



Toxicology Communications

ISSN: (Print) 2473-4306 (Online) Journal homepage: <http://www.tandfonline.com/loi/ttxc20>

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To cite this article: Andrew Scourfield, Catherine Flick, Jack Ross, David M. Wood, Natalie Thurtle, Darryl Stellmach & Paul I. Dargan (2019) Synthetic cannabinoid availability on darknet drug markets—changes during 2016–2017, Toxicology Communications, 3:1, 7-15, DOI: [10.1080/24734306.2018.1563739](https://doi.org/10.1080/24734306.2018.1563739)

To link to this article: <https://doi.org/10.1080/24734306.2018.1563739>



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Published online: 17 Jan 2019.



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Synthetic cannabinoid availability on darknet drug markets—changes during 2016–2017

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ABSTRACT

Changes in legislation have affected supply routes of new psychoactive substances such as synthetic cannabinoids with evidence of supply over the darknet. We identified darknet drug markets using an index database and Tor Browser to access markets. We identified SC in product listings using a custom-programmed script. We collected data at bimonthly intervals (August 2016–April 2017). Eleven darknet markets listed SC for sale, the largest number from China, UK, US, Netherlands, and Germany. Formulations available were high purity powder/crystal, smoking preparations and vape preparations. The top five listed compounds from China across the time points were FUB-AMB, ABD-FUBINACA, 5F-NPB-22, MAB-CHMINACA, and NM-2201. 5F-CUMYL-4CN-PINACA was unavailable at early time points but emerged during the study. Cost of high purity formulations from China ranged from 1.3 to 3.1 Euro per gram for quantities ≥ 1000 g. Europe and North America accounted for 99% smoking preparations predominantly in small packages (<50 g). SC are widely available on the darknet with availability changing over time. High purity formulations are predominantly available from China in quantities up to kilograms with price per gram reducing with increased quantity. Small packages of ready-made smoking mixtures are available from Europe and North America.

KEYWORDS

Darknet; dark web; synthetic cannabinoids; novel psychoactive substance

Background

With expansion of the World Wide Web in the late 1990s, internet-based forums relating to drug use and internet sites specifically marketing drugs began to proliferate [1]. In the 2000s, there was an increasing market for the online sale of prescription-only medicine and new psychoactive substances (NPS) over the internet opening the drugs market to a wider audience. However, it was relatively easy for law enforcement to track transactions for illicit drugs between sellers (or vendors) and buyers on the open (surface) web. It was only with improved email encryption, and later anonymity networks combined with electronic cryptocurrencies, such as bitcoin, that anonymous online transactions became possible. As a result, in early 2010 hidden darknet or cryptomarkets began to emerge. Initially, these cryptomarkets were used for sale of traditional recreational drugs such as cannabis, opioids, cocaine, and synthetic stimulants such as 3,4

methylene dioxymethamphetamine (MDMA) [2], whilst prescription-only and NPS remained available on open web [3–6]. Classification of NPS in many countries and the introduction of the UK Psychoactive Substance Act in 2016 and similar legislation in other countries has impacted upon supply routes, potentially increasing sale through darknet markets [7].

Cryptomarkets function in a similar way to online trading websites such as eBayTM or Amazon[®], but to avoid detection use anonymity networks such as Tor (The Onion Router) that allow for hidden services. Tor is free software that enables online anonymity using a process known as onion routing to encrypt and transmit data through a series of network nodes to hide the user's location. When a buyer and seller agree upon a transaction, the buyer transfers cryptocurrency to an escrow in the darknet marketplace. The seller receives the funds after the buyer confirms receipt of product. As with all online marketplaces,

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ratings play a key role in identifying trustworthy buyers and vendors but the key difference with darknet markets is the anonymity—buyers and sellers only know one another only by their online pseudonyms. Some darknet markets only admit new users with referral from existing users offering a further layer of protection.

Cryptomarkets are part of a dynamic process; as old markets close, new ones emerge. After law enforcement activity forced the closure of one of the most well-known darknet market—the Silk Road—in 2013, other cryptomarkets rapidly emerged. Closures of darknet markets are commonly due to raids from law enforcement, exit scams (where money held in escrow is removed by site administrators prior to order completion), hacking of marketplaces, or voluntary closure. A review of 103 darknet markets showed most remained active for just over 8 months [2]. The sale of drugs on the darknet is a global phenomenon, from 2011 to 2015 sales from EU, Norway, and Turkey accounting for 46% of global sales value, amounting to 79 million Euro compared to 93 million Euro for the rest of the world [8]. Within Europe, the majority of the drug trade on the darknet occurs in United Kingdom, Netherlands, and Germany [2].

