



EMCDDA PAPERS

Developments in the European cannabis market

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Key points:

- This publication reviews how a number of factors impact on the diversity and content of products and forms of cannabis available in Europe. Drivers of change in this area include policy developments in Europe and elsewhere; advances in production and extraction techniques; and consumer interest.
- Understanding and monitoring trends in the composition of cannabis products available to European consumers is important, as it is likely to both be associated with the attractiveness of different products to consumers and have implications for associated health risks.
- This analysis focuses on cannabinoids (such as Δ^9 -tetrahydrocannabinol (THC) and cannabidiol (CBD)), which are synthesised by/in the cannabis plant. THC is the most important component of cannabis in relation to its attractiveness for recreational use, although consumer interest in CBD is growing, both because it is considered to have some beneficial effects and because it may moderate some of the less desirable effects associated with THC consumption.
- In recent years, various synthetic cannabinoids have appeared in Europe and complicate further analysis in this area. Some of these are now

controlled internationally and national legislation in some countries also restricts the use of synthetic cannabinoids or specific synthetic cannabinoids. While synthetic cannabinoids mimic to some extent the action of THC in the brain, they should be distinguished from natural cannabis-based products. This is because they may sometimes be associated with both greater and different health risks.

- Analysis shows that THC concentrations have risen in European cannabis. Recently, this increase has been most pronounced for cannabis resin. For herbal cannabis, increases in potency have been associated with the growth in domestic production, under intensive conditions, within the EU. For cannabis resin, changes in THC concentrations have been attributed to the introduction of strains of cannabis plants in Morocco producing high levels of THC, although

(Continued on next page)

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other factors may have also played a part in this development.

- Advances in extraction techniques can be, and are now being, used to produce extremely high-potency products known as cannabis concentrates.
- Cannabis can also be prepared in edible form and may be sold in this form ready for use. The prevalence of concentrated and edible cannabis products has increased in legal markets in the United States, which may indicate that similar trends could arise as regulated medical (and potentially recreational) use of cannabis gains traction in Europe. However, it should be recognised that the regulatory frameworks in the United States and Europe are markedly different.
- Monitoring developments in the area of cannabis is also complicated because the number of cannabis-based medical and health-orientated products has expanded. These include products manufactured to pharmaceutical quality standards, and others with varied composition and product descriptions. Some of these may potentially be confused with forms of cannabis available on the illicit drug market.
- Recently, cannabis products with very low levels of THC have also appeared on the market in some European countries based on the argument that the THC concentrations are so low that they

are not restricted by drug control regulations. These can be sold as foodstuffs, healthcare products and cosmetics. CBD oils have recently been marketed as 'food' supplements and these oils may also contain THC, although usually at low concentrations.

- Overall, the dynamic nature of the current cannabis market and diversification of cannabis products available gives rise to considerable challenges for existing monitoring approaches. Sound information on the nature of the cannabis available to European consumers is important for policy and regulatory discussions. In addition, new forms of cannabis have the potential to impact on the public health consequences of cannabis use; the attractiveness of cannabis products to users; and regulation across a range of complex policy areas. There is therefore an urgent need to both improve the conceptualisation of the cannabis market for monitoring purposes and develop a comprehensive set of tools that are commensurate with the growing needs in this area.

Introduction

This paper provides an overview of established and emerging cannabis products in Europe. For each type of product, major issues in its production, distribution, use and effects on health are detailed. In doing so, the paper seeks to inform a discussion of the new challenges that may emerge in the monitoring of these products and the consequences of their use. At the time of writing, regulated markets for recreational cannabis had yet to emerge in Europe, though the policy in some countries in the Americas is rapidly shifting towards the legalisation of the recreational and medical use of cannabis. It is therefore timely to provide an overview of the diversification of cannabis products in Europe, to contribute to the available knowledge on cannabis market changes and their implications for policy and practice. While there are other aspects of relevance, including the *modus operandi* of organised crime groups and traffickers, prevalence and other consumption metrics, these are not addressed in this report, as detailed information is provided in other European Monitoring Centre for Drugs and Drug Addiction (EMCDDA) publications.

Cannabis is by far the most widely used illicit drug in the European Union (EU), accounting for 38 % of all money spent on the illicit drug retail market (EMCDDA and Europol, 2016). Among adults (aged 15-64), it is estimated that 24.7 million (7.4 %) have used cannabis in the last year (EMCDDA, 2019). The two main cannabis products used in Europe are herbal cannabis (marijuana) and cannabis resin (hashish). In Europe, these are typically smoked in joints (rolled cigarettes) containing tobacco (Hindocha et al., 2016).

The cannabis plant synthesises at least 144 unique compounds known as cannabinoids ⁽¹⁾ (Hanuš et al., 2016). The most abundant of these is Δ^9 -tetrahydrocannabinol (THC). THC produces the effects that people who use cannabis seek from the drug, such as feeling 'high' and relaxed with changes in the perception of colours and sounds. THC can also cause unwanted effects such as memory impairment, anxiety and paranoia. These adverse effects become more severe with higher doses of THC. Concentrations of THC in cannabis products have risen in recent years, and evidence suggests that users only partially adapt to changes in THC (Curran et al., 2016). As a result, people who use cannabis may have been exposed to rising doses of THC over time. These changes may have increased the level of adverse health effects related to cannabis use. In Europe, the number of first-time admissions to drug treatment for cannabis problems increased by 76 % from 2006 to 2017 (EMCDDA, 2019). It is possible therefore that an increase in the concentration of THC in cannabis is associated with this increase in admissions to treatment

(Freeman et al., 2018). However, conclusions in this regard need to be made with caution, as other factors — such as a greater awareness of cannabis-related treatment needs, an overall increase in the level of provision and changes in referral practice, including direct referrals from the criminal justice system in some countries — could also explain this increase.

