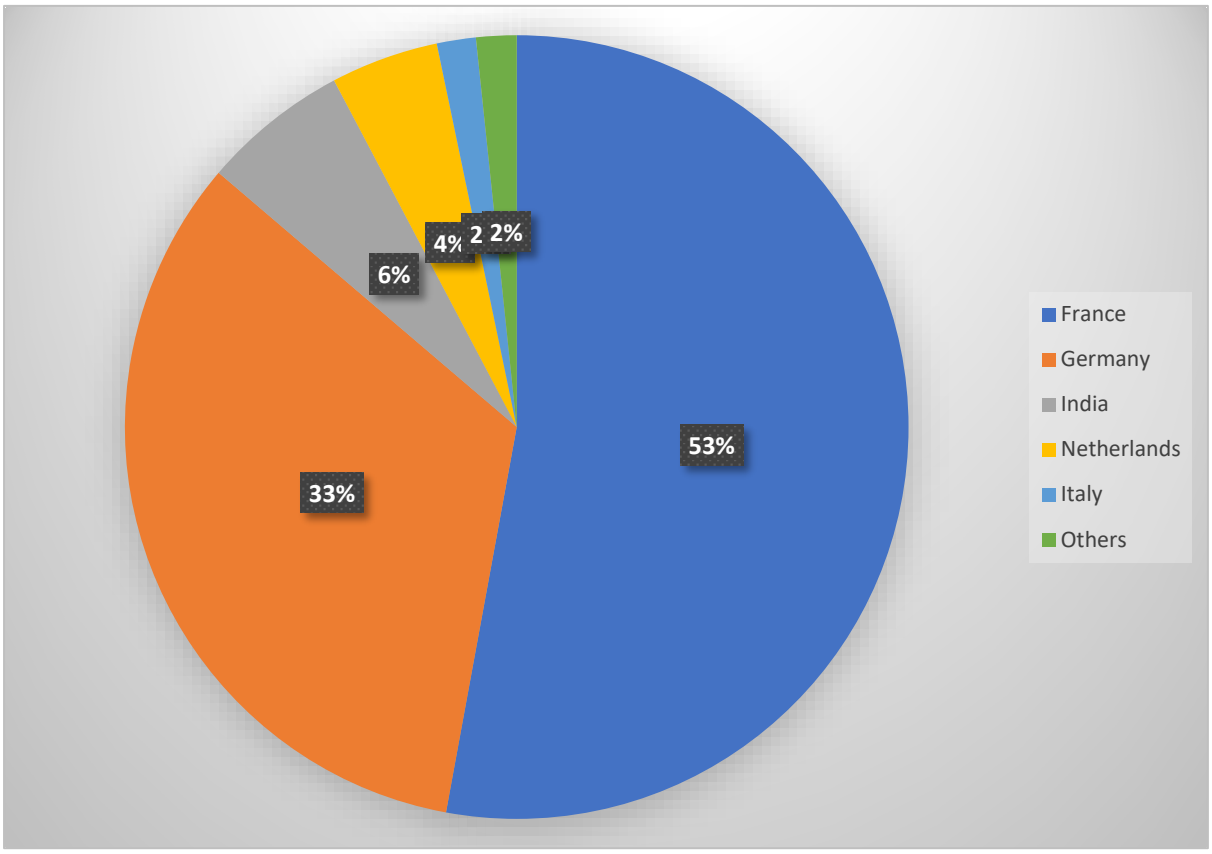

Figure 11: Top five countries the UK exported hemp seeds to in 2021. Source: Own computation based on HMRC data 2021

Hemp fibre

Figure 12 shows the countries supplying hemp fibre to the UK. The top five suppliers of hemp fibre supply about 98 per cent of the total imports. The biggest supplier of hemp fibre to the UK is France, supplying 53 per cent of total UK imports. The second biggest supplier of hemp is Germany (33 per cent), followed by India (6 per cent), Netherlands (4 per cent), and Italy (2 per cent). The remaining 2 per cent was supplied United States, Turkey, Australia, Switzerland, Canada, Nepal, South Africa, Austria, and Poland.

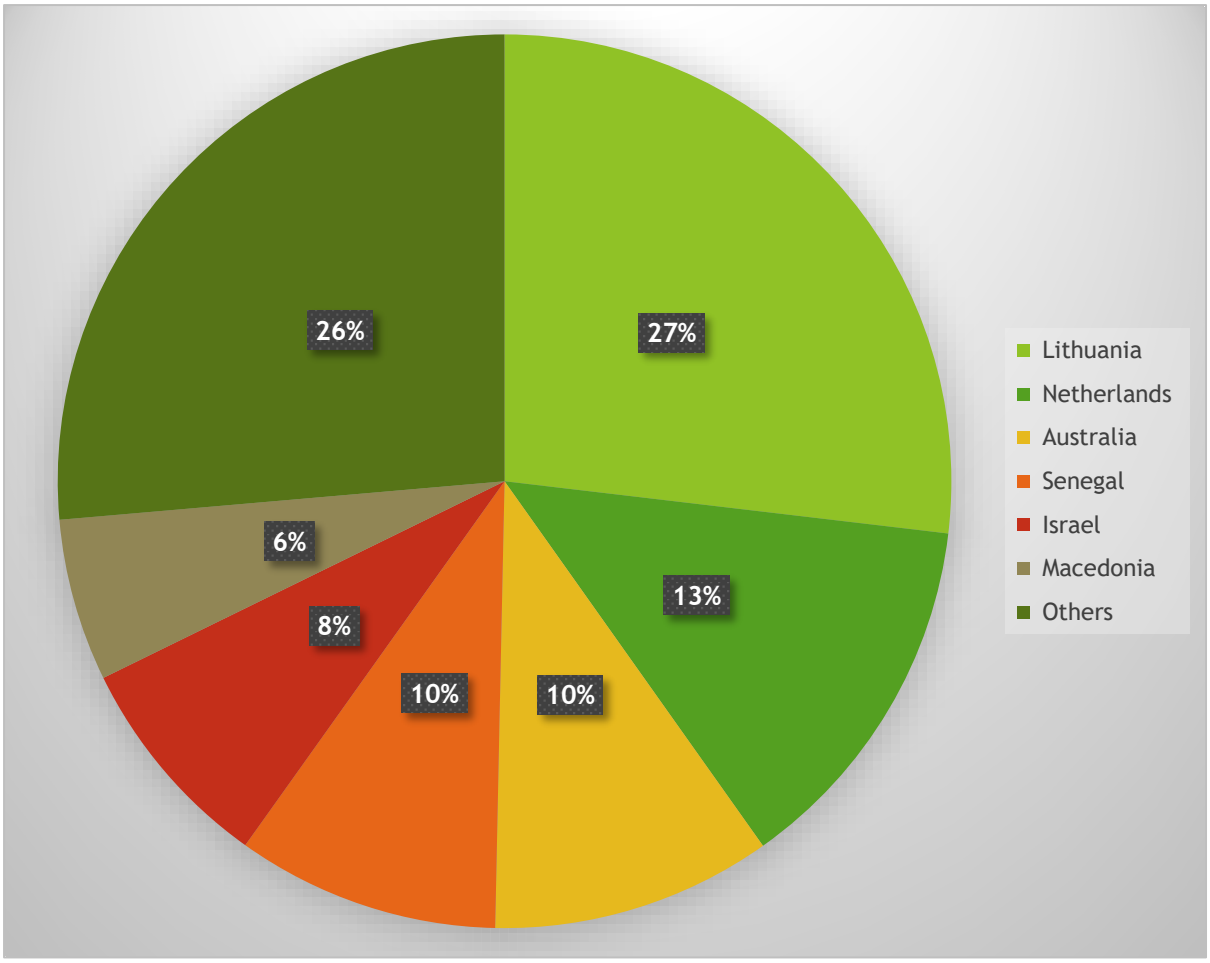

Figure 12: Top five countries the UK imported hemp fibre from in 2021. Source: Own computation based on HMRC data 2021

Figure 13 shows the top six export markets for UK hemp fibre. These countries import about 97 per cent of the total hemp fibre exported in 2021. France is the biggest importer of UK hemp fibre, importing about 41 per cent. The second biggest importer of the UK's hemp fibre is Australia which imports about 36 per cent. The following imports less than 10 per cent of the UK's hemp fibre: USA (9 per cent), UAE (4 per cent), Japan (4 per cent), and Netherlands (3 per cent). The remaining three per cent is exported to Denmark, Ireland, China, Singapore, Gibraltar, Italy and Croatia.

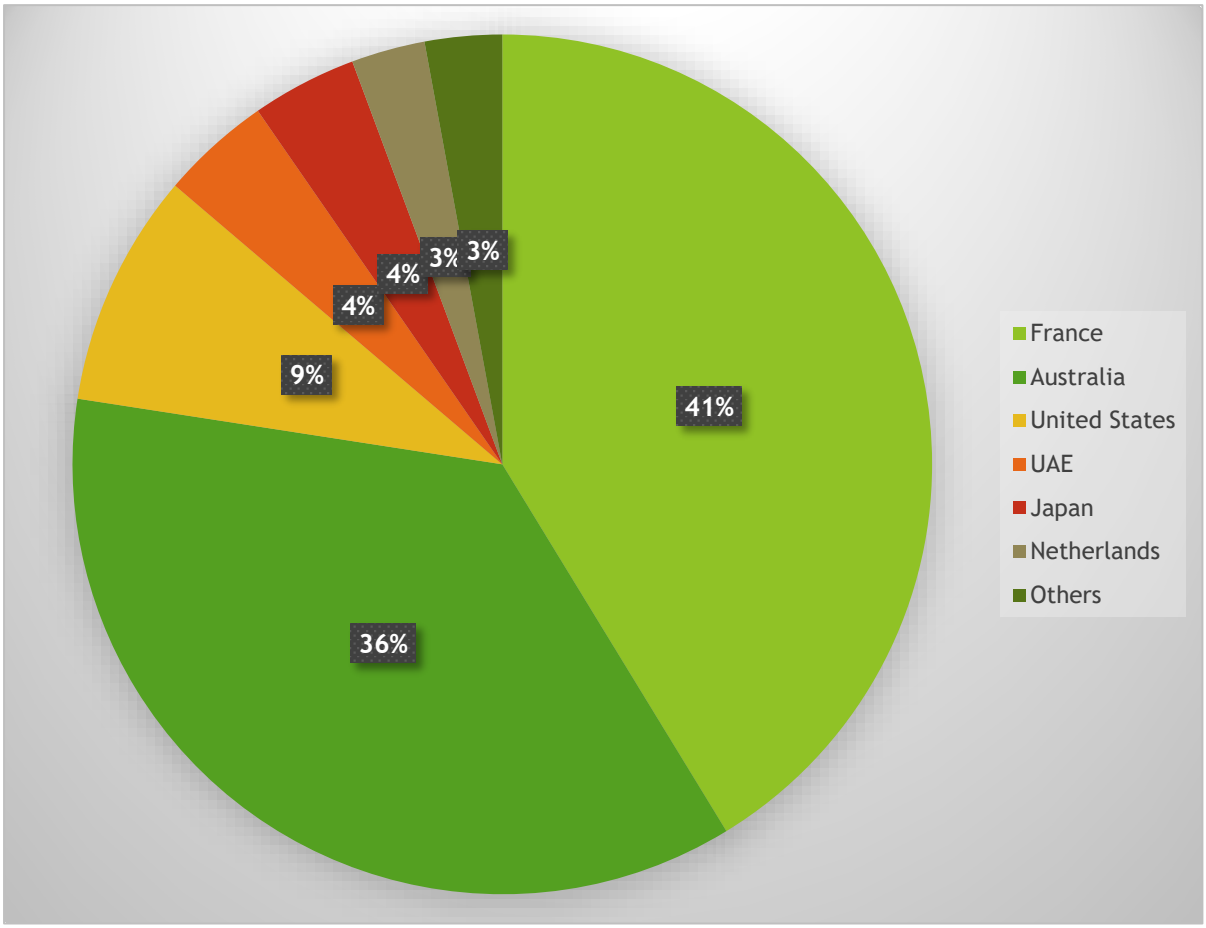

Figure 13: Top countries the UK exported hemp fibre to in 2021. Source: Own computation based on HMRC data 2021

Economic Outlook

Fortune Business insight a global market analyst projects that the hempseed market is estimated to grow at 11 per cent to about 1.6 billion dollars in 2027. In 2019, the market was valued at 0.7 billion constituting whole hemp seed, hemp seed oil, hulled hemp seed and hemp protein powder (Fortune Business Insights, 2022). The demand for hemp seed and its products is expected to be fuelled by rising demand for personal hygiene products as well as milk, oil, and cheese substitute and alternative proteins. Also, the relaxation of the restriction on industrial hemp farming in certain countries like Canada and the US is likely to drive up the demand for hempseed and its products. Third, demand for eco-friendly food products and strict climate policies may force producers and consumers to demand more environmentally friendly products.

Data from the US suggests that in 2017 alone, the total retail value of industrial hemp products was 820 million dollars. This figure includes food and body products, clothing, automobile parts, building materials etc. In 2021, the USDA estimated the total value of industrial hemp to be 824 million dollars, an increase of 4 million compared to the 2017 figure. About 623 million dollars was attributed to floral hemp grown in the open, 5.99 million dollars was attributed to seed or hempseed grown in the open, and 41.4 million dollars was attributed to hemp fibres plants grown in the open. Hemp under protection contributed about 112 million dollars. In Europe, France is the biggest producer of industrial hemp. Hemp fibre is estimated to generate more than 40 million euros annually for the French economy (Omnes, 2021).

Currently, there are no official data on the economic value of hemp and hemp products in Scotland. However, the figures from the US demonstrate the immense economic value of industrial hemp the national economy.