Over the past 10 years, there has been a rapid increase in the availability of synthetic cannabinoids (SC) for recreational purposes as NPS. Between 2009 and 2016, there were 739 NPS reported to the United Nations Office on Drugs and Crime (UNODC) from 106 countries or territories. Of these NPS, SC make up the largest category, accounting for 32% [9]. They are also the largest group of substances monitored by the EU Early Warning System, with a total of 169 SC having been notified to the European Monitoring Centre for Drugs and Drug Addiction (EMCDDA) by the end of 2016 [10]. SC are most commonly smoked after being dissolved in solvent and sprayed onto plant material but can also be vaped, used in topical oil or ingested. They are potent drugs that are relatively cheap to purchase and difficult to detect on standard occupational and other drug screening programmes, which has resulted in high levels of use in certain groups including the homeless, military, and prisoners [11–13]. There are many different street names for SC but *spice* is the most commonly used generic term. SC demonstrate high affinity binding to cannabinoid receptors and produce a variety of effects from euphoria and relaxation to agitation and paranoia [14]. Their use has also been associated with seizures, acute kidney injury [15], and arrhythmias [16]; with numerous fatalities associated with their

use reported from around the world, for example 29 deaths were associated with MDMB-CHMICA in Europe between 2014 and 2015 [17]. In the US, there have been reports of mass intoxication or “Zombie” outbreaks caused from use of SC [18]. There has been anecdotal evidence of increasing supply of NPS on the darknet therefore we aimed to determine the profile of synthetic cannabinoid availability on the darknet between August 2016 and April 2017.

Methods

We performed a study of publicly available darknet drug markets that were hosted on Tor hidden services, i.e. the darknet. The darknet drug markets were discovered through an Internet-facing index (deepdotweb.com) that is a frequently updated database of accessible darknet cryptomarkets with lists of currently available sites (and those which have been taken down, or might be scams, or have disappeared for other reasons). An exhaustive list of addresses and (where appropriate) referrals were taken from DeepDotWeb for drug-selling cryptomarkets from this site to establish accounts at each market where needed—some were open to browsing without accounts. No search terms were needed to identify which cryptomarkets sold drugs—there was a simple list that was maintained frequently by the administrators of the site, based on community input and new drug markets submitting their details to the site. The list that we curated over the span of the data collection activities kept the addresses of all markets originally indexed on DeepDotWeb, and those that were removed from the DeepDotWeb index in later data collection activities were verified to have disappeared. Sometimes there were explanations for the disappearances given on the DeepDotWeb site, such as FBI takedowns, but not always. Given the nature of the darknet, however, verifying the exhaustiveness of this list was impossible. Thus, although we made every effort to be exhaustive in our data collection, we can still only describe our study as descriptive. The Tor Browser (tor.com) was used to access the drug markets via their .onion addresses.

As darknet drug markets are highly volatile, we established a list at the beginning of the project with each of the markets tested and the list added to as new markets emerged. We excluded markets or sellers unlikely to traffic in SCRA (e.g. markets dedicated to lysergic acid diethylamide (LSD)) and markets requiring authentication beyond usernames, passwords, and PGP keys (*Pretty Good Privacy*: a widely-used

encryption program for encrypting and decrypting data communications) were not included in the sample. Tor-enabled discussion boards where sales were made rather than traditional eBay-style markets were also not included. After logging into each drug market site, listings of SC were identified by navigating to the cannabis/synthetics pages (this was the usual categorisation for SCRAAs across markets). Each listing was saved manually using the Tor browser's "Save As..." functionality. This is significantly different from approaches using web spiders [19–21], as current darknet drug markets are concerned about Distributed Denial of Service (DDOS) attacks and shut out automated scraping tools that request pages too frequently. Manual handling of data was undertaken to filter out listings that were obviously not SC (e.g. miscategorised or spam listings). The collection of listings was verified by comparing the number of records saved against those reported by the market (each market reported a total number of listings in each category). One site, AlphaBay, had erroneous listing numbers, greatly inflated the numbers of listings that it advertised. These listing numbers were checked manually by counting the number of pages of listings, with 25 listings per page. The HTML data for each listing page was saved and catalogued in a directory structure identifying the date and market it was taken from. Each site had a custom program written for it in Python, an open source scripting language, to extract data (e.g. price, location, shipping information, descriptions) from each listing's HTML page using the lxml parsing library. The script extracted data into a comma-separated value (CSV) file for analysis. All data was saved to a secure drive and shared using a secure data share facility within De Montfort University and the University of Sydney.