Cannabidiol (CBD) is typically the second-most abundant cannabinoid produced by/in the cannabis plant. CBD is non-intoxicating and has shown promise as a treatment for several medical conditions including epilepsy, psychosis and anxiety disorders (Bergamaschi et al., 2011; Devinsky et al., 2017; McGuire et al., 2017; EMCDDA, 2018b). CBD has been found to offset some of the harmful effects of THC, such as memory impairment and paranoia, without influencing the 'high' sought by users (Englund et al., 2017). Some evidence also suggests that the balance of THC to CBD may contribute to the level of harm experienced from long-term cannabis use. While frequent use of cannabis with high THC to CBD ratios has been associated with a greater risk of psychosis and dependence, it has been argued that this is less commonly observed with the use of cannabis with a more balanced THC to CBD ratio (Di Forti et al., 2015; Freeman and Winstock, 2015). It has also been suggested that encouraging the use of cannabis with a more balanced THC to CBD ratio may therefore be a strategy for harm minimisation (Englund et al., 2017).

THC and CBD are both synthesised by/in the cannabis plant in the glandular trichomes. These structures are resinous and sticky, helping to defend the plant against herbivores and environmental stresses. They differ from non-glandular trichomes, which occur in either cystolithic (found on the upper surface of the cannabis leaves) or non-cystolithic (appearing mainly on the lower side of the leaves and bracts) form. Capitate-stalked trichomes (Figure 1) are most abundantly distributed around the female flowers and produce the highest quantity of cannabinoids (Turner et al., 1978). Maximising the production of these capitate-stalked trichomes (and/or improving the efficiency of extracting THC from them) is a key method for increasing the potency ⁽²⁾ of cannabis products. Bulbous trichomes are also glandular but are smaller in size and produce fewer cannabinoids. In addition to the cannabinoids, glandular trichomes also contain essential oils known as terpenes, which give cannabis its distinctive odour. Variations in the terpene profile affect the experience of using cannabis by influencing its taste and smell, and may influence its pharmacological effects (Russo, 2011).

⁽¹⁾ Here the term 'cannabinoid' is used to refer to those synthesised by/in the cannabis plant, or phytocannabinoids. These differ from synthetic forms of THC (e.g. dronabinol) and from synthetic cannabinoid receptor agonists, or 'synthetic cannabinoids', which are discussed later in this report.

⁽²⁾ In pharmacology, 'potency' is often related to the amount (dose) of the drug required to produce an effect. Therefore, using 'potency' to describe the concentration of THC in cannabis products is not technically correct. A more accurate term would be 'strength', which is the amount of THC in a defined unit of the product. However, for consistency with previous publications and to allow comparison with other studies the term 'potency' is used throughout this report.

FIGURE 1

Both THC and CBD are synthesised and deposited in capitate-stalked trichomes on the cannabis plant (top). Trichomes help to defend the plant and are abundant in the flowering tops of female plants (bottom).



Photos: © David Potter.

Herbal cannabis

The flowers of female cannabis plants contain the greatest density of capitate-stalked glandular trichomes and therefore the highest concentration of cannabinoids. For this reason, the flowers of female cannabis plants are preferentially harvested and dried to produce herbal cannabis. Leaves contain low concentrations of cannabinoids, while other parts of the plant, such as the stem, seeds and roots, contain minimal or no cannabinoids. After drying, the floral material is removed from the stems and is ready for use.

In 2017, there were 440 000 seizures of herbal cannabis in the EU, accounting for 40 % of the total number of drug seizures in the EU that year (EMCDDA, 2019). In broad terms, there appear to be two main types of herbal cannabis in European markets, imported herbal cannabis and 'sinsemilla' or indoor-grown herbal cannabis, produced within the EU. While it is recognised that there are a few exceptions to this classification, the distinction is sufficiently widespread to make these categories valid. Under natural conditions, the pollination of female cannabis flowers by male plants results in the production of seeds. Herbal cannabis containing seeds is typically produced from outdoor-grown landrace ⁽³⁾ crops outside the EU. This is referred to here as 'imported herbal cannabis'. Imported herbal cannabis is often heavily compressed or vacuum packed after drying to facilitate international trafficking, and is typically a dark green to brown colour. It may be sold in compressed blocks, as bundles of herbal material or as loose plant material containing flowers, stems and seeds (Figure 2). Data collected by the EMCDDA indicates that the Balkans and Sub-Saharan Africa are major sources of imported herbal cannabis (EMCDDA, 2012).

When herbal cannabis is produced under controlled conditions, female plants are almost exclusively cultivated in the absence of male plants. This process prevents fertilisation, enabling female plants to continue flowering for longer and to expend additional energy producing more trichomes, resulting in a greater concentration of cannabinoids. Herbal cannabis produced in this way is referred to as 'sinsemilla' (from the Spanish words '*sin*' (without) and '*semilla*' (seed)); it is also known as 'indoor-grown herbal cannabis', '*nederwiet*' in the Netherlands and '*skunk*' in the United Kingdom ⁽⁴⁾ (see Figure 3). This form of herbal cannabis is typically produced in the EU and appears to be the most common type of herbal cannabis used in the EU. The freshness of the product and the high abundance of glandular trichomes results in high levels of terpenes creating its strong and distinctive odour.

A number of other factors contribute to the cannabinoid profile of herbal cannabis (Potter, 2014). The synthesis of THC and CBD is genetically determined, with plants either producing high levels of THC, high levels of CBD or a mixture of THC and CBD. THC and CBD are synthesised in the plant from a common precursor via distinct biosynthesis pathways, which means that CBD production limits the amount of THC synthesised and vice versa. As a result, THC-producing

⁽³⁾ A landrace is a domesticated, locally adapted, traditional variety of a species that has developed over time, through adaptation to its natural and cultural environment of agriculture and pastoralism, and as a result of isolation from other populations of the species.

⁽⁴⁾ 'Skunk' is one of many specific hybrid strains of cannabis (others include 'White Widow' and 'K-2'); however, this term is also used in the United Kingdom as a generic name for unfertilised female cannabis flower with high concentrations of THC.

FIGURE 2

Imported herbal cannabis in a compressed block.