Hemp legislation in the EU/UK

The United Nations comprehensive "Single Convention" of 1961 on narcotic drugs include hemp due to the presence of D9-Tetrahydrocannabinol (THC). The definition "cannabis" means the flowering or fruiting tops of the cannabis plant (excluding the seeds and leaves when not accompanied by the tops) from which the resin has not been extracted, by whatever name they may be designated"; "cannabis plant" means any plant of the genus cannabis"; "cannabis resin" means the separated resin, whether crude or purified, obtained from the cannabis plant (United Nations, 1973). Also, THC contained in cannabis is captured within Schedule II of the Convention on Psychotropic Substances of 1971 (United Nations, 1971). This makes any product containing THC to fall within the scope of the convention and hence being illegal for sale – general food law 2002.

Hemp produced for agricultural purposes versus its medical-grade relative is often defined by low (<0.2%) levels of the psychoactive compound THC (Tallon, 2020). Hemp low in THC has

been present on the European market since 1994. Its extracts are, however, classified under novel foods and the sale of its plant or extract (cannabidiol or CBD) is not harmonized under the European Union (EU) law. The isolation of CBD was achieved in the early 1940s (Adams, 1942), however, scientists were able to determine its full structure only in the 1960s (Mechoulam & Gaoni, 1967). Currently, the EU-authorized hemp varieties (EU Regulation 1307/2013) contain 0.056 (Futura) – 0.27% (Finola) of CBD (Pavlovic et al., 2019).

In the UK, the home office controls the use of illicit drugs has the authority to implement and enforce the narcotic conventions under the Misuse of Drugs Act (MDA) 1971 (Misuse of Drugs Act 1971, 1971). The Act contains a list of illicit drugs which includes cannabinol, cannabinol derivatives, cannabis and cannabis resin (classified as Class B drugs). Misuse of Drugs Regulations (MDR) (2001) provides requirements for the licensing of production, possession, and supply of illicit substances. These regulations in the UK make it unlawful to possess, import, export, supply, and cultivate any plant of the genus cannabis except under the Home Office license. In the summary, all products promoted as food containing THC are considered controlled substances by UK law.

Profitability of hempseed and hemp fibre production

Hemp is grown on a large scale in some states in the USA, Canada, China, and Europe. The economic viability of hemp cultivation varies on annual basis due to price fluctuations. Table 2 shows data from the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) indicating that the production of both hempseed and fibre is more profitable than hempseed or hemp fibre only. (Baxter, 2000). Similar can be said for hemp production in Kentucky, USA. (Thompson et al., 1998). In Turkey, the production cost and revenue per acre for hemp fibre, hempseed, and hemp fibre and seed farms are higher compared to the US and Canada. The data

from France, shows a relatively high gross margin of for hemp fibre cultivation of about $512.74/acre (Girouard, 1994).

Hemp, when compared to other crops, has been shown to perform better. For instance, Das et al., (2017) compared the profitability of industrial hemp when used for seed and ethanol with that of kenaf, switchgrass, and sorghum. Hemp had higher profitability of about 35 – 70 per cent more than the three crops.

	hemp fibre		**hempseed**		**hemp fibre and hempseed**	
	Operating expenses ($) (Per acre)	Revenue ($) (Per acre)	Operating expenses ($) (Per acre)	Revenue ($) (Per acre)	Operating expenses ($) (Per acre)	Revenue ($) (Per acre)
Canada	617	510	424	400	532	580
USA	363.55	680	256.76	476.91	403.49	723
Turkey	1732.85	2887.98	1510.87	2994.38	2130.95	4207.89
France	364.21	876.95				

Table 2: Profitability of hemp production. Source: (Baxter, 2000, Thompson et al., 1998 & Girouard, 1994).

Trends and developments in the hemp processing sector

Figure 14 shows the trend in the number of hemp-based products launched in in the world from 1997 to 2021. Growth in the number of products launched was slow from 1997 to 2012. This could be due to strong restrictions on the farming of industrial hemp in across the world. The number of hemp-based products launched began to experience exponential growth from the beginning of 2013. This could be due to the relaxation of restrictions on the farming of industrial hemp, increasing demand for sustainable products, and the growing number of health and nutrition-driven consumers. In 2021, the total number of hemp-based products launched was 713 products compared to 8 products in 1997: about 88 times higher.

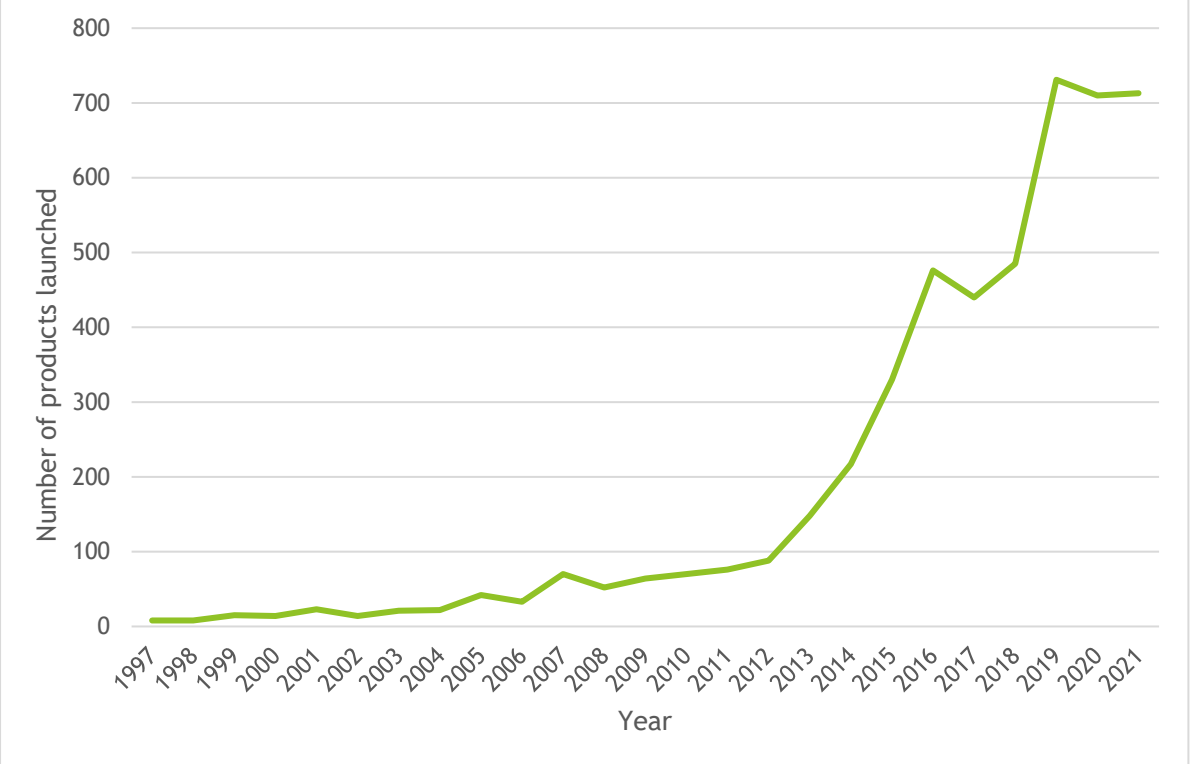

Figure 14: The number of hemp-based products launched in in the world from 1997 to 2021. Source: Own computation based Global New Product Database (2022)

Figure 15 presents the categories of products launched in the world from 1997 to 2021. A total of 4,870 unique products were launched. The category with the largest number of products to be launched are snack-based food products (1,019) whilst sweeteners and sugar have the least number of products (2). Health care products are the second-largest categories with hemp-based ingredients. A total of 696 health care products containing hemp ingredients were

launched between 1997 and 2021, this is followed by nutritional drinks and other beverages, breakfast cereals, and bakery products. Based on these figures, it can be deduced that the demand for hemp-based products is driven by nutrition and health concerns.

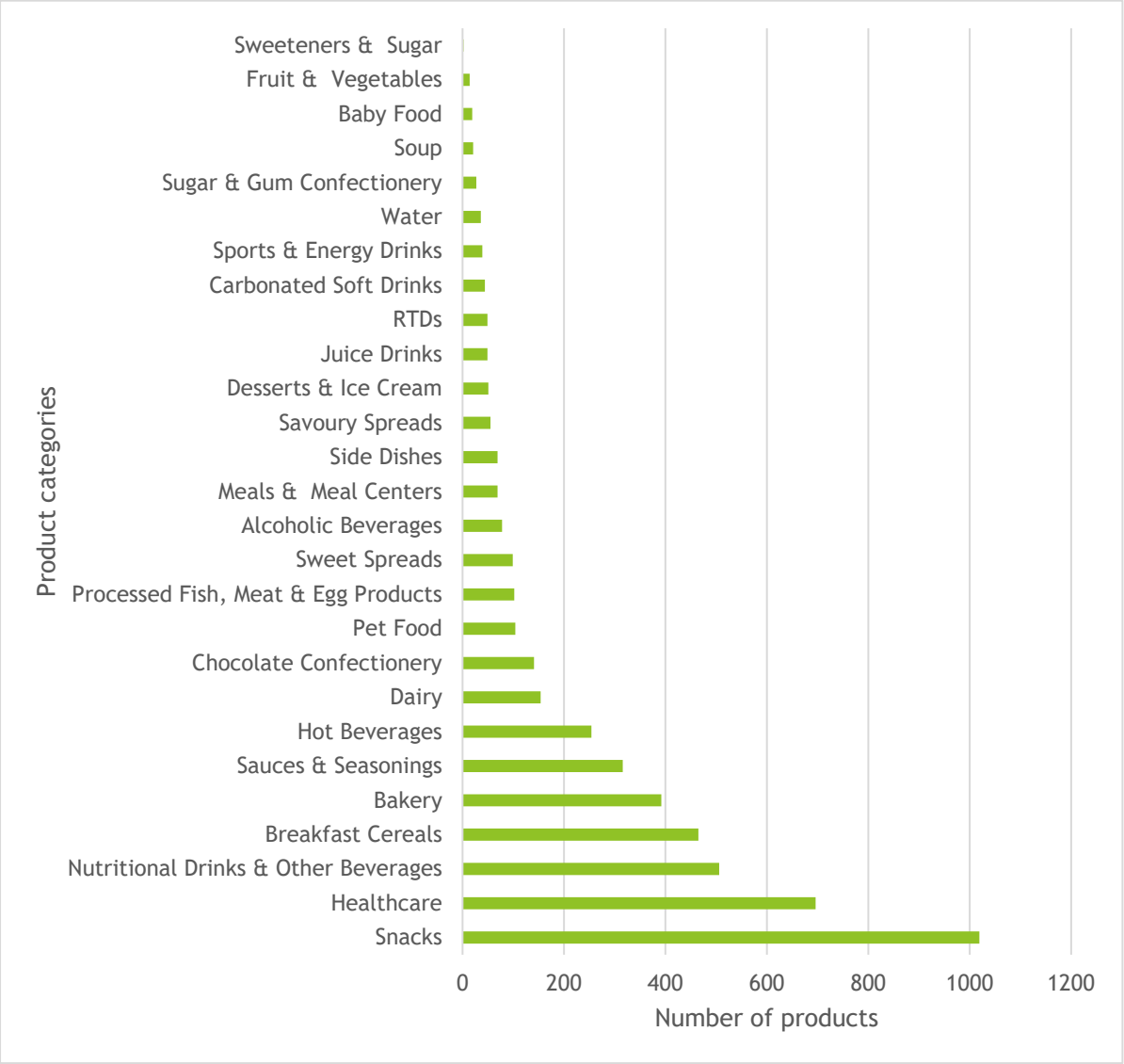

Figure 15: Categories of hemp-based products launched in worldwide from 1997 to 2021
Source: Own computation based Global New Product Database (2022)

Figure 16 shows the top 20 leading manufacturers of products with hemp ingredients and the remaining manufacturers have been summed together. These companies together launched 16.3 per cent of the total hemp-based products. There are about 1,884 companies worldwide that launched hemp-based products from 1997 to 2021. The top five companies in the world in descending order are Sequel Natural, Pukka Herbs, Manitoba Harvest, Nature's Path Foods,

and Whole bake. Sequel Natural launched about 1.7 per cent of the total number of hemp-based products whilst Planet organic (least among the top 20) launched only about 0.4 per cent of products between 1997 and 2021. The distribution shows that no producers launched more than 3 per cent of products with hemp ingredients making the market less concentrated, and with no market power issues.

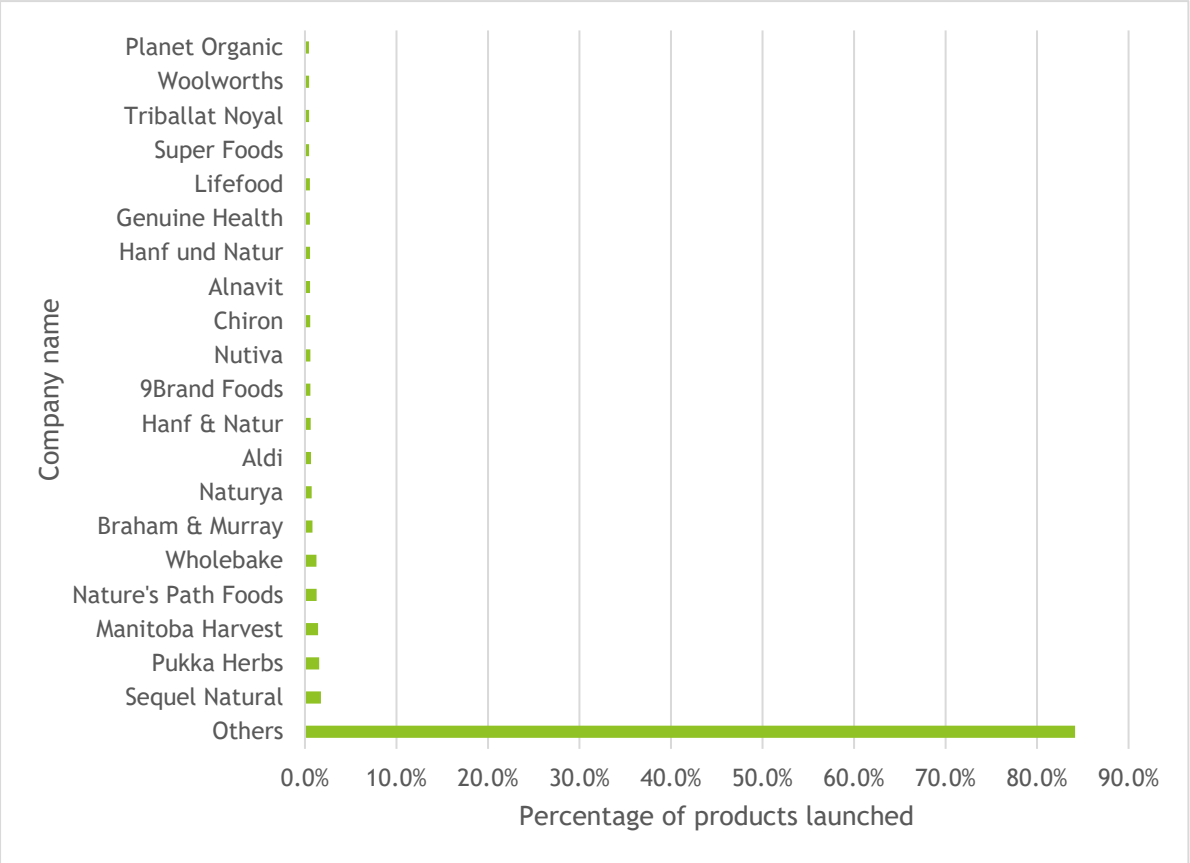

Figure 16: Top 20 manufacturers and others launching hemp-based products from 1997 to 2021. Source: Own computation based Global New Product Database (2022)

Figure 17 shows the number of products launched by claims category by the top five companies in Europe and North America. There are five claims category, namely convenience, sustainable, health and nutrition, safety, and demographic[3]. The figure shows that the focus of the top five companies with regards to product claims is different. Sequel Natural, and Wholebake launched most of their products under health and nutrition claims. Pukka Herbs,

[3] Demand is driven by consumers who are in different demographic strata and have special product needs. These products are directed towards specific groups of people like the aged, toddlers, females, males etc.