Snapshot data was collected at a single time point, at two-monthly intervals from August 2016 to April 2017. After collection, data was transferred to Microsoft Excel and analysed. Cost calculations were converted from product listing in bitcoin to Euro using the exchange rate at each time point using the currency conversion website www.XE.com. Chemical compounds or brands, formulation of synthetic cannabinoid preparation, weight, and cost were obtained from title of listing or from the product description. Location of vendors was recorded, where this was unclear from product listing these were categorised "unknown." The study was granted ethical approval from De Montfort University Ethics Committee, Leicester (Reference 1516/352).

Results

Across the five study time points, 31 darknet drug markets were screened, 11 were identified listing synthetic cannabinoid products for sale. The three largest darknet markets selling SC were AlphaBay (mean 171 SC listed for sale per study time point), Dream Market (mean 163), and Valhalla (mean 86). At each study time point, there were approximately 500 synthetic cannabinoid items listed for sale on the darknet (range 396–576). Table 1 shows darknet markets with SC available and the combined cost of listings.

We identified 38 individual or combination synthetic cannabinoid compounds and 24 branded SC products, these are shown in Table 2. Vendors from 12 countries listed SC for sale. China had the largest number of synthetic cannabinoid items listed at each study time point (ranging from 188 [February 2017] to 245 [October 2016]). There was variability in the number of SC in other countries, the remainder of the top five selling countries varied between the US, UK, Germany, and the Netherlands (Table 3).

During the study, there were a total of 2314 darknet listings for SC, the most common descriptors were high purity (>98% pure in product description) powder/crystal (1206 (52%) listings) and ready-made smoking preparations (1075, 46%); vape preparations were less common (32, 1%) and a single listed item for blotters. High purity powder or crystal formulations were predominantly available from vendors in China (87%, 1048/1206), followed by Unknown (6%, 68/1206), Poland (2.7%, 33/1206), Spain (2.1%, 25/1206), Finland (1%, 11/1206), US (1%, 11/1206), and UK (0.7%, 9/1206). In contrast, listings for smoking mixtures were almost exclusively available from Europe (78%, 838/1075) and the US (20.6%, 221/1075) with a small amount from Australia (0.5%, 5/1,075) and Unknown 1% (11/1075). All Chinese SC listings were for high purity powder or crystal, prices for these ranged from 2.4 to 25.5 Euro per gram for quantities less than 100 g decreasing to 1.3 to 3.1 Euro per gram for 1000 g. The top five listed compounds from China across the time points were FUB-AMB, ABD-FUBINACA, 5F-NPB-22, MAB-CHMINACA, and NM-2201. With all compounds the price per gram was greater for smaller purchase amounts and cost reduced with increased quantities; the top five listed compounds by Chinese vendors and price per gram in Euro are shown in Table 4. Darknet listings for SC from Chinese vendors contained detailed scientific information in approximately half of listings

Table 1. Darknet markets with synthetic cannabinoid (SC) listings and total number of synthetic cannabinoid products and combined cost of listings in Euro (converted from exchange rate for bitcoin on date). If no synthetic cannabinoid items listed at a time point reason explained in table.