Photos: © Tom Freeman (left) and David Potter (right).

strains are almost exclusively selected to maximise THC yields. Cannabis plants are selectively bred for desirable characteristics such as a desirable profile of cannabinoids and terpenes (contributing to odour and taste), a high yield of cannabis flower and resistance to disease. There are many different strains available. An analysis of cannabis samples sold in coffee shops in the Netherlands from 2005 to 2015 found that the most commonly sold strains were 'White Widow', 'K-2', 'Power Plant', 'Amnesia Haze' and 'Jack Herrer'; all had mean THC concentrations of 16-17 % (Niesink et al., 2015). The most recent (2016-2017) THC data published by the Trimbos Institute showed that domestic herbal cannabis (*nederwiet*) had an average THC concentration of 17 % (Rigter and Niesink, 2017). In addition to genetics, optimising

growing conditions can have marked effects on cannabinoid production. Indoor cannabis production facilities therefore typically utilise powerful lighting systems, which maintain flowering throughout the year by manipulating the length of the day-night cycle, and CO₂ generators, which enhance photosynthesis by increasing CO₂ levels. In addition, fertilisers and pesticides are commonly used to promote plant growth and prevent damage by mould or insects.

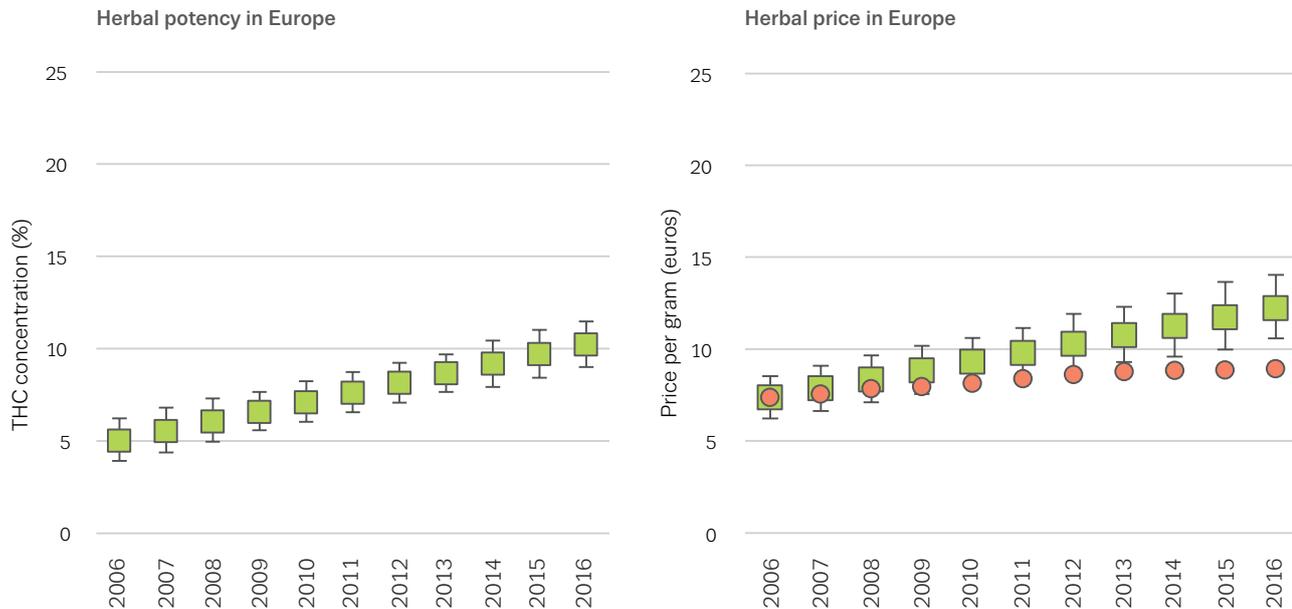
FIGURE 3

Sinsemilla is produced by preventing the pollination of female plants, resulting in the production of large flowering tops (left). Sinsemilla is typically sold in the form of whole flower (right).



Photos: © David Potter (left) and Tom Freeman (right).

FIGURE 4

Changes in the potency and price of herbal cannabis in Europe, 2006-2016.

Note: Data show means (+/- 95 % confidence intervals) for estimated trends after accounting for variation across countries. Expected changes based on inflation of consumer goods are shown in red circles.

Changes in the potency and price of herbal cannabis

Data collected by the EMCDDA (Figure 4) show that the potency of herbal cannabis in Europe doubled from an estimate of 5 % to 10 % THC from 2006 to 2016 (Freeman et al., 2019). There was also an increase in the price of herbal cannabis from an estimated EUR 7 to EUR 12 per gram (Freeman et al., 2019). This upwards trend was still evident after adjusting for inflation according to the Harmonised Indices for Consumer Prices (Eurostat, 2018).

Country-specific studies have also reported changes in herbal cannabis products. For example, the Trimbos Institute reported increases in cannabis potency in the Netherlands from 2000 to 2004: the potency of *nederwiet* rose from 9 % to 20 % THC and the potency of imported herbal cannabis rose from 5 % to 7 % THC (Pijlman et al., 2005). However, from 2005 to 2017 the potency of *nederwiet* decreased marginally, from 18 % to 17 % THC, and the potency of imported herbal cannabis remained at the same level, around 7 % THC (Niesink et al., 2015; Rigter and Niesink, 2017). Surveys in the United Kingdom found that the potency of both imported herbal cannabis and sinsemilla were similar in 2004/2005 and in 2016, but that the market share of sinsemilla increased from 51 % in 2005 to 94 % in 2016, increasing the mean potency of all cannabis products seized (Potter et al., 2008, 2018). Studies in France and Italy also found that increases in the potency of herbal cannabis are partly attributable to an increased market share of sinsemilla relative to imported herbal cannabis. While not routinely tested, the ratio of cannabiol to THC provides an indication

of the freshness of the cannabis, which may be useful for assessing domestic cultivation dynamics in Europe (Zamengo et al., 2014, 2015; Dujourdy and Besacier, 2017). Increases in the market share of sinsemilla may account for the observed increase in THC content at the European level.