Manitoba Harvest and Nature's Path Foods launched most of their products under sustainable claims. Products launched under demographic claims was the second most popular for Sequel Natural, Pukka Herbs, Manitoba Harvest and Wholebake. The number of products launched under convenience claims are the least across four of the five manufacturers. Overall, products with nutrition and health claims dominate the hemp market.

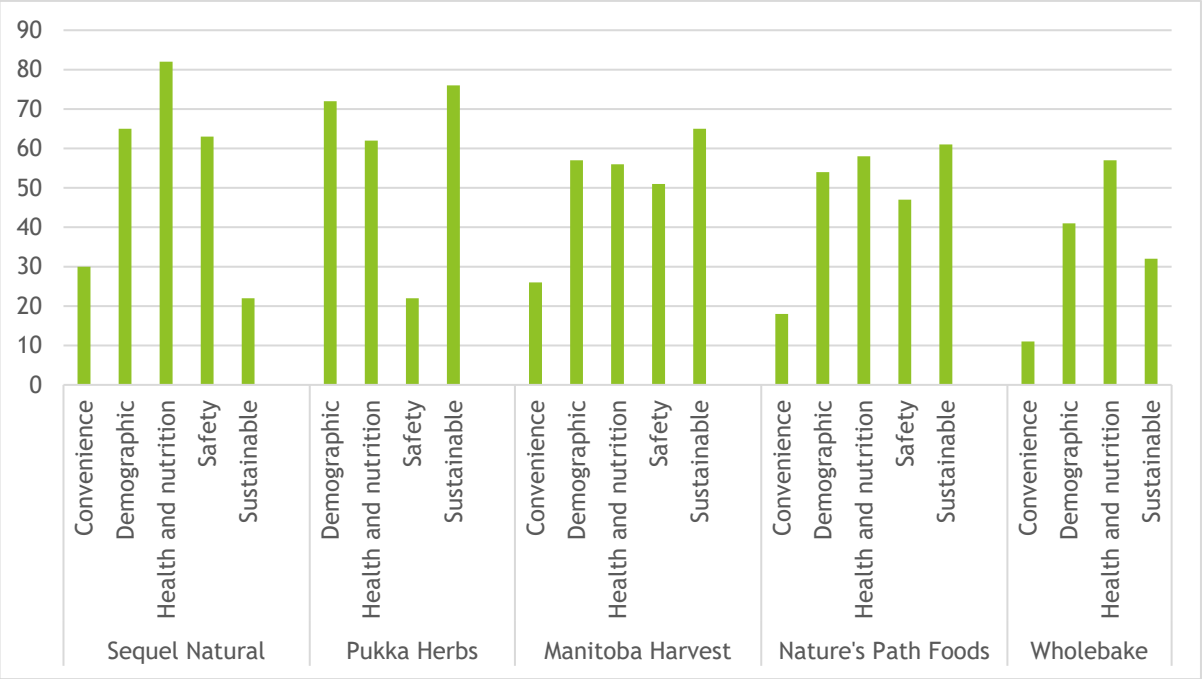

Figure 17: Number of products launched by claims category for the top 5 Companies. Source: Own computation based Global New Product Database (2022)

Figure 18 shows the countries and the number of hemp-based products launched from 1997 to 2021. These countries launched more than 99 per cent of the total hemp-based products launched worldwide whilst the others[4] launched less than 1 per cent. The top five countries in descending order are the USA, Germany, Canada, UK, and France. The USA is the biggest manufacturer of products with hemp ingredients whilst Singapore is the least. The two North American countries i.e., Canada and the USA launched about 29 per cent of the total number of products. The UK launched 10 per cent, the remaining 61 per cent is distributed among the

[4] Belarus, Chile, Colombia, Indonesia, Israel, Philippines, Tanzania, Argentina, Cameroon, Egypt, Ghana, Guatemala, Kuwait, Pakistan, Peru, UAE

remaining countries. Although the UK is not among the top growers of industrial hemp in the world, it is among the top five manufacturers of/companies launching hemp-based products. This suggests hemp ingredients used in the UK are sourced externally presenting a potential market opportunity for hemp growers.

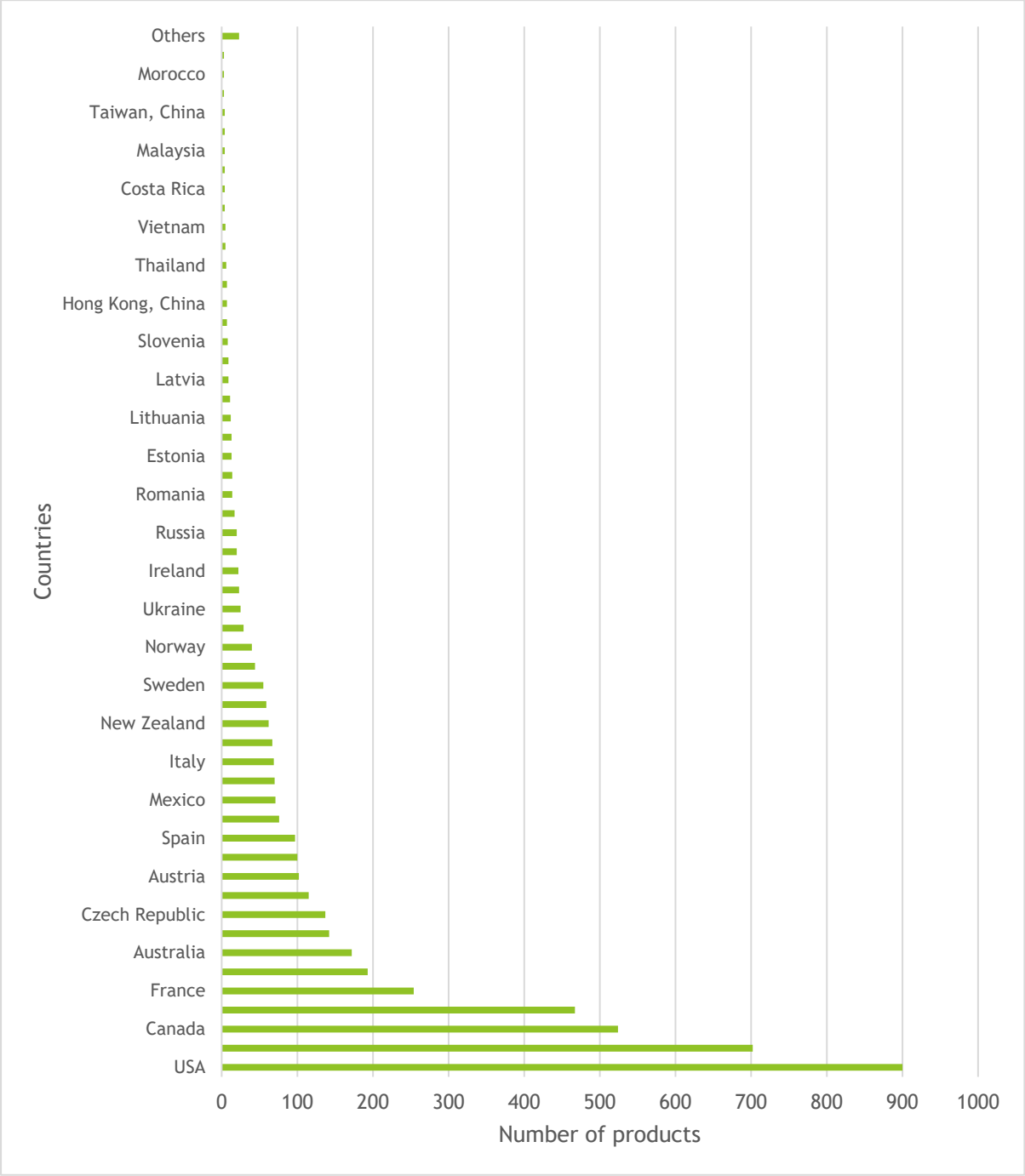

Figure 18: Number of hemp-based products launched by countries from 1997 to 2021. Source: Own computation based Global New Product Database (2022)

Figure 19 shows the claims categories of hemp-based products launched by the top five countries in the world from 1997 to 2021. Health and nutrition claims are the dominant claims across all three out of the five countries with the USA having the largest number of products launched. This is followed by Canada and the UK. France has the lowest number of hemp-based products launched under nutrition and health claim. The next dominant claim is demographic claims, however, it does not dominate in any country. Sustainable claims are the third most important, dominating in France. Convenience claims are less important across all countries as shown by the number of products launched between 1997 and 2021. In the UK, products with health and nutrition claims dominate, followed by demographic claims, sustainable claims, convenience claims and safety claims.

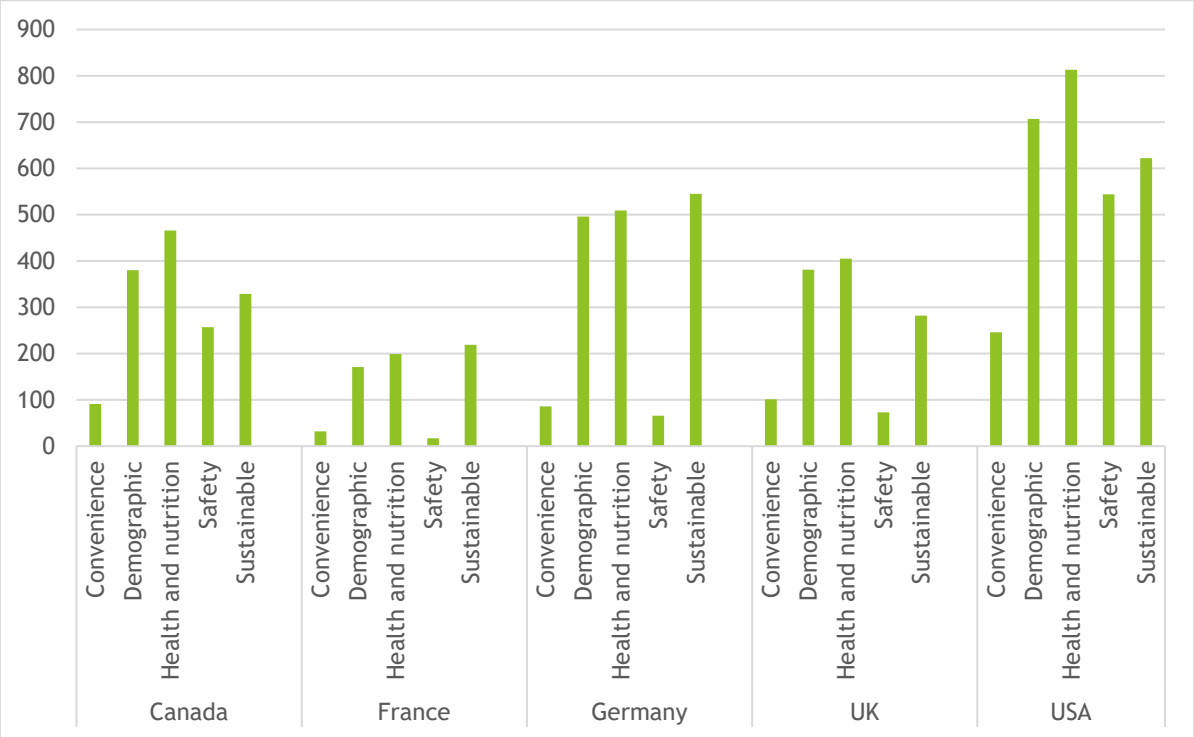

Figure 19: Top five countries and the number of products launched by claims category. Source: Own computation based Global New Product Database (2022)

Figure 20 shows the trends in the number of products launched by claims category from 1997 to 2021. The number of products launched has experienced an increasing trend across all claims categories. The dominant claims category across all years is health and nutrition suggesting

that demand for hemp-based products is driven by consumers who are health and nutrition-conscious. Products with Demographic claims are the second most important. Products with Sustainable claims are the third important in the hemp products markets. These products are driven by consumers who are driven by demand for environmentally friendly foods. Convenience and safety claims are the least important in the hemp market as shown by the figure. This suggests that manufacturers do not think consumers are interested in hemp-based products with such claims.