Darknet market	23-August-2016		31-October-2016		21-December-2016		24-February-2017		21-April-2017	
	Total no. SC listed	Combined value SC listed	Total no. SC listed	Combined value SC listed	Total no. SC listed	Combined value SC listed	Total no. SC listed	Combined value SC listed	Total no. SC listed	Combined value SC listed
AlphaBay	137	51,793	210	61,976	144	57,616	165	61,006	199	99,657
Apple	No SC listed		Referral only members	Referral only members	Referral only members	Referral only members	4	149	10	603
Darknet Hero	2	97	2	99	Referral only members	Referral only members	Referral only members		No new members	
League										
Dream	171	89,446	211	98,974	138	70,477	145	79,378	148	83,690
Market										
Hansa	14	7,120	43	17,510	43	17,204	34	22,508	33	24,317
Oasis	9	515	Market closed	Market closed	Market closed	Market closed	Market closed	Market closed	Market closed	Market closed
Silk Road 3.1	Market not created		Market not created	Market not created	Market not created	Market not created	Market not created	Market not created	Market closed	37
The Real Deal	9	4,101	Market closed	Market closed	Market closed	Market closed	Market closed	Market closed	1	
TradeRoute	No SC listed		No SC listed	No SC listed	No SC listed	No SC listed	10	7,243	1	106
Valhalla	54	32,868	110	52,085	115	56,405	82	56,131	67	51,480
Zion	Market not created		Market not created	Market not created	Market not created	Market not created	2	27	1	5
Total	396	185,941	576	230,644	440	201,673	442	226,442	460	259,894

as shown in the following examples (cost in Euros added for comparison):

ADB-FUBINACA 1kg, 4.27 BTC (2,731.22 Euro).
Formula Name: N-(1-Amino-3,3-dimethyl-1-oxobutan-2-yl)-1-(4-fluorobenzyl)-1H-indazole-3-carboxamide
CAS: 1445583-51-6 Formula: C₂₁H₂₃FN₄O₂ Exact Mass: 382.4 Molecular weight: 382.43 g/mol. Compound purity: >99%

NM-2201 1kg, 4.33 BTC (2,233.07 Euro). NM2201 is an analog of AM2201, the potent synthetic cannabinoid (CB) with Ki values of 1.0 and 2.6 nM for the central cannabinoid (CB1) and peripheral cannabinoid (CB2) receptors. The physiological actions of NM2201 have not been characterized. This product is intended for forensic and research applications.

When specific SC compounds were unavailable, Chinese darknet vendors often suggested alternatives;

MMB-Chminaca/MMBC powder, it is the best replacement of AB-Chminaca powder. White powder, the purity is at least 99.0%.

1000g NM-2201 powder, the best replacement of JWH-018, 100% Shipping Warranty, No signature required.

ADB-FUBINACA was the most commonly listed synthetic cannabinoid from Chinese vendors but availability declined over the study from 43 (August 2016) to 23 (April 2017). 5F-CUMYL-4CN-PINACA was unavailable at early time points but emerged in December 2016 with 21 items. SC from Chinese vendors and the numbers listed for the study are shown in Figure 1.

Interestingly, all 33 listings for SC products from Poland were for high purity powder of MMB-CHMINACA or 5F-MDMB-2201. Price per gram of SC was more costly than Chinese vendors markets with equivalent price of 5.6–12.3 Euro per gram for smaller quantities ≤25 g and 2.8 to 3.3 Euro per gram or quantities 500 g or more. However, Finnish vendors listing powdered SC were by far the most expensive selling very low quantities (1 g or less) at equivalent price of mean 160 Euro per gram (range 105–283, *n* = 11 listings).

Vendors from within the European Union (EU) promoted greater chance of successful delivery as seen in this listing from Poland;

20 grams of 5F-MDMB-2201 methyl-2-(1-(5-fluoropentyl)-1H-indole-3-ylcarbonylamino)-3,3-dimethylbutanoate a very potent CB1/CB2 receptor agonist, structurally related to MMB-2201. This product is intended for research and forensic applications. Products are sent from EU (Poland) so

Table 2. List of synthetic cannabinoid chemical compounds and brand names available across study (mean number of listings per time point).