Cannabis resin

In addition to herbal cannabis, plant material can be used to produce cannabis resin. This can create products with higher THC concentrations than herbal cannabis preparations, increasing the value of the products relative to their weight. Cannabis resin is typically brown in colour and is compressed into bars, balls or other shapes. This facilitates trafficking by allowing relatively large quantities of the drug with a high retail value to be concealed in smaller packages than would be the case for herbal cannabis. Moreover, cannabis resin may not have the strong and distinctive odour of sinsemilla, reducing the risk of detection. These factors, together with consumer preferences in some countries, make cannabis resin a desirable product for international drug trafficking. In 2017, there were 311 000 seizures of cannabis resin in the EU, accounting for 28 % of all drug seizures (EMCDDA, 2019). Although there are currently a greater number of seizures of herbal cannabis than of cannabis resin, the total quantity of resin seized (424 tonnes) in 2016 exceeded that of herbal cannabis (124 tonnes).

FIGURE 5

Traditional resin production using the 'rubbing method'. The flowers of female cannabis plants are rubbed between the hands, depositing the sticky resinous trichomes. Resin produced in this way is often called 'charas'.



Photos: © David Potter.

Morocco is believed to be the largest producer of cannabis resin for export to European markets. Trafficking routes into Europe include Spain, Portugal and eastwards along the Mediterranean Sea. The Netherlands is a major distribution point for Moroccan resin throughout Europe (including to Denmark, Germany and the United Kingdom) and beyond (Russia and Belarus). Resin produced in Afghanistan is also trafficked directly to the United Kingdom from south-west Asia (EMCDDA, 2017a). Resin produced in Lebanon, though less frequently encountered, may also be trafficked into Europe. In addition, there is also now some evidence of the limited domestic production of cannabis resin within Europe (Chouvy, 2016).

Traditional methods of resin production include the 'rubbing method' (Figure 5), typically used in south-west Asia and the Himalayas, and the 'sieving method', used in Morocco, Afghanistan and Pakistan, and domestically within Europe. Manicure waste from the plant or 'trim' is often used for sieving, but sinsemilla can be used to produce a higher potency product. In addition to screens, alternative devices can be used for sieving such as a rotating drum or 'pollinator'. When using the sieving method, the efficiency of extraction can be improved by including additional stages in the process such as freezing the plant material or processing it with icy water/dry ice (solid carbon dioxide). This hardens the trichomes, allowing their heads to be easily removed and increasing the potency of the extracted product (Figure 6).

FIGURE 6

Exposing cannabis plant material to cold temperatures can increase the efficiency of extraction. Cannabis is placed in icy water and aggravated using a food processor to remove the trichomes (1) before sieving (2). Dry ice can also be used to remove the trichomes (3) before sieving (4).



Photos: © David Potter.

FIGURE 7
Cannabis resin samples from police seizures in England in 2016 (Potter et al., 2018). The THC concentrations of each product are shown in red, and the CBD concentrations are shown in blue.



Photo: © David Potter.

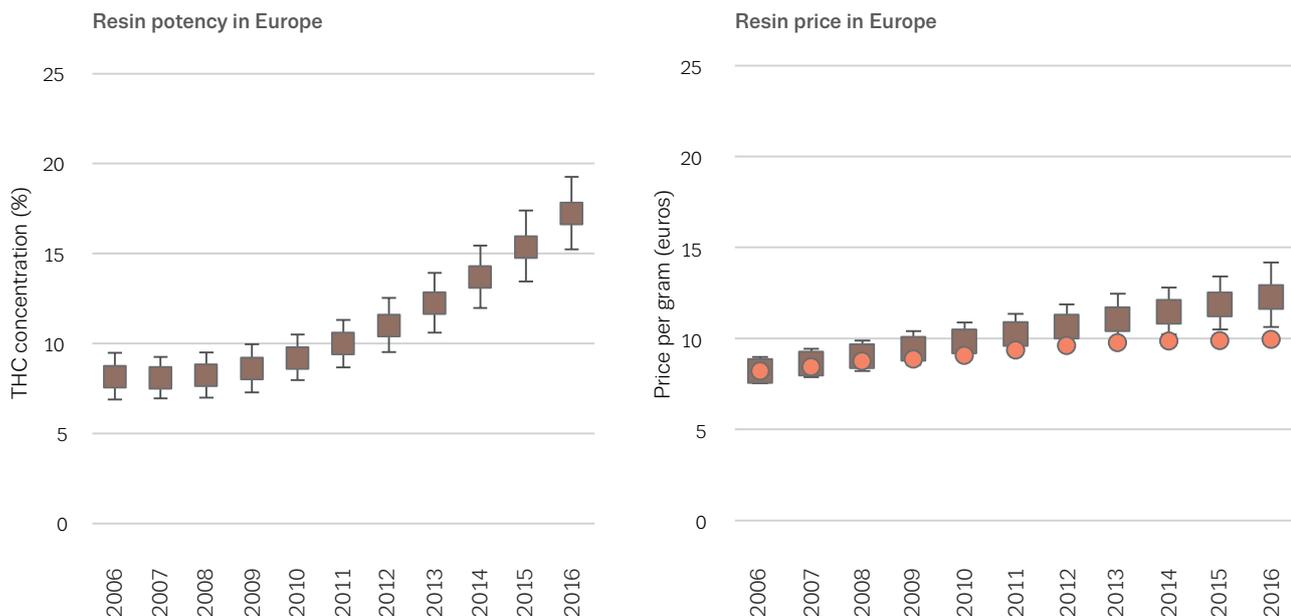
Changes in potency and price of cannabis resin

European cannabis resin is a highly variable product. Resin produced from landrace crops can have a relatively low concentration of THC with a balanced quantity of CBD. Newer products often contain high concentrations of THC and limited CBD. It is not possible to estimate the potency of resin on the basis of its appearance (Figure 7).

Data collected by the EMCDDA indicate that the potency of cannabis resin in Europe has increased substantially in recent years (Freeman et al., 2019). As shown in Figure 8, the potency of resin remained relatively stable from 2006 to 2011 (8-10 % THC) before rising more sharply to 17 % in 2016. While trends in THC concentrations have been monitored in Europe, EMCDDA data collection on CBD content is not currently standard. Therefore, trends in CBD content at European level are uncertain at present. From 2006 to 2016, the price of cannabis resin increased, from approximately EUR 8 to EUR 12 per gram.