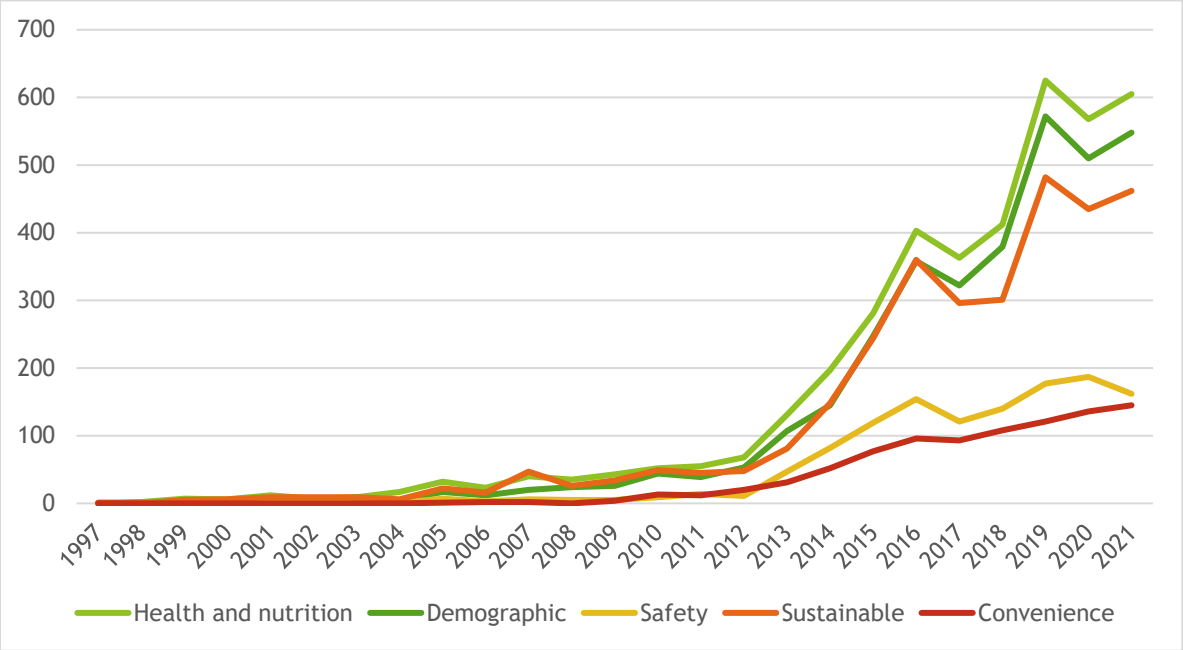

Figure 20: Trends in the number of products launched by claims category from 1977 to 2021. Source: Own computation based Global New Product Database (2022)

Figure 21 shows the percentage of products launched under the top 20 claims positioning in the world. These make up 91.8 per cent of all claims positioning attributed hemp-based products. Products with organic claims are the largest constituting 19.9 per cent of all hemp-based products launched between 1997 and 2021. However, products with convenient packaging claims have the lowest share among the top twenty claims. The second largest claim category is demographic, followed safety and nutrition and health claims. The top sustainable claims are environmentally friendly products and environmentally friendly packages.

Convenience hemp-based products have ease of use, time/speed, on-the-go, and microwaveable claims. Demographic claims within the top 20 claims are vegetarian, vegan/no animal ingredients, social media, and kosher.

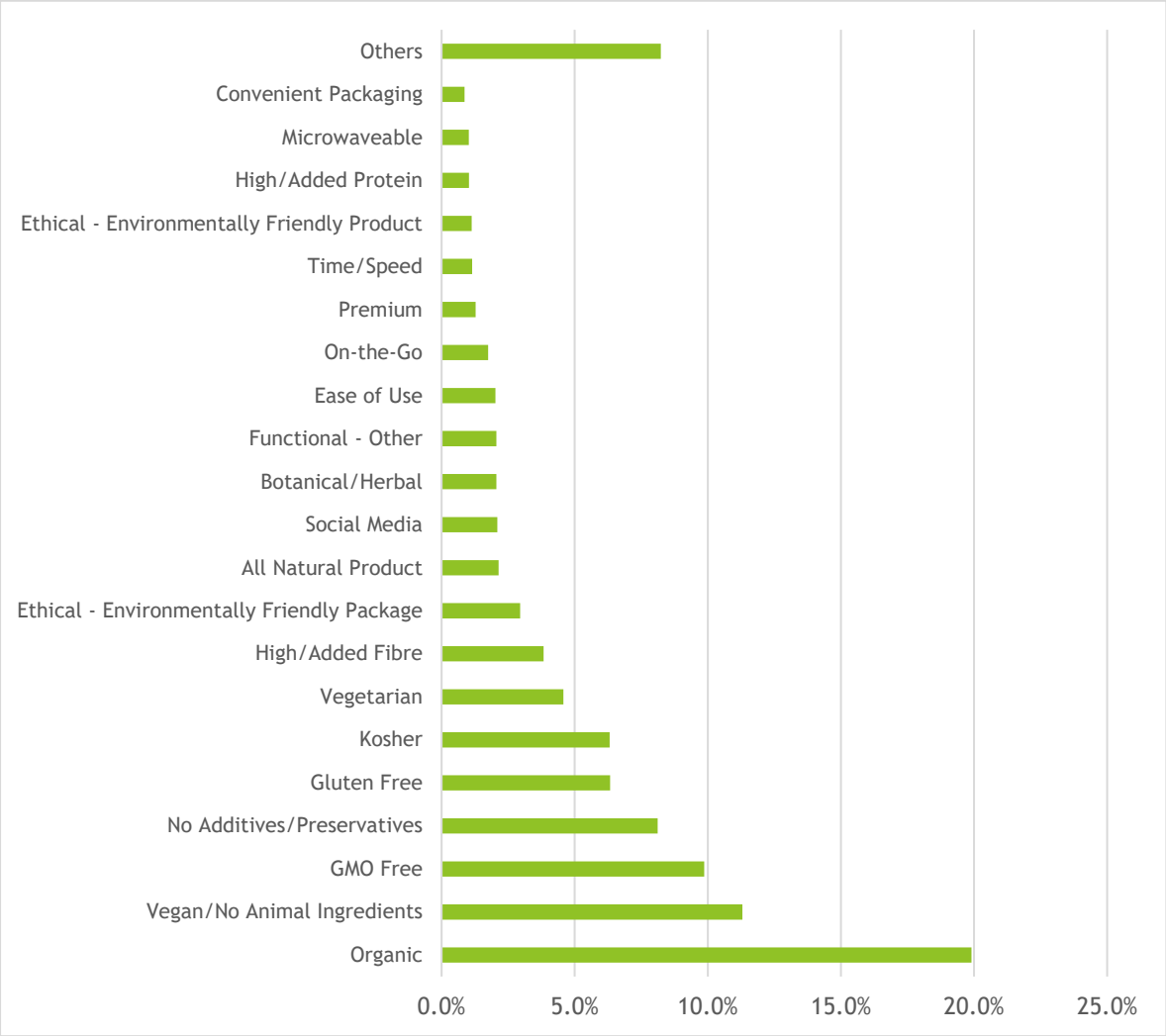

Figure 21: Percentage of products launched under each claim positioning from 1997-2021. Source: Own computation based Global New Product Database (2022)

Figure 22 shows trends in the number of products launched under different claims category in the UK from 1997 – 2021. The number of products launched under the different categories follow a similar pattern as those launched worldwide. Products with demographic, and health and nutrition claims form the majority across all years. The number of products launched under these two claims including sustainability increased exponentially after 2014. Products under safety and convenience claims were low across all years until 2016. In 2021, 47, 57, 54, 15,

and 10 products were launched under sustainable, health and nutrition, demographic, safety, and convenience claims, respectively.

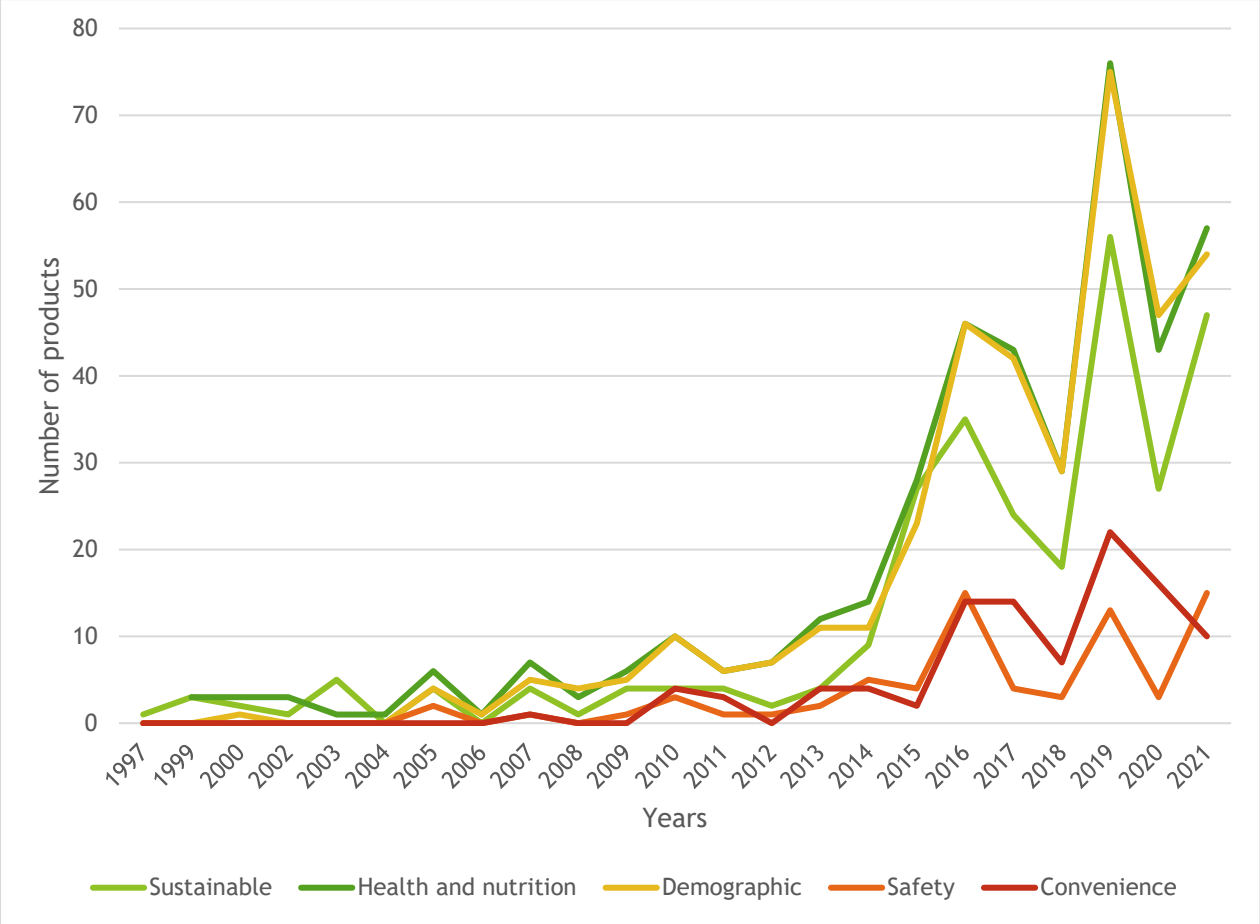

Figure 22: Trends in the number of products launched under different claims category.Source: Own computation based Global New Product Database (2022)

Figure 23 presents the top 20 claims positioning associated with hemp-based products launched in the UK from 1997 to 2021. Claims positioning with more than five per cent share are ethical - environmentally friendly package, gluten free, high/added fibre, GMO free, no additives/preservatives, vegan or no animal products, vegetarian, and organic. Organic hemp-based products were the most launched. Whilst the least among the top twenty are low/no/reduced calorie products.

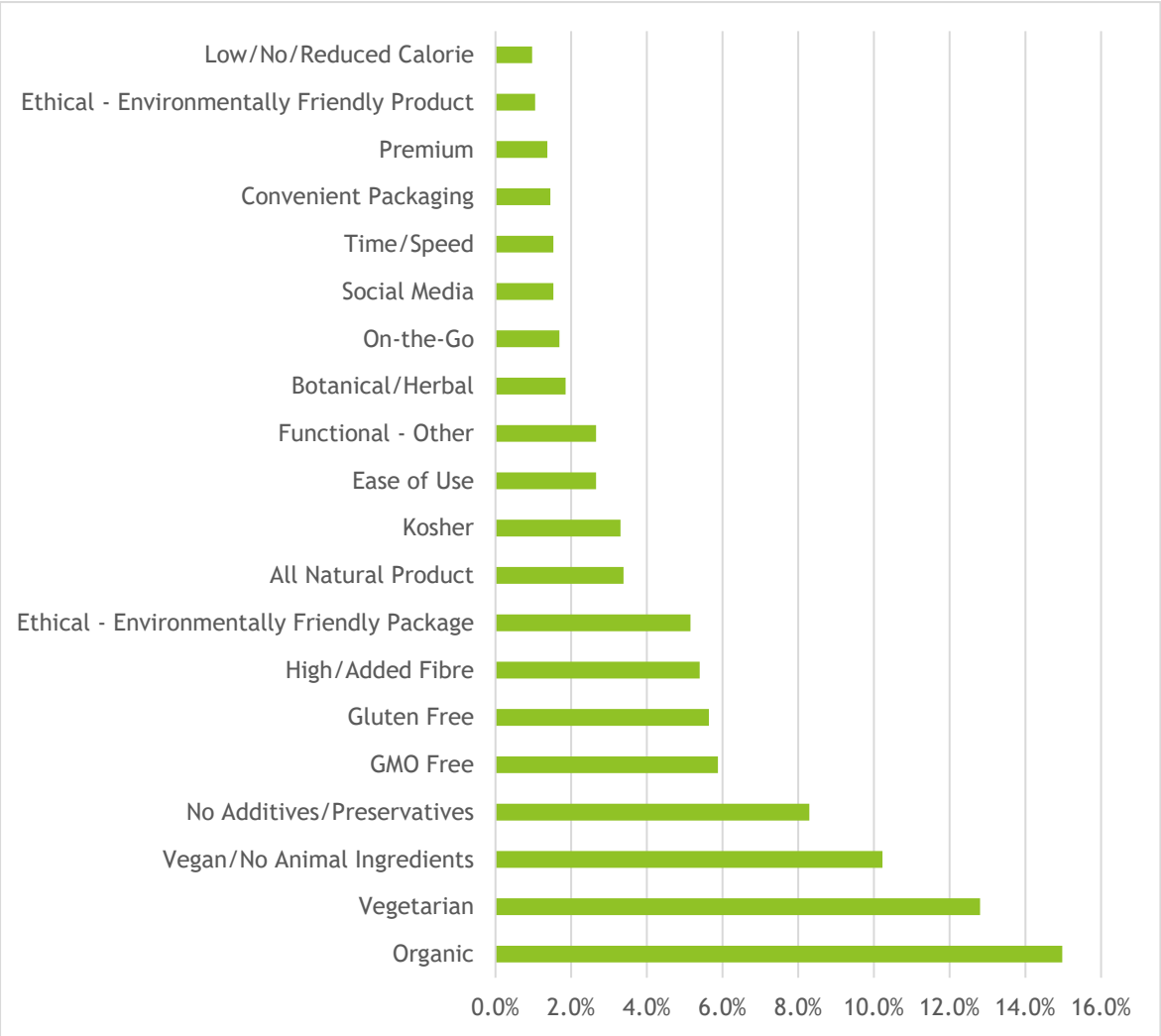

Figure 23: Top 20 claims positionings launched with hemp-based products from 1997 to 2021. Source: Own computation based Global New Product Database (2022)