Individual or combination synthetic cannabinoid compound (mean number of listings per time point)		
5F-ADB (2.8)	AB-PINACA (14.4)	JWH-081 (0.2)
5F-ADB-FUB (0.2)	ABD-FUBINACA (1.2)	JWH-122 (1.6)
5F-AKB48 (3.2)	ADB-FUBINACA (39.2)	JWH-210 (2.2)
5F-AKB-57 (0.4)	AKB-48 (0.8)	MAB-CHMINACA (22.8)
5F-CUMYL-4CN-PINACA (11.8)	AKB-48 + UR-144 (0.8)	MDMB-CHMICA (10.6)
5F-MDMB-2201 (6.4)	AKB-48F, PB-22 & AB-CHMINACA (16)	MMB-CHMINACA (16.8)
5F-MDMB-2201 + FUB-AMB (0.6)	AM-2201 (0.2)	NM-2201 (24.4)
5F-MN-22 (3.4)	CUMYL-5F-PINACA (2.4)	NM-2201 + FUB-AMB (1.6)
5F-NPB-22 (12.2)	EAM-2201 (1.4)	SDB-005 (5.4)
5F-PB-22 (11.8)	FUB-AKB (19)	THJ-2201 (14.4)
5F-PB-25 (0.2)	FUB-AMB (39.4)	UR-144 (1.4)
AB-CHMINACA (1.0)	FUBINACA (0.4)	UR-144 + JWH-122 + JWH-210 + AKB-48 (0.6)
AB-FUBINACA (6.2)	JWH-018 (0.6)	
Brand of synthetic cannabinoid		
AK48	Fairly Legal	Kronic
Angrybirds	Game Over!	Kush
Axa Blends	Geeked Up	Liberty Liquids
Bizarro	Gorilla Glue Indoor Soil	Scooby Snacks
Blue Dream	Green Buddah	Spice diamond
Bonzai	Green Giant	Strong Spice
Diablo	Herbal Incense	Weekend Blend

Table 3. Origin of vendors selling synthetic cannabinoids (SC) on darknet markets and the number of SC listed items per time point.

Country of vendor	23-August-16	31-October-16	21-December-16	24-February-17	21-April-17
Australia	0	1	1	1	2
Austria	5	0	0	0	0
China	198	245	218	188	199
Finland	3	2	2	2	2
France	10	11	5	5	6
Germany	6	63	7	56	52
Netherlands	29	42	41	60	61
Poland	0	1	3	16	13
Portugal	0	0	11	10	11
Spain	3	9	19	17	12
United Kingdom	34	130	66	45	46
United States	89	54	49	22	20
Unknown	19	18	18	20	36
Total	396	576	440	442	460

your package will be not suspicious because they are send from EU not from China. How we all know that most of parcels from China are captured by customs offices. You can also order a sample to check our competence and quality of product. All my products are laboratory tested.

A Spanish vendor offered instructions on how to make "spice";

You make order-get powder from me. Then Finalize order. After you get Full instruction How to make Spyce blends. All ingriedients [*sic*] cost about 35euros. You made about 2-2,6 KG Spyce herbal

Across all study time points, there were 1075 ready-made smoking mixtures listed. Many of these were small packages 5 g or less (357, 33.2%) with the majority being 50 g or less (812, 75.5%). Price per gram of ready-made smoking preparations also reduced with increasing quantity purchased and varied with country of sale. For smaller volumes (5 g or less) France was cheapest, mean 3.33 Euro per

gram followed by Portugal 4.38, Netherlands 9.95, UK 11.57, US 11.95, Germany 12.50, Austria 15.57, and Spain 16.48.

A Spanish vendor directly referred to the UK psychoactive substance act to market their product again highlighting delivery from within EU;