The timing of these changes is notably similar to that reported in a 25-year monitoring study (1992-2016) of cannabis samples in France (Dujourdy and Besacier, 2017). That study found that THC concentrations in resin increased from 2000 onwards, and from 2011 THC concentrations increased substantially. From 2011 to 2016, the potency of cannabis resin in France rose from a mean of 12 % to 23 % THC. However, concentrations of CBD remained stable at approximately 4 % throughout the 25-year period. The authors

FIGURE 8
Changes in potency and price of cannabis resin in Europe, 2006-2016.



Note: Data show means (+/- 95 % confidence intervals) for estimated trends after accounting for variation across countries. Expected changes based on inflation of consumer goods are shown in red circles.

FIGURE 9

Traditional and new forms of resin production.

Photos: © David Potter.

attributed the increase in THC to the emergence of a new type of Moroccan resin (mean of approximately 26 % THC) replacing traditional resin (mean of approximately 13 % THC). This has also been evidenced by cannabis resin seized in Morocco (Stambouli et al., 2016). Similar results were found in Denmark, where the THC concentration of resin increased marginally from 8 % THC in 2000 to 11 % THC in 2011, followed by a marked increase to 25 % THC between 2011 and 2017 (Rømer Thomsen et al., forthcoming). During this period, CBD concentrations in resin remained relatively stable at 6 %. This resulted in an increase in the THC to CBD ratio over time. Studies in Italy and the United Kingdom have also reported increases in the THC concentrations and in the THC to CBD ratios of resin samples in recent years (Zamengo et al., 2014, 2015; Potter et al., 2018).

Fieldwork conducted in Morocco suggests that these changes may be attributable to the introduction of new strains of cannabis with higher yields and greater potency, replacing the landrace 'kif' plants previously used for resin production (Chouvy and Afsahi, 2014). In the past, Moroccan cannabis resin was typically produced in 9-ounce (250-gram) bars known as 'soap bars' or 'savonettes' (Figure 9). The left image shows a 'soap bar', weighing 230 g. The potency of this resin was 3.7 % THC, resulting in a total of 8.5 g of THC. The right image shows a 15-gram ball of resin at 58 % THC, amounting to a similar quantity of THC (8.7 g).

European police services have recently reported an increase in seizures of resin in new quantities and shapes, including 200-gram melon-shaped balls, 100-gram tablets and 10-gram olive-shaped pellets (Chouvy, 2016). It is unclear whether these changes are attributable to new resin production methods and/or an attempt to create products with a different appearance.

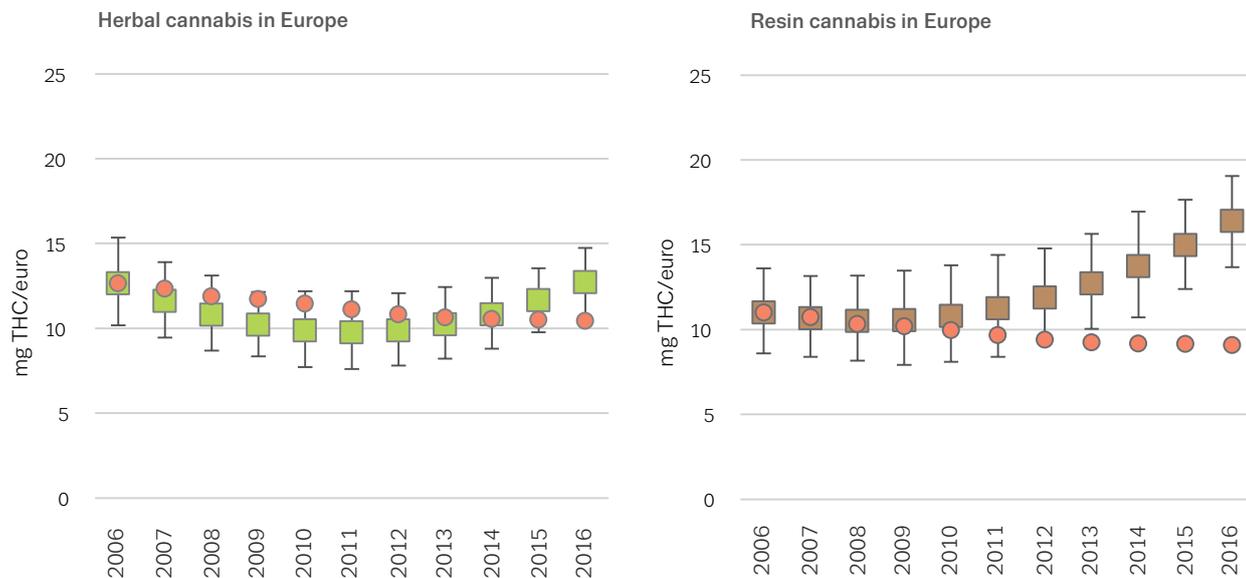
Changes in resin production methods in Morocco may have been driven by the relatively low potency and poor reputation of Moroccan resin among European consumers, and increased competition because of domestically produced sinsemilla within Europe (EMCDDA, 2017a). At the European level, it is evident that recent increases in potency have been substantially greater for cannabis resin (from 8 % to 10 % THC in the 2006-2011 period to 17 % in 2016) than for herbal cannabis (from 5 % THC in 2006 to 10 % THC in 2016). Moreover, recent increases in price have been less pronounced for cannabis resin, from approximately EUR 8 to EUR 12 per gram between 2006 and 2016, than for herbal cannabis, from an estimated EUR 7 to EUR 12 per gram from 2006 to 2016. Data limitations need to be recognised, however, which may influence the accuracy and representativeness of these estimates. First, the use of police seizures for obtaining cannabis products and police surveys for estimating price may result in sampling bias. This is a limitation common to cannabis monitoring exercises in most countries and areas, although in the Netherlands it has been possible to sample directly from the market place (Niesink et al., 2015). Second, data collection methods across countries may differ. This issue persists even though data reporting tools have been improved and harmonised to improve the accuracy, reliability and comparability of data collected on European drug markets (EMCDDA, 2017c). Third, annual data for each cannabis product were not consistently available for each of the 28 EU Member States, Norway and Turkey. However, the statistical techniques used improve the handling of missing data and increase the generalisability of the analysis undertaken (see Freeman et al., 2019).