Figure 24 shows the top 20 companies launching hemp-based products in the UK. A total of about 467 products were launched between 1997 – 2021 by 178 UK companies. Wholebake is the market leader launching about 5.6 per cent of the total number of products launched. About 20 per cent of all hemp-based products were launched by Wholebake, Naturya, Braham & Murray, The Food Doctor, 9 Brand Foods and Aldi. In the top 20, the lowest share of hemp-based products launched is attributed to Pep & Lekker (1.1 per cent). Major retailers in the UK launching hemp-based products include Aldi, Asda, Boots, Lidl, Marks & Spencer, and Waitrose.

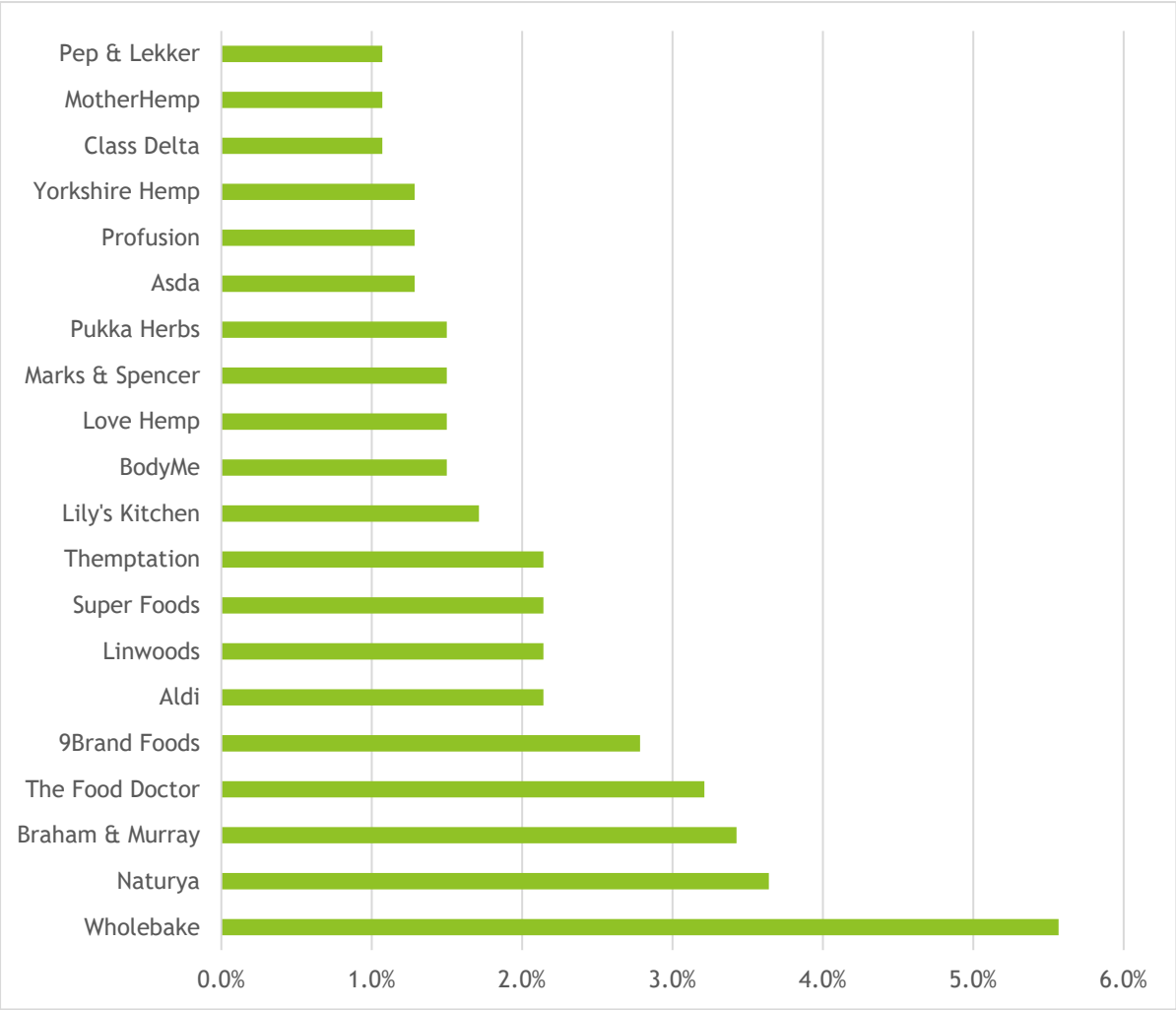

Figure 24: Top 20 companies launching hemp-based products in the UK from 1997 – 2021. Source: Own computation based Global New Product Database (2022)

A total of 463 brands were launched in the UK from 1997 to 2021. Figure 25 shows the top 20 brands of hemp-based products launched in the UK from 1997 to 2021. Wholebake which is the leading company also has the largest number of brands to launched into the UK market, representing about 5.4 per cent of the total products launched. Naturya is the second-largest brand launched in the UK, followed by Braham & Murray, The Food Doctor, 9 Brand Foods, and Aldi brands. All these makeup about 20.2 per cent of the total hemp-based products launched in the UK. Good Hemp brands which are popular in Sainsbury, Waitrose and Mark & Spencer launched 3.5 per cent of the total hemp-based products launched in the UK.

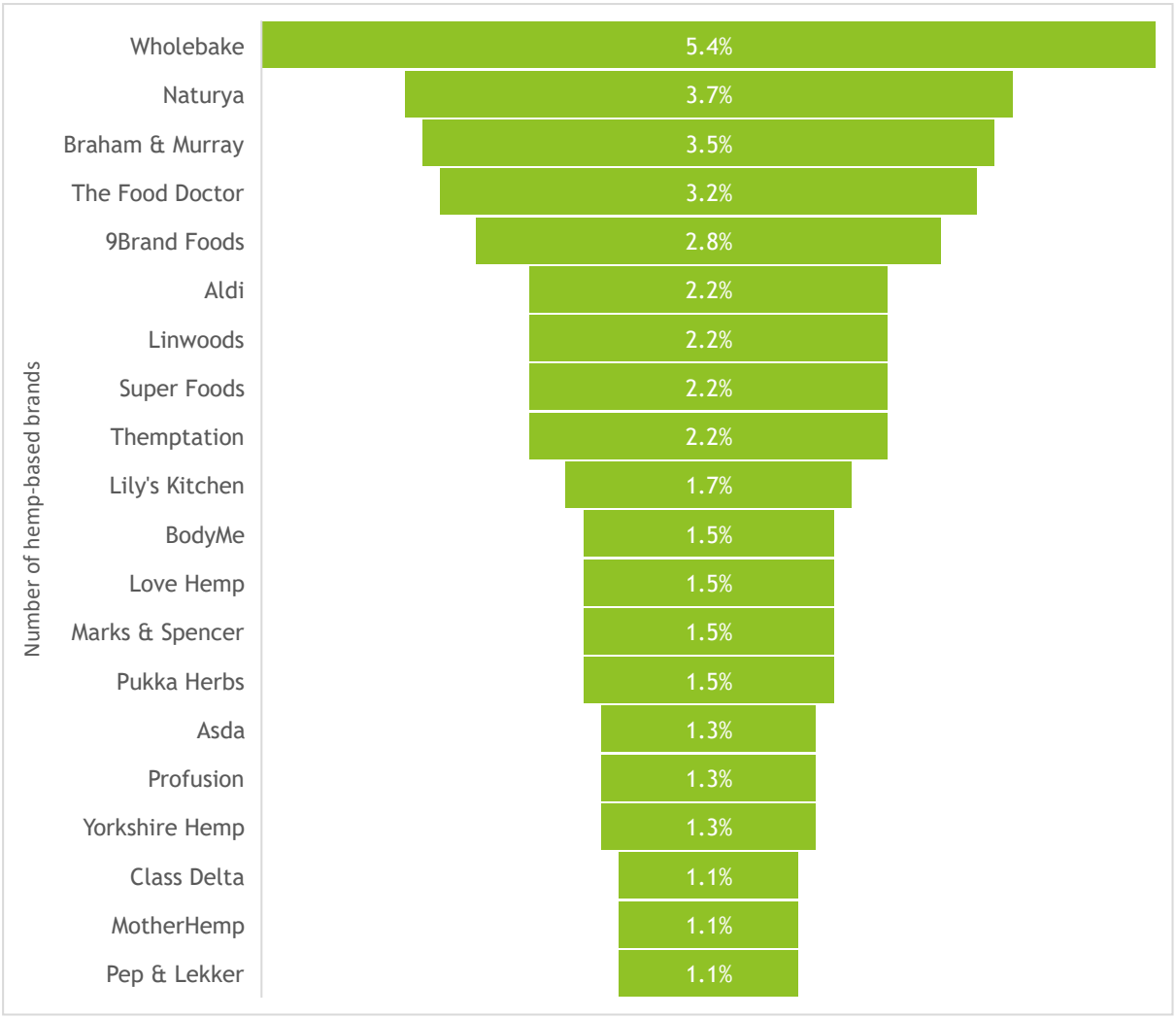

Figure 25: Top 20 brands of hemp-based products launched from 1997 to 2021. Source: Own computation based Global New Product Database (2022)

Figure 26 shows the number of products launched by claims category by the top five companies in the UK. Products with health and nutrition claims are the largest to be launched by all five companies. The companies with the largest number products in ascending order are launched by 9 Brand Foods, The Food Doctor, Braham & Murray, Naturya, and Wholebake. Products with Demographic claims are the second largest to be launched the five companies. The largest number of products under this claim was launched by Wholebake whilst the least was launched by The Food Doctor. Products with sustainable claims are the third largest whilst safety and convenience claims are the least across all companies.

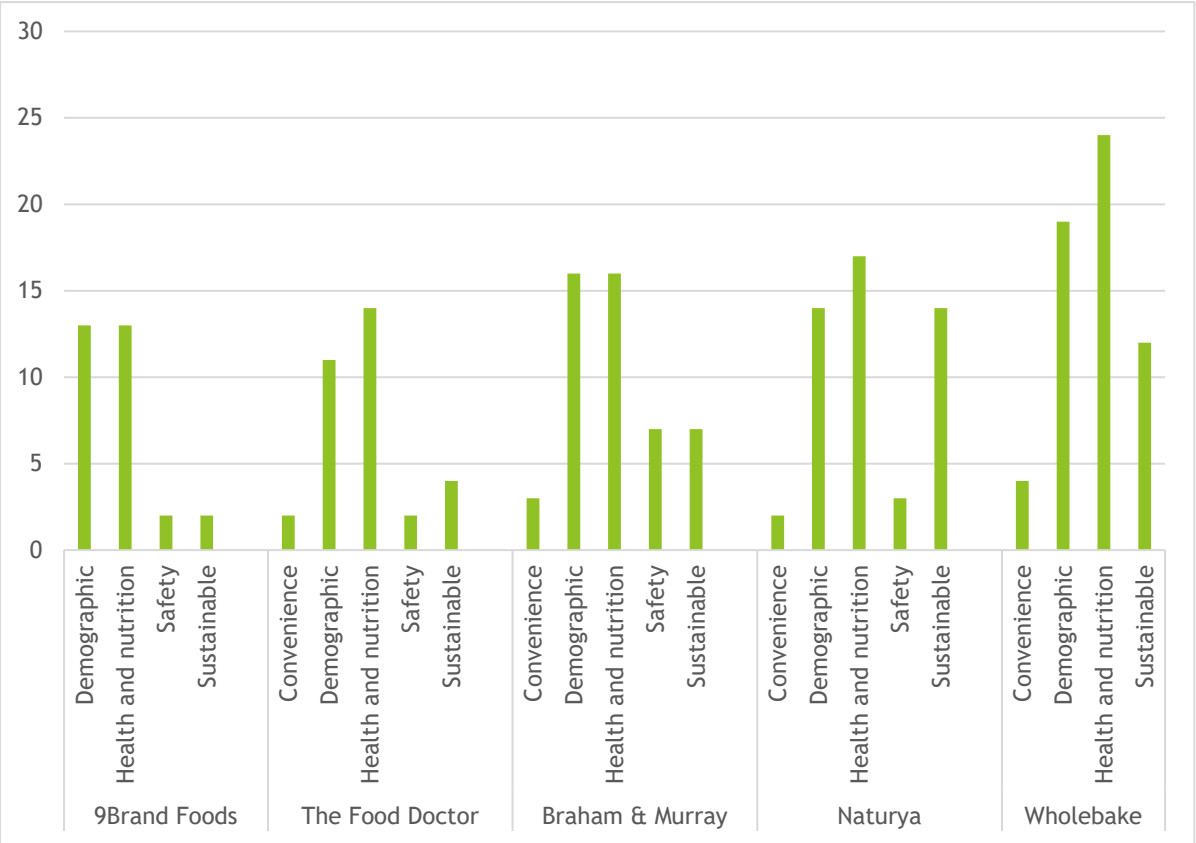

Figure 26: Top 5 companies in the UK and the number of products launched by claims category 1997 – 2021. Source: Own computation based Global New Product Database (2022)

Figure 27 show the top five companies in the UK and the number of products launched under different product categories. First, for Naturya, healthcare products are the main types of products launched containing hemp ingredients. Snacks are the second most launched products whilst Breakfast cereals have the least number of products launched. For Braham & Murray, sauces and seasoning products containing hemp ingredients form the majority, followed by dairy. Snacks and bakery are the categories with the least number of products to be launched. Wholebake and 9 Brand Foods launched only snack products with hemp ingredients. Majority of products launched by The Food Doctor are snacks. Savoury spreads, and meal and meal centres have the least share of products to be launched. In summary, health care, dairy, and snacks represent the largest categories of products with hemp ingredients launched by the top five manufacturers in the UK.

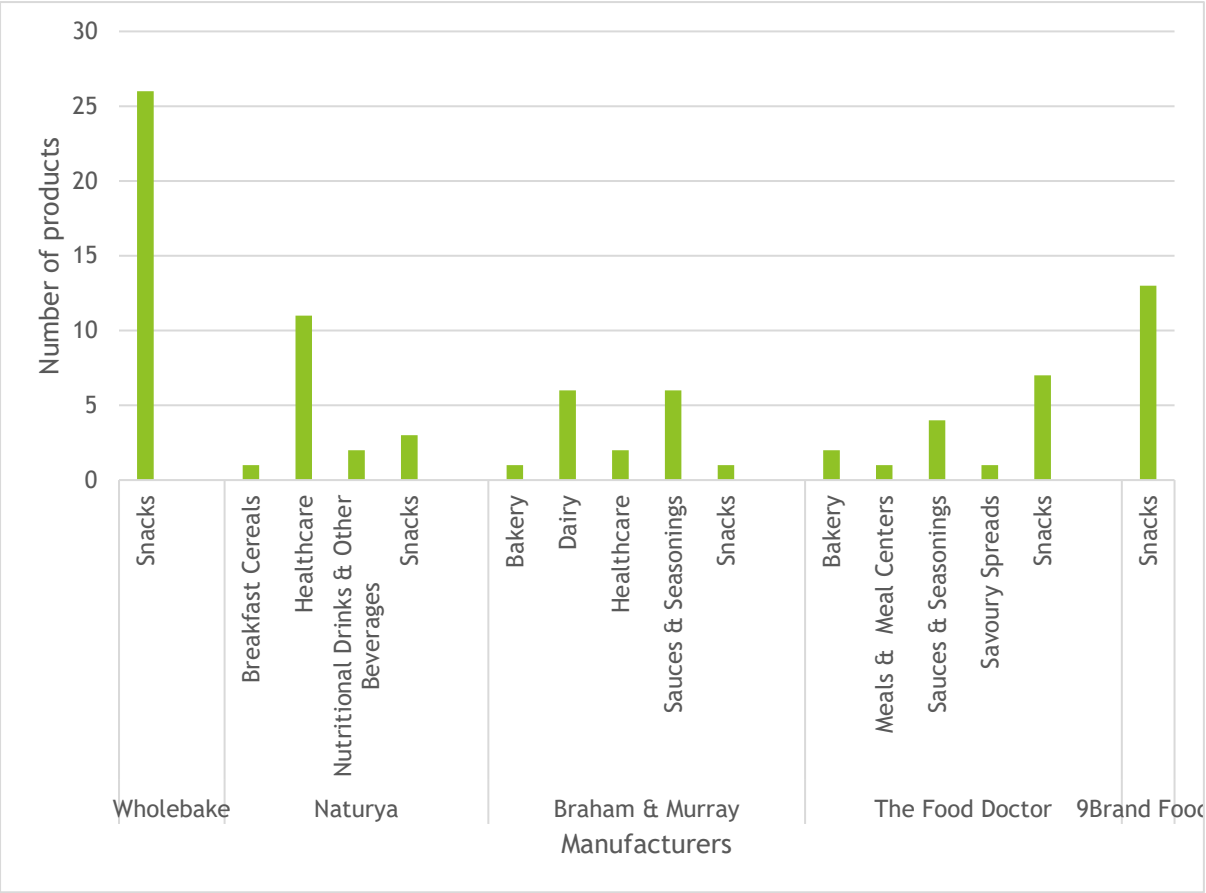

Figure 27: Top 5 UK companies and categories of products launched from 1997 – 2021. Source: Own computation based Global New Product Database (2022)

IV. Supply Chain

The hemp sector is still being developed in Scotland. We sent out questionnaires to about 20 - 25 farmers in Aberdeenshire and the Scottish border and had 7 (28 – 35% response rate) of them fully completing the questionnaires. The analysis below is based solely on responses obtained from these farmers. Although small in number these responses allowed us to outline the current existing supply chain as well as the strength, weaknesses, opportunities, and threat that these farmers foresee in the sector.

Supply chain map

Hempseed growers

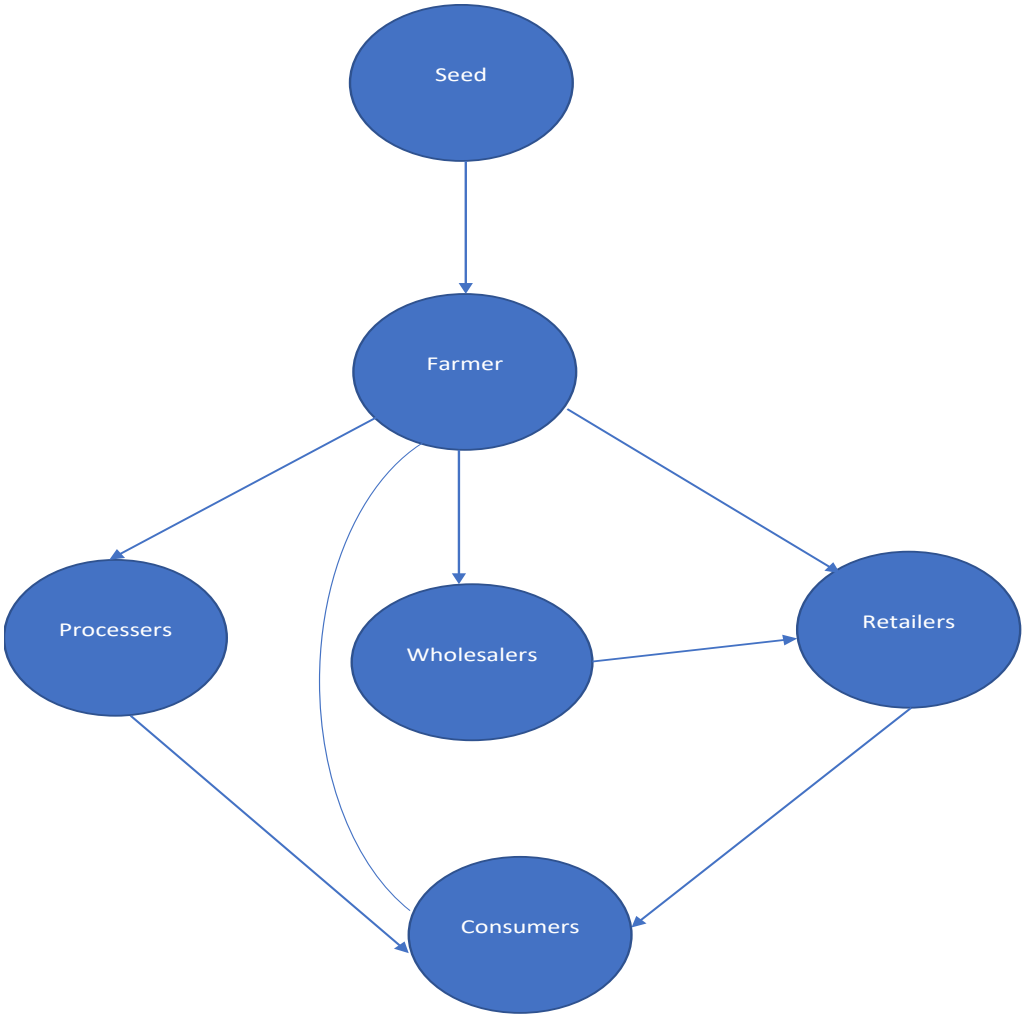

Figure 28: Supply chain map for hempseed

Production

The supply chain map for Scottish hempseed growers is a basic one. The seed for cultivation are imported and not produced in the UK. Based on the small amount of responses to the questionnaire, the majority of farmers grow hemp for the seed. These together cultivate a total of 17 hectares. The seeds are sown outdoors in the spring and take about three to seven days to germinate. The crop is cultivated once annually due to the prevailing weather condition in Scotland.

The farmers stated various reasons for cultivating hemp. Among them, and in no particular order, are: 1) Environmental benefits resulting from improved biodiversity of farmlands and the low input requirement of the crop; 2) Diversification benefits – most farmers think that planting hemp is a safety net. It is risky to produce only one type of crop; 3) Crop rotation - instead of leaving the land idle for years due to deterioration, most farmers prefer to cultivate hemp to take advantage of its role in soil remediation and improve soil biodiversity; and 4) Health benefits – farmers who are motivated to grow hemp are driven by the potential health benefits of the hempseed oil. Other farmers grow hemp because they want to try a new crop or produce their own food.

Processors

In June 2022, the first commercial production of cold pressed hemp oil was initiated in Scotland (Milne, 2022). This is a strong motivation for commercial production of hempseed in Scotland. Our data also shows that there are rapeseed oil processors who have expressed interest in pressing the hempseed into oil. However, these processors are unable to buy from Scottish hempseed growers due to the lower output and the high cleaning cost required to alternate between hempseed and rapeseed oil processing. Three out of seven farmers intend to sell their output to processor. These cultivate 11 hectares of hempseed which will produce an optimal output of 82.5 tonnes of hempseed.

According to the farmers lack of processing facilities for their produce is a major limitation to the commercial production of hempseed in Scotland. A total of five out of the seven farmers who answered the questionnaires reported this.

Wholesalers and Retailers

Some farmers listed wholesalers and retailers as the potential buyers of their output. This aspect of the supply chain is under-developed because there are currently no official wholesalers of hempseed. However, in the interim farmers can sell their output to the association British Hemp Alliance and the Scottish Hemp Farmers Association to increase their bargaining power. The data analysis from the GNP database suggests that there are retailers like Sainsburys, Aldi, Lidl, M & S who are potential buyers of the hempseeds. It is important for farmers to consider futures contract with these retailers before starting to plant the hempseeds. This is necessary considering the fluctuation of hempseed prices and to hedge themselves against potential price shocks.

Consumers

About three out of seven farmers intend to sell their outputs directly to consumers. The nature of marketing is not fully understood. However, farmers are required to clean the seed of debris and package them before offering them for sale. Whilst this will increase profit margins of farmers as there are no middle-men, farmers are required develop their own marketing channels and skills to ensure that they reach a large group of consumers. A major limitation to this is the prejudice people have towards the hemp crop. Some farmers suggested educating the public to distinguish between industrial hemp and marijuana.

Hempseed and fibre growers

The supply chain map of hempseed and fibre is simpler than that of hempseed described above. The same explanation for hempseed can be said for hempseed and fibre growers. However, a major distinction is that the supply chain of hempseed and fibre growers do not consider retailers and wholesalers.

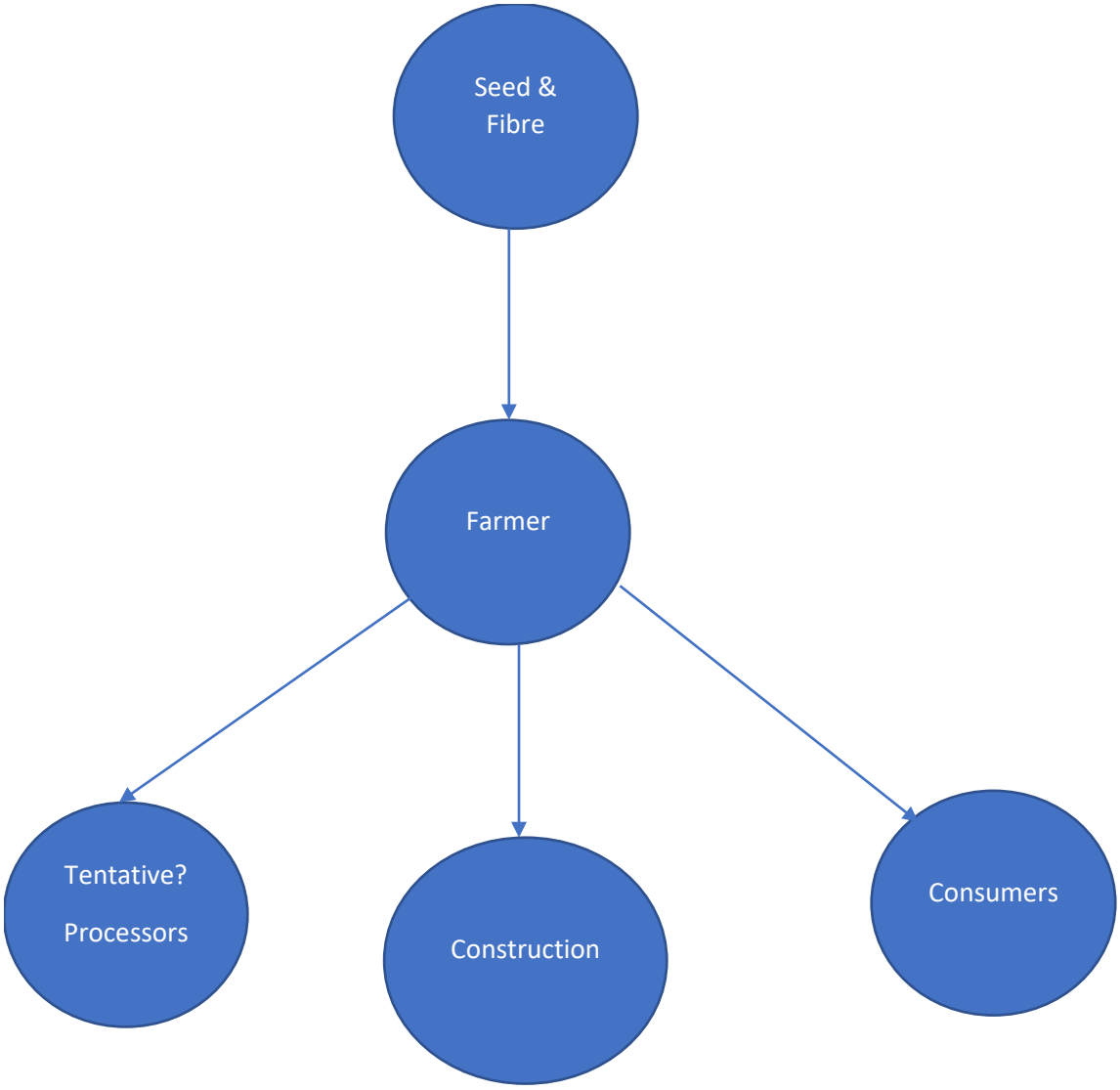

Figure 29: Supply chain map for hemp fibre

The farmers intend to sell their outputs directly to consumers, the construction sector, and processors. Therefore, the potential buyers of hempseed in this map are processors and consumers. The construction sector (not directly) uses the hemp fibre for insulation materials and wood for building. There is the need to establish a strong market link between hemp farmers and manufacturers (such as IndiNature) of insulation material and wood for the construction sector.