These changes in potency and price appear to have affected the relative value of herbal cannabis and cannabis resin. When combining information on potency and price, the quantity of THC for every euro spent on herbal cannabis was similar in 2006 (13 mg THC per euro) and 2016 (13 mg THC per euro). This suggests that herbal cannabis has remained relatively stable in terms of value for money during this time. For cannabis resin, value remained stable at 11 mg THC per euro between 2006 and 2011, before increasing to 16 mg THC per euro in 2016 (Figure 10). This suggests that cannabis resin became a better-value product between 2006 and 2016, driven by a larger increase in potency relative to price between 2011 and 2016. It may be the case that the introduction of new cannabis strains in Morocco has enabled producers to create a better-value resin product, and that these savings have been passed on to European consumers. As a result, cannabis resin may now be a more attractive product to some European consumers because of its higher potency and better value for money than herbal cannabis (Freeman et al., 2019).

It is important to remember that information on the source of cannabis products may not be reliable, and informants have suggested that some 'Moroccan' resin may have actually been

FIGURE 10

Changes in the value of herbal cannabis and cannabis resin, reflecting the quantity of THC for every euro spent on cannabis from 2006 to 2016.



Note: Data show means (+/- 95 % confidence intervals) for estimated trends after accounting for variation across countries. Expected changes based on inflation of consumer goods are shown in red circles.

produced in Europe and sold as a Moroccan product (Chouvy, 2016). The appearance of resin does not provide reliable information about the source of production. It is rarely possible to determine the origins of seized resin with certainty, and, now that Moroccan producers appear to be using plants originating in Europe, verifying the classification of resin as Moroccan is even more challenging. Although a number of sources suggest that the plants used to produce Moroccan resin have changed, information on the methods used to produce resin in Morocco also remains limited. Some informants have argued that the traditional 'sieving method' would not be efficient enough to produce the high concentrations of THC recently found in European resin samples, and that newer methods including those involving freezing, icy water or dry ice may have been used (Chouvy, 2016).

Concentrated extracts of cannabis

In addition to resin production, there are several other methods for extracting cannabinoids from plant material. The methods of resin production previously described involve the physical removal of the trichomes, which removes the cells and basal structure of the trichome heads as well as their secretions. In the process, trichome stalks and leaf fragments are unintentionally captured in these crude sieving processes. Greater efficiency can be achieved through the use of solvents or gases. These methods can achieve significantly higher potencies by extracting only the resinous secretions from trichome cells. Concentrated extracts of cannabis are often

consumed by 'dabbing', in which a small quantity is applied to a 'nail' after heating with a blowtorch, and the smoke is inhaled through a waterpipe. As a result of the high levels of THC exposure, cannabis concentrates may be associated with greater dependency and more mental health problems than standard cannabis products (Chan et al., 2017; Meier, 2017).

One method of extraction uses liquefied butane gas to produce concentrated extracts ranging from 70 % to 80 % THC, known as 'butane hash oil' or 'BHO' (Figure 11).

FIGURE 11

Production of butane hash oil. Ground cannabis flower is packed into a tube. Butane is passed through the tube and collected in a tray below. This liquid is then heated or 'purged' to evaporate the butane.



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FIGURE 12

Cannabis concentrates seized in the United Kingdom (Potter et al., 2018). The shatter sample (left) contained 79 % THC and the crumble sample (right) contained 83 % THC.



Photos: © David Potter.

To produce BHO, ground cannabis flower may be packed into a sealed tube with a fine mesh covering the base. Butane is added from a compressed canister to the top of the tube and is collected in a tray under the base. The solution is then evaporated through heating to produce the final product (this is sometimes referred to as 'purging'). Depending on the solvent used and the method of purging, the finished product can vary in consistency (Figure 12). For example, 'shatter' is hard and brittle, 'wax' resembles a soft wax and 'crumble' is soft and flaky.

The use of highly flammable solvents such as butane can carry significant risks. There have been numerous press reports of explosions caused by this method in Europe, some of which resulted in injury or death. Other methods of extraction include closed-loop systems that minimise the chance of gas ignition, and other relatively safe extraction methods such as those that use supercritical CO₂. However, these require the use of more advanced and expensive technical equipment, which might be more commonplace in large-scale commercial production sites (e.g. for licit sale in the United States or Canada) than in smaller illicit production sites typically detected in Europe. Another concern with solvent-based extractions is the adverse health effects of solvent residues, which often remain in the final product. A study of 57 cannabis concentrate samples in the United States found that 83 % contained solvent residues, most commonly isopentane (Raber et al., 2015).

Another new method for producing concentrated extracts involves the application of heat and pressure to cannabis material to create a concentrated extract known as 'rosin'. This method may be desirable, as it removes the risk of explosion and produces no solvent residue. Rosin production techniques are more accessible, as they can be achieved using simple household materials (hair straighteners and greaseproof

paper). Rosin is reported to have similar potencies to butane hash oil (approximately 70-80 % THC).

Concentrated extracts are typically brown to yellow in colour and reach up to 80 % THC content, with minimal CBD (Raber et al., 2015). However, it is possible to separate out these products further using distillation. This can create high-potency clear crystalline products or 'distillates'. Examples of these products can be seen on sale in the United States (Figure 13). Distillation can also be used to make highly concentrated liquids and cartridges used for vaping (Caulkins et al., 2018).

European data on cannabis concentrates are limited at present. However, recent data in the United States may provide an indicator of emerging trends. An analysis of sales data in a new legal market in Washington state found that, within only 2 years (2014-2016), cannabis concentrates grew

FIGURE 13

Crystalline forms of THC extract



Photo: © iStock.

FIGURE 14

Edible cannabis products. 'Pop tarts' are a breakfast food produced by Kellogg's (left) 'Pot tarts' containing 35 mg THC (right).