SWOT Analysis for the Scottish hemp sector

To be able to understand the Strengths, Weaknesses, Opportunities and Threats (SWOT) that will influence the success of the Scottish hemp sector, farmers were asked to answer a series of questions. A summary of the result can be found in Figure 30.

Strength	Weaknesses
• Environmental benefit of the crop • High yield or returns • Diversification/Crop rotation • Health benefits of the crop	• Difficult to obtain licence • Low profitability of the crop • Lack of technical support • Lack of processing facilities • No established market routes • High seed cost • Weather limitations
Opportunity	**Threats**
1. Financial support 2. Market routes 3. Farmer rewards i.e., carbon credits 4. Relax licencing process	1. Difficulty in obtaining license 2. Destruction of leaves and flowers 3. High licensing cost 4. Labelling of hemp as a restricted crop

Figure 30: Summary of SWOT analysis

Strengths

Environmental benefit of the crop

A major motivation or strength of the hemp sector is the environmental benefits attributed to the hemp crop. All farmers agreed that the crop is a low input one and has low climate impact. This is confirmed by the literature above that suggest that the hemp crop is low input and has numerous environmental benefits including improved biodiversity of the soil, soil remediation, carbon storage potential of the crop etc. This makes the hemp crop an important one to consider in crop rotation and on marginal agricultural lands contaminated with pesticides and fertilizer residues.

High yield or returns

Most farmers agree that the strength of the hemp sector is based high yield of the crop and maturity within a short period of time. The hemp crop can be grown for both fibre and seed for higher profitability. A small field could produce a large amount of hemp fibre as little spacing is required. In addition, the crop requires little or no pesticides and insecticides making it less capital intensive. However, most farmers prefer to grow the crop for its seed. Section 4 provides details of the economic returns of the crop. The crop has been shown to be profitable irrespective of the country or continent on which it is grown. Though hemp fibre and seed prices are unstable due to competition from other arable crops, farmers could harness their profitability by using the futures market to hedge themselves against price fluctuations.

Diversification/Crop rotation

The hemp crop is important to consider in crop diversification. Crop diversification allows the farmer to spread both production and economic risks over a broader range of crops. The crop improves both the soil and the environment as well as generating profits when the seed or fibre is sold. The risk of growing hemp is low due to its low input requirements and the usefulness of each part of the crop; flowers, leaves, stalk and seed. The crop is also essential to include in crop rotation as it can improve the soil for subsequent crops. It is able to absorb toxins and contaminated ions from the soil, improve the soil ecosystem, loosen the soil etc. These benefits coupled with the ability of the crop to grow in all types of soil makes it essential to include in arable cropping systems as well as on grasslands to feed livestock.

Health benefits of the crop

As discussed above, the hemp oil has many health benefits. hempseed is a potential source of gluten free flour for people diagnose of Celiac diseases; it is also a rich source of essential amino acid for vegans or people who do not take animal proteins. Its fibre is essential for producing allergen free clothes and an excellent substitute for cotton and synthetics. Furthermore, the hempseed oil is used in pharmacology to produce vast number of drugs to

treat diseases. It is also used in cosmetics to produce products that improve the skin and treat variety of skin conditions. The health benefits of the hemp crop is indispensable and a good strength of the hemp sector.

Weaknesses

Difficult to obtain licence

A major challenge faced by all hemp growers especially in Scotland is the process required to obtain licence for production. Most farmers describe the process as cumbersome, and the licence fee too expensive. As discussed above, the hemp crop is classified under regulated drugs requiring approval from the UK home office prior to cultivation. Without relaxing the regulation, it will be difficult for interested farmers to pursue the cultivation of hemp.

Low profitability of the crop

Although the hemp crop is traditionally believed to be a highly profitable crop, Scottish growers tend to disagree. This could be due to many local factors affecting commercial production of the crop. First, farmers are unable to sell their output due to low acreage under cultivation. Most processors who import hempseed or fibre are unable to buy from these farmers because of the low tonnage. These processors consider changing suppliers as a big risk if these farmers are unable to meet their monthly or annual demand for production. Moreover, there are criteria that the seed or fibre must met before they can be sold to these

"LICENSING LAWS IN CANADA, US AND EUROPE HAVE ALLOWED THE HEALTH, WELLBEING, MEDICINAL, CONSTRUCTION, TEXTILE INDUSTRIES TO FLOURISH. UK IS WELL BEHIND THE TIMES; WE ARE PLAYING CATCH UP IN AN ONLINE WORLD!"

processors/manufacturers/wholesalers. As a results, most farmers process their own products using inefficient technologies. Second, the highly distributed and small number of farmers does

not give Scottish hemp growers market power to influence the price they attract from potential buyers.

Lack of technical support

Another major weakness of the Scottish hemp sector is the lack of extension or technical support. Famers do not receive agronomic and marketing support from government trained agencies due to the prejudice attached to the crop. This has resulted in farmers using trial and error techniques which affect their output and profit margins.

Lack of processing facilities

The lack of processing facilities for hempseed and fibre is a major setback to the growth and development of the Scottish hemp sector. This has implications for value addition and profit margins. Farmers are forced to sell the raw produce since they are unable to add value to the products. As a result, a major share of the profit is lost to either the processer or the retailer. Moreover, the product are disposed off soon after harvesting at lower prices because farmers are unable to process to extend it shelf life.

No established market routes

Another major barrier to the success of the Scottish hemp sector is the lack of well-established market routes. Farmers are unsure about who their potential buyers are even though most have proposed to sell their products to consumers, retailers and wholesaler. There are no clearly defined marketing channels or established agents who are readily available to purchase their output. As a results, farmers have to market the product themselves to be able to continue producing each year. Well established wholesalers, processors and retail centres are essential for the growth of the Scottish hemp sector.

High seed cost and weather limitations

There are no established seed growers in Scotland and the UK. As a result, farmers must important 100 per cent of the seed they grow. This imposes a great financial burden on the farmers since they do not have the market power to affect the price they pay for the seeds. In addition, the constant fluctuation of the hempseed price affects the price they pay each year. There is therefore the need for to establish a hempseed production farm to remove this barrier. Another important limitation is the weather. The weather in Scotland does not allow the farmers to grow hemp all year round.

"I also believe the Zimbabwean hemp growers are able to achieve 3 crops per year in their climate"

A Scottish farmer

Opportunities

Financial support

The first important opportunity mentioned by farmers is financial support to ensure viability of the sector. Each part of the hemp crop provides opportunity for financial growth. However, this is only possible if farmers are able to receive financial support to build infrastructure to process and add value to the raw output. Hemp processing machinery require huge financial commitments and serves as an opportunity to develop and expand the sector. A well-established processing facility will extend the shelf life of the hempseed or fibre until it moves along to the next link in the supply chain. Farmers also mentioned the need for a financial assistance to fund more growing trials of different varieties of hemp seed in Scotland. Whilst this is important, establishing a seed centre where farmers can buy their seeds for cultivation will reduce the cost and difficult they face to import hempseed.

Market routes

Farmers identified that the lack of established market routes for both hempseed and fibre was a challenge. Several interviewees suggested that a well-developed market route will enhance the development of the Scottish hemp sector. Therefore, stakeholder's support is necessary to assist growers in getting marketing routes within Scotland, the UK and on international markets. GNP database suggests that large number of hemp-based products are produced each year by food and drinks manufacturers. A strong link between Scottish farmers and these manufacturers or processors is necessary for a thriving hemp sector.

Farmer rewards i.e., carbon credits

The cultivation of hemp enhances carbon sequestration which should be considered as an opportunity for hemp farmers to receive carbon credits. Moreover, the hemp plant can store up most of the carbon it takes from the atmosphere during its life cycle. Farmers could be rewarded for allocating land to the production of hemp and improvement of the natural ecosystem. Rewards in a form of carbon credits will encourage other farmers to incorporate hemp in their farming system.

Relax licencing process

The current legislation regarding the growing of hemp in Scotland does not encourage farmers to produce on a large scale. This deters farmers from venturing into hemp production. Farmers are unable to sell the leaves and the flowers which have important pharmaceutical benefits. Moreover, the required Tetrahydrocannabinol (THC) level of less than 0.2 per cent is a major limiting factor since this has been raised to about 2 per cent in Uruguay (Hudak et al., 2018). Switzerland and Australia allow their farmers to grow hemp varieties with a THC level of 1%. By relaxing the current regulation on the cultivation of hemp, many farmers will take advantage of the conducive environment to expand production as well as attracting new farmers.

Threats

There are several internal and external factors that have the potential to harm the developing of a sustainable hemp supply chain. To identify these factors, farmers were asked to select among several factors about the hemp legislation that they considered as a threat to the hemp sector.

The following factors were identified as threat to the development of the hemp sector in Scotland:

1) Difficulty in obtaining license. Currently licences for industrial hemp are valid for 3 growing seasons. After which the farmer needs to grow through the same process to have the licence renewed. A one time licence for industrial hemp cultivation could encourage farmers to make long term plans regarding the cultivation of the crop.

2) Destruction of leaves and flowers of industrial hemp prior to cultivation represents a loss of additional revenue to the hemp sector considering the importance of these two parts of the crop. As described above, the leaves and flowers are of both of cosmetic and medicinal value.

3) High licensing cost. According to the Home Office, a new licence application to cultivate cannabis with a THC content of 0.2% or lower will cost £580. In addition, farmers are required to pay a compliance visit fee of £1,371 and a licence renewal fee of £326. These costs may disincentise new farmers as the sector does not have strong market routes for the outputs.

4) Labelling of hemp as a restricted crop. Categorizing industrial hemp under controlled drugs has created an image that undermines the acceptance of the crop and its parts for domestic and industrial uses. The UK Government could consider listing the crop under tree crops planted in the UK.

In addition, other factors such as difficulty in getting the farmers to work together and restrictions on the type of fields to grow the hemp crop were considered as threat to the success of the sector.

Recommendations to improve the sector

The chart below shows a roadmap to developing a strong and resilient supply chain for hemp in Scotland. The roadmap is divided by timescale. The short-term recommendations can be achieved with the minimal resource in a period of 1 – 5 years. Medium-term measures are those that would require some amount of planning and commitment from policymakers and stakeholders in the hemp sector. These could be achieved within a timeframe of 6 – 10 years. Finally, the long-term recommendations are expected to be achieved after 10 years when the supply chain is well developed. A brief description of the recommendations is provided below.

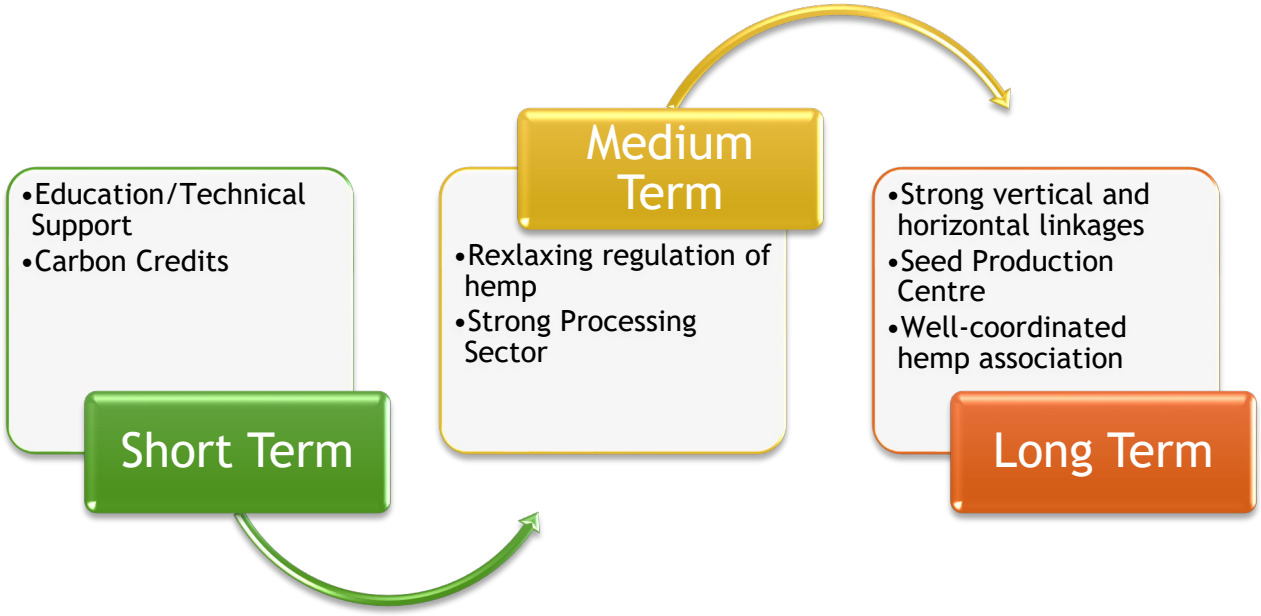

Figure 31: A roadmap to developing a supply chain for Scottish hemp

Education/Technical support

Our report suggests that the farmers believe that there is prejudice towards the hemp crop. The Scottish Hemp Association in collaboration with the British Hemp Alliance could develop a programme through educational resources, such as a podcast and/or video series to educate the population about the benefits of industrial hemp and explain the differences between industrial hemp and Marijuana. This will help to garner support from the grassroots to advance the call for the relaxation of the legislation. This will

help to eliminate the prejudice that the public has towards the crop and gain support from the population to advance the goal of developing a supply chain for hemp in Scotland.

Also, the Scottish Agricultural College which delivers extension services to farmers in Scotland could develop programs to provide both agronomic and technical support to hempseed and fibre farmers. There is a need to inform hemp farmers about the number of seeds to grow for hemp and fibre per acre of land, the depth to sow the seed, cultural practices to carry out before and after planting and how to harvest their products to minimize postharvest losses. This will be crucial to developing a strong production chain in the supply channel.

Carbon credits

The Scottish Government aims to reach a net-zero emission of all greenhouse gas an emissions by 2045. Hemp cultivation could be a cost effective means to contribute to a net zero goal. This report, therefore, recommends including hemp cultivation in the strategy to decarbonise the agricultural sector. An advantage of growing hemp is its environmental benefit i.e., carbon sequestration and the ability of the crop to store up about 45 per cent of the carbon it takes from the atmosphere during photosynthesis (Bouloc, 2013). However, a greater evidence base is required to ascertain the extent of hemps carbon sequestering potential and how this compares to other crops. The provision of permits to sell the carbon credits generated from planting hemp could support hemp farming. Businesses looking to offset their carbon footprint could be linked with these Scottish hemp farmers through the Woodland Carbon Guarantee[5]. Farmers will not only benefit from the economic value of hempseed and fibre but also contribute towards their sector and wider society becoming net zero.

Removal/relaxing of restrictions on hemp

A review of restrictions on places where hemp can be grown would both assist the sector but also create opportunity to grown hemp on marginal lands. Moreover, the UK government (Home Office) could ensure that the number of days it takes for farmers to obtain licence is reduced since the crop can be grown once each year. Moreover, licencing cost and processing

[5] The Woodland Carbon Code is a government scheme administered by Scottish Forestry but available UK wide

time is a major deterrent for new entrants. New farmers will not be able to benefit from the environmental impact of the crop if this limitation is not lifted.

Strong horizontal and vertical linkages

A major setback identified in the Scottish hemp sector is weak horizontal and vertical linkages. This report recommends that the farmers develop strong horizontal linkages amongst them to give a strong voice to the sector. Horizontal linkages refer to the collaboration between farmers either formally or informally. Strong coordination and communication are necessary to build a strong and resilient hemp sector, reduce transaction costs, and enhance the competitiveness of

> "Restrictions in which fields we grow in, time taken to get license"

the industry. Farmers must agree on what type of hemp variety to grow, the quality, the price to offer for sale etc. Vertical linkage refers to the relationship between firms at different levels of the supply chain i.e., between farmers and processors, processors and retailers, retailers and consumers etc. Strong coordination between marketing channel members is necessary for the development of the Scottish hemp sector. Farmers must understand what processors want and how to meet their needs; while processors must understand the needs of retailers; and retailers must understand what consumers want. The existence of a strong vertical linkage between processors and consumers will enable retailers to communicate better the health and environmental benefits of hemp products to consumers and receive appropriate feedback to give to processors. This will facilitate the development of innovative, affordable and appealing products that meet the taste and preferences of consumers. In summary, a strong vertical linkage will likely reduce waste and inefficiencies in the supply chain.

Development of a strong processing sector

The Scottish hemp sector cannot achieve both national and international impact without a thriving hemp processing sector within the supply chain. Although, new products containing hemp ingredients are developed each year in the UK food and drinks sector, other avenues like the construction sector, livestock, poultry and aquatic feed sector, cosmetic, textile, and automotive industry should be brought into the loop. Hemp processing machinery requires huge financial investment and therefore requires stakeholder support. A strong manufacturing/processing sector will enhance the hemp supply chain in Scotland as this is the main limitation to the development of the hempseed and fibre sector. Farmers are concerned about reducing the risk of their investment and will only commit to large production when there is a ready market for their output[6].

In the short term, the Scottish Hemp Association can act as a middle person to develop links with hemp processors like Good hemp and IndiNature. Farmers would be required to meet the quality requirements and supply-demand of these major processors to become their suppliers. This could be achieved by working together with the academic sector/extension services to develop innovative and higher-value products that meet the demand of processors.

Scottish seed production centre

Currently, there are two types of hemp varieties under trial in Scotland: Finola and Henola. These are imported from outside the UK and may not be productive under Scottish conditions. To establish a strong Scottish hemp sector, it is recommended the sector, supporting organisations and research institutes explore the potential to establish a hemp seed production centre. This will enable the centre to breed seeds that are suitable for the Scottish climate and soils and meet the quality requirements of UK-based processors. This will potentially reduce the reliance on foreign partners like Germany and France for seeds. A strong Scottish seed

[6] According to a news item by *The press and journal*, cold pressed hemp oil was commercially produced in Scotland in June 2022. This is a breakthrough for hemp seed farmers in Scotland.

production sector will also enhance the sustainability of the sector by limiting the impacts of external market shocks on the growers.

Strong and well-coordinated hemp growers' association

Finally, this report recommends the SHA works to develop a strong and well-coordinated hemp growers association for Scotland. This could be done by holding regular meetings to educate farmers on happenings in the sector and address challenges faced by the farmers. Working together as a farmer group can enhance the capacity of farmers, give them market power to buy seeds and market their outputs, and a strong voice to influence policy. Farmers can also pull resources together to establish a strong processing sector to extend the shelf life of their products and increase their profit margins. Moreover, the association could rely on the expertise of researchers working for the SEFARI and on SG-funded research programmes on hemp. This will help to bridge the knowledge gap.

V. Final remarks

This report is based on desk research, primary and secondary data analysis. The first part of the report aims to summarize, collate, and synthesize results from existing research on hemp production worldwide. It gathers online data on published scientific and grey literature, and government published data such as FAOSTATS, EUROSTAT, and HMRC data. The second part of the report relies on secondary data from the Global New Product Database (GNPD) which contains information on hemp-based products launched by major retail supermarkets and manufacturers from 1997 to 2021. This information was used to assess trends in new product development in the hemp market. The final part of the report analyses the supply chains for hempseed and fibre in Scotland using primary data collect from farmers in Aberdeen, Aberdeenshire, and along the Scottish borders. The report concludes with strong and time bound recommendations necessary to advance the Scottish hemp sector.

Our findings show that world production of industrial hemp has been on the decline since 1960s due to unfavourable political climate regarding the cultivation and use of the crop. For instance, the world production of hemp fibre fell from 368 thousand tonnes (highest) in 1966 to 83 thousand tonnes (lowest) in 1990 and rose again to 305 thousand tonnes in 2017. Also, the production of hempseed fell from 103 thousand tonnes (highest) in 1966 to 2.9 thousand tonnes (lowest) in 2014.

Globally, China, France, Netherlands, and Poland are the biggest producers of hemp fibre whilst Russia, Chile, Ukraine, and Iran are the biggest producers of hempseed. Similarly, in Europe, France, Poland, and Netherlands are the biggest producers of hemp in terms of tonnage and area allocated to hemp production. There are no official statistics on hemp production in the UK or Scotland. However, the HMRC has trade data which shows that the UK is a net importer of hempseed and hemp fibre. Major suppliers of hempseed to the UK are the Netherlands, France, Spain, and China whilst major countries importing UK produced

hempseeds are France, Germany, India and Netherlands. Also, major suppliers of hemp fibre to the UK are Lithuania, Netherlands, Australia, and Senegal. The UK also supplies hemp fibre to France, Australia, France, and UAE.

The potential markets for both hempseed and fibre are diverse, from food to construction. The environmental benefit is the ability of the crop to sequester carbon dioxide it extracts during growth; the ability to loosen the soil and beneficially impact on rotational cropping; has a lower requirement for nutrients, pesticides, and scores positively across biodiversity indices. It performs well in contaminated soils and can extract toxins from soil through phytoremediation. Also, hemp provides an eco-friendly insecticides and pesticides for use on agricultural farms. The oil from hempseed has a good balance of omega-3 and omega-6 fatty acids making it an essential ingredient in human and animal feed. The fibre can also be used for composites for manufacturing of car parts and furniture. The hemp oil is considered to be good for the skin and has been used in cosmetology to produce a range of products. Hemp can also be used to produce biofuel and it is a good substitute for biofuel produced from corn and soybean. Hemp can be used to produce a paper that is biodegradable and recyclable and used in eco-friendly and allergen-free textiles and fabrics. In the construction sector, hemp fibre presents a sustainable material for insulating buildings.

In the food and drinks sector, more than 4,076 hemp-based products have been launched worldwide from 1997 - 2021. Hemp-based products became very important after 2012 leading to exponential growth in the number of products launched. The UK is among the top five countries launching hemp-based products in the world. The USA is the country with the biggest number of hemp-based products, followed by Germany, Canada, the UK, and France. The majority of the products launched are in the following product categories: snack, nutritional drinks and beverages, health care, breakfast cereals and bakery.

Hemp-based products with health and nutrition claims, demographic claims and sustainability claims are the most dominant in the retail market. The top five claims positioning usually associated with hemp-based products are low, no or reduced allergen, vegan, gluten-free, organic and vegetarian.

The supply chain for Scottish grown hemp is still under development. Currently, there are no well-established market routes for farmers. However, the hempseed supply chain is well integrated than that for hemp fibre because only a few farmers intend to grow hemp for seed and fibre. The supply chain is exposed to many shocks limiting its development, including no established market routes, low profitability, lack of technical support, weather limitation, lack of financial assistance etc. However, the potential benefits and opportunities for the crop are enormous outweighing the current threats and weaknesses found in the sector.

A quick glance at the report suggests a huge market potential for hemp seed and hemp fibre in Scotland and worldwide despite the strong barriers, especially in legislation. Deficits in trade, the enormous environmental benefit of hemp, and the numerous ranges of products derived from hemp and its products makes it necessary for the government and stakeholders re-consider the prospect of the hemp crop in Scotland. This is relevant to developing the capacity to ensure that a thriving industry is established here in Scotland.

Some important and time bound recommendations have been made to strengthen the development of the hemp sector in Scotland. First, there is the need for farmers to have access to the agronomic requirements of the crop. Second, a review of the licensing system may enable new or existing farmers to better benefit from the environmental advantages offered by the crop. Third, restrictions on where hemp can be grown, limit of THC, and destructions of the hemp flowers should be reconsidered. In addition, the time to obtain the licence and cost should be reduced to encourage new entrants into the sector. Fifth, strong horizontal and vertical

linkages are required to ensure a resilient hemp supply chain. All supply chain agents in the hemp sector are required to play a conscious role in this to achieve the goal. Finally, there is the need for the association to consider establishing both hemp processing facilities and seed production sites to ensure a sustainable hemp sector is developed.

VI. References

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Appendix – Agronomic/Life cycle of industrial hemp

Industrial hemp is a medium to tall, erect annual herb. The plant does well in an open sunny environment, light well-drained soil, and adequate nutrients and water. The plant can grow as high as five meters within four-six months after germination. Research has shown that the plant grows well when planted along exposed riverbanks, meadows, and agricultural lands. Hemp grown for fibre are usually planted in close stands for the plant to grow tall, thin, straight stalks. For seed production, the plant is usually spaced and not crowded by its neighbours, the limbs bearing flowers grow from small buds located at the nodes along the main stalk (Clarke, 1999).

The cannabis seeds are sown outdoors in the spring and take about three to seven days to germinate. The first true leaves, usually, germinate about 10 cm or less above the cotyledon. Under the favourable condition, the plant grows up to 10 cm a day during the long summer days. The hemp plant has a dual response to day length. During the first two or three months, it responds to daylength with more vigorous vegetative growth, however, later in the season it requires shorter days to flower and completes its cycle. Flowering takes place when the cannabis plant is exposed to a critical day length of twelve to fourteen hours depending on the variety and origin. More importantly, dark (night) cycles must be uninterrupted by light periods in order to induce flowering.

The plant is a dioecious annual wind-pollinated crop, meaning that male and female flowers develop on separate plants. Monoecious cannabis is very rare (Clarke, 1999). Both male and female hemp plants exhibit different growth rates and development – males tend to flower and senesce earlier (Meijer et al., 1995). Before flowering, it is difficult to differentiate between male and female cannabis, except for general trends in growth habits in certain varieties such as height and extent of branching. After flowering, male cannabis can be differentiated by their curved claw shape flower primordia, followed by the differentiation of round, pointed flower buds having five radial segments. The female Cannabis crop has enlarged symmetrical tubular

bract (Clarke, 1999). Female plants also tend to be shorter and have more branches than males. They are leafy to the top with many small leaves surrounding the flowers. Whilst the female plant may mature up to five months after viable flowers are formed, the male plant usually dies soon after pollen is shed. Compared to the female plants, male plants exhibit quick increase in height and a more rapid decrease in leaf size to the leaflets that accompany the flowers.

Fresh and fully matured seeds have about 100 per cent viability, however, this decreases quickly with age. At least 50 per cent of the seed will germinate after three to five years of storage at room temperature (Clarke, 1999).