Photos: © iStock (left) and Drug Enforcement Administration (right).

to constitute 21 % of all sales and contained a mean THC content of 69 % (Smart et al., 2017). Furthermore, data from illicit seizures across the United States demonstrate a marked increase in the proportion of concentrated hash oil samples seized (0.5 % to 4.7 % of all cannabis samples) and their mean THC concentration (6.7 % to 55.7 % THC) from 2008 to 2017 (Chandra et al., 2019).

A study of cannabis samples seized by five UK (English) police constabularies in 2016 (Potter et al., 2018) reported two samples of hash oil (51 % THC and < 1 % CBD) and a small number of butane hash oil samples (ranging from 73 % to 83 % THC, with < 1 % CBD). No samples of this kind were found in previous surveys of cannabis samples conducted in England and Wales in 2008 (Hardwick and King, 2008) or in 2004-2005 (Potter et al., 2008). Concentrated extracts or oils have not been reported in forensic studies conducted in Italy (Zamengo et al., 2014, 2015) or France (Dujourdy and Besacier, 2017) and, because of restrictions on their sale, did not form part of the standardised purchasing protocol used in Dutch coffee shops by the Trimbos Institute (Pijlman et al., 2005; Niesink et al., 2015). Given the lack of information on these new products, it would be wise to include and specifically target cannabis concentrates in future European data collection exercises aimed at establishing patterns of cannabis use and in the analysis of data from drug seizures.

Edibles

Another important type of cannabis products are 'edibles', an umbrella term referring to foods, often sweets or liquids, containing THC and/or CBD for oral administration. The addition of cannabis products to foodstuffs results in slower

absorption and a longer duration of effects than inhalation. For this reason, careful dosing is especially important. In the United States, there is a limit of 10 mg THC per serving or recommended unit in Colorado and Washington, and 5mg THC in Alaska and Oregon (Gourdet et al., 2017). There is also a serious risk of unintentional exposure, as these products may be difficult to distinguish from other foods, sweets or drinks (Figure 14). Edible cannabis products were found to be responsible for 48 % of paediatric emergency hospital visits due to cannabis in Colorado in the 2009-2015 period (Wang et al., 2016).

There is evidence that edibles currently form a significant and probably growing part of licit cannabis markets, representing for example approximately 10 % of all sales in Washington state (Caulkins et al., 2018). Furthermore, the use of edible products is reported to be higher in US states with medical cannabis laws than in those without (Borodovsky et al., 2016).

Information about the use of edibles in Europe is limited, but the available data suggest that at present this is a rare route of administration among European cannabis users (Hindochoa et al., 2016). On the basis of recent trends in the United States, it can be expected that the prevalence of edible products and cannabis concentrates might increase in Europe in the future as consumers become more aware of innovations taking place in licit markets in North America. Moreover, in Europe, there has been a recent increase in the availability of cannabis-based products that contain less than 0.2- 0.3 % THC (see below). These are argued to be of such low potency that they do not fall under existing drug control regulations. Some of these are edibles; however, they may still be considered illicit in some countries even though only small amounts of THC are present.

Synthetic cannabinoids

Synthetic cannabinoids are a group of artificially made substances that act on the same receptors in the body as THC but are usually much more potent. This means that their effects can be markedly different from and more powerful than cannabis. They were originally developed by scientists to study how the body works and to explore the potential of cannabinoids as medicines. Since the mid-2000s, entrepreneurs and, increasingly, criminal groups have sold plant material mixed with synthetic cannabinoids in Europe as 'licit' replacements for cannabis. The first synthetic cannabinoid detected in Europe was JWH-018 in 2008. Since then, more than 180 synthetic cannabinoids have been reported to the EMCDDA, making them the largest group of new psychoactive substances monitored by the EU Early Warning System (EMCDDA, 2019).

Most synthetic cannabinoids in Europe are imported from China in powder form. They are then dissolved in solvents such as acetone and mixed with plant material to create a product that can be smoked. These 'smoking mixtures' are sold online, in 'head shops' or on the illicit market and are often packaged with brand names such as 'Spice', 'K-2' or 'Black Mamba' (Figure 15) or increasingly in unlabelled bags. The brand and the name provide no guarantee of its contents, which vary within and between batches. More recently, synthetic cannabinoids have also been found in products resembling cannabis resin and in e-liquids for vaping. The amount of synthetic cannabinoids in smoking mixtures varies widely, both within batches and across different batches. In addition, mixtures of different synthetic cannabinoids may be used in the products. These factors, combined with the high potency of the substances, make it difficult for users to control the dose that they are exposed to and can lead them to unintentionally administer a toxic dose. The emergence of synthetic cannabinoids has led to the rapid introduction of various legislative approaches to their control in Europe.

The prevalence of synthetic cannabinoid use is low among the general population according to surveys carried out in Europe (EMCDDA, 2017b). While it is thought that many people prefer the effects of cannabis over synthetic cannabinoids (Winstock and Barratt, 2013), in some areas, these substances have developed a reputation as powerful and cheap intoxicants among vulnerable groups, such as the homeless and prisoners, who use them for their 'mind-numbing' effects. As synthetic cannabinoids are not included in routine drug testing, some people may use them (rather than cannabis or other drugs) to avoid detection. This is particularly important in the context of road safety, where more research is needed to assess the prevalence of use of these substances among drivers and the severity of the impairments they cause (EMCDDA and CCSA, 2018).

FIGURE 15

'Spice' is one of several products containing synthetic cannabinoids added to inert plant material.



Photo: Lance Cpl. Damany S. Coleman/Wikimedia Commons/Public Domain.

The high potency and difficulties that exist in the detection of synthetic cannabinoids make them particularly attractive to those wanting to smuggle or use drugs in a prison setting. This is reflected in data from a survey conducted in nine prisons in the United Kingdom, which found that synthetic cannabinoids were the most widely used of all drugs (User Voice, 2016). Of the 635 people surveyed, 33 % had used synthetic cannabinoids in the last month compared with 14 % for cannabis and 8 % for heroin. A number of European countries have highlighted the role of synthetic cannabinoids in aggravating existing mental health conditions or mental states associated with self-harm (EMCDDA, 2018c). Severe poisoning is more common with synthetic cannabinoids than with cannabis. In some cases, the poisoning may even be fatal (Trecki et al., 2015). Sometimes these products can cause explosive outbreaks of mass poisonings involving dozens or hundreds of people. This is because of the high potency of the synthetic cannabinoids as well as the large dose that users are exposed to in smoking mixtures. For further information on synthetic cannabinoids, see the EMCDDA Perspectives on Drugs *Synthetic cannabinoids in Europe* (EMCDDA, 2017b).

Cannabis-based medicinal products

There is growing interest in the medical value of cannabis and cannabinoids, and these are increasingly becoming available as medicines in Europe (see EMCDDA, 2018b). Some cannabis-based medicines contain CBD only, and may be used to treat specific conditions such as paediatric epilepsy. Other cannabis-based medicines contain significant levels of THC and/or a combination of THC and CBD. These may be subject

to national legal sanctions unless approved for medical use. While medicines containing cannabinoids can resemble other medicinal products, some cannabis-based preparations can be very difficult to distinguish from illicit cannabis.

The most widely approved cannabis-based medicinal product in Europe is Sativex® (nabiximols), an oromucosal spray containing equal amounts of THC and CBD derived from the cannabis plant. Sativex® has gained approval in 21 EU countries for the treatment of spasticity in multiple sclerosis. The drug first received regulatory approval in 2010 and is produced by GW Pharmaceuticals (United Kingdom). Dronabinol (Marinol®; AbbVie Inc., United States) is a synthetic form of THC available in capsule form, which is approved as a treatment for nausea and vomiting for patients receiving chemotherapy who have failed to respond to conventional antiemetics, and as an appetite stimulant for patients with HIV/AIDS. Dronabinol is also available in liquid form (Syndros®; Insys Development Company, Inc., United States). Another cannabinoid approved for medical use is nabilone (Cesamet®; Bausch Health, Canada). Nabilone is a synthetic cannabinoid similar to THC, available in capsule form and used to treat nausea and vomiting for patients receiving chemotherapy who have failed to respond to conventional antiemetics.

Epidiolex®, an oral liquid containing 100 mg/ml plant-derived CBD developed by GW Pharmaceuticals (United Kingdom) is another cannabis-based medicine. In June 2018, it was approved by the Food and Drug Administration in the United States as a treatment for patients suffering from rare paediatric epilepsy syndromes (Dravet and Lennox-Gastaut syndromes). As of May 2019, this medicine had not been approved in the EU.

Several EU countries allow doctors to prescribe cannabis for various conditions. The most commonly used products in these countries are those produced by the Dutch medical cannabis company Bedrocan. It provides highly standardised cannabis varieties, all of which comply with the EU's good manufacturing practice (GMP) standards. This implies that the cannabis produced by Bedrocan meets pharmaceutical-level quality standards and is consistent from batch to batch in terms of cannabinoid content. Currently available products include Bedrocan® (22 % THC, < 1 % CBD (see Figure 16)), Bedrobinol® (13.5 % THC, < 1 % CBD), Bediol® (6.3 % THC, 8 % CBD), Bedica® (14 % THC, < 1 % CBD) and Bedrolite® (< 1 % THC, 9 % CBD). Standardised cannabis-based medicines are also available from other companies such as Tilray in Canada.

FIGURE 16

Medicinal cannabis in 5 g containers.



Photo © nscsm.nl.

In addition to standardised herbal cannabis-based medical preparations, Tilray produces a number of standardised cannabis oils containing varying THC to CBD ratios. These include '10:10 Balance Oil' (10 mg/ml THC and 10 mg/ml CBD), '25:0 Oil' (25 mg/ml THC) and '5:20 Oil' (5 mg/ml THC and 20 mg/ml CBD).

Cannabis oils

Although uncommon, high-concentration cannabis oil has been available on the illicit drug market for many years. In recent years, however, there has been an increase in the sale on the high street and online of low-concentration THC products. These included a variety of product types with one of the more common of these being oils, often referred to as 'cannabis oils' or 'CBD oils' (Figure 17). Broadly speaking, cannabis oil is any oil that contains cannabis or cannabis compounds, and hence the composition can vary greatly depending on what type of cannabis was used in the manufacturing process, and whether the final product predominantly contains CBD, THC or a combination of both. Many CBD oils are manufactured using hemp. Hemp can be used to produce oils with high levels of CBD but with THC levels remaining below a threshold of 0.2 %. Below this level of THC, such oils may potentially not be controlled under drug legislation in many EU countries, although national practices vary and regulatory approaches differ in this area (EMCDDA, 2018a). These products are often available as some sort of 'health supplement' or wellness product, although it is often unclear on what basis these claims are made. The EMCDDA

FIGURE 17

CBD oils are widely available as health food supplements.



Photo © Tom Whettem.

recently produced a review of the medical use of cannabis and cannabinoids (EMCDDA, 2018a). This is a complex and rapidly evolving area and it is not possible to discuss it in detail here.

Recent studies testing cannabis oils in Europe found that CBD concentrations often differed significantly from those claimed and, in addition, some contained THC, which would make them illicit in many jurisdictions (Hazekamp, 2018; Pavlovic et al., 2018).

It should also be noted that there is also a long-established market for oils containing much higher concentrations of THC (e.g. approximately 50 %). These are available as products for medicinal use in some jurisdictions, as described in the previous section (Tilray). Although uncommon, these high-concentration THC products have also existed for many years on the illicit drug market. High-concentration THC cannabis oils may be attractive from the perspectives of drug trafficking because of their high monetary value relative to weight.

Conclusions

Cannabis products have become increasingly diverse in Europe. This trend may continue, especially if policy changes increase the availability of products for medical (and potentially recreational) use. It is therefore important to ensure that countries capture adequate information with which to monitor these products and their effects on health. In particular, it is recommended that information about cannabis concentrates is gathered at the national and European levels. It would also be advisable, from a harm reduction perspective, to monitor concentrations of CBD in cannabis. Finally, distinguishing cannabis products for recreational use from medical cannabis products and unregulated CBD oils will be important for law enforcement in many jurisdictions.

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