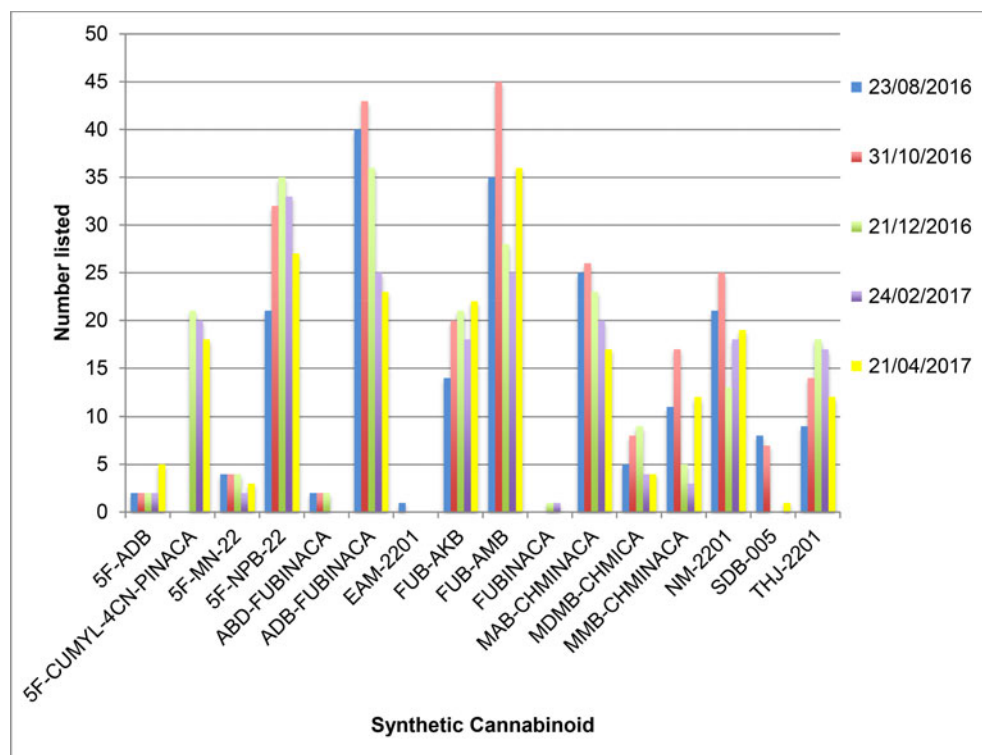
UK residents here is an opportunity to make some low risk money, since the psychoactive ban come into effect there is many addicts not knowing where to get it from at any price, I ended up with a ton of it so hit me up if u wanna make money! Bulk bag of strong shit, ideal money maker! sells for up to \$30 per gram, Sent from within the EU!

Others warned of the strength of their product, the following is a listing for a smoking mix from a UK vendor;

7g of the Synthetic Cannabanoid known as Spice. This batch is blueberry flavoured and contains AKB-48F, PB-22 & AB-CHMINACA. This was a legal high in the UK untill [*sic*] very recently, it is extremely strong

Table 4. Number of synthetic cannabinoids listed and price per gram in Euro by weight of most frequent Chinese vendor listings across darknet markets per time point.

Compound	23 August 2016		31 October 2016		21 December 2016		24 February 2017		21 April 2017	
	Number listed	Price per gram (€)	Number listed	Price per gram (€)	Number listed	Price per gram (€)	Number listed	Price per gram (€)	Number listed	Price per gram (€)
FUB-AMB	35		45		28		25		36	
<100 g	16	5.21	19	9.74	10	9.85	10	10.8	16	8.28
100 g	7	3.98	8	4.32	7	4.90	6	4.71	7	4.07
200 g	2	2.57	3	2.70	2	3.11	1	3.03	3	2.59
500 g	6	2.51	9	2.32	6	2.47	6	2.35	6	2.34
1000 g	4	1.75	6	1.85	3	2.10	2	2.01	4	1.89
ADB-FUBINACA	40		43		36		25		23	
<100 g	16	7.93	18	10.54	20	9.23	16	11.57	11	10.61
100 g	6	5.00	6	5.76	6	5.34	4	5.53	5	4.86
200 g	3	2.61	2	2.74	1	3.18	1	3.03	2	2.95
500 g	12	2.44	9	2.66	4	3.06	2	3.12	2	3.08
1000 g	3	2.19	8	2.02	5	2.18	2	2.60	3	1.85
5F-NPB-22	21		32		35		33		27	
<100 g	8	7.32	12	7.28	11	7.78	12	7.70	10	7.25
100 g	2	4.65	3	4.70	3	5.04	3	4.85	3	4.80
200 g	4	4.08	6	4.08	7	4.41	6	4.15	5	4.24
500 g	5	2.17	7	2.22	9	2.38	8	2.24	6	2.27
1000 g	2	1.89	4	1.93	5	2.07	4	1.98	3	1.97
MAB-CHMINACA	25		26		23		20		17	
<100 g	12	5.49	13	6.44	12	9.04	10	9.24	9	9.13
100 g	5	3.92	5	3.32	5	5.21	5	4.96	2	3.25
200 g	3	2.64	3	2.70	2	3.11	2	2.96	2	2.95
500 g	4	1.92	2	2.35	2	2.52	1	2.42	2	2.39
1000 g	1	1.96	3	2.00	2	2.14	2	2.04	1	2.04
NM-2201	21		25		13		18		19	
<100 g	5	6.27	10	6.50	3	6.31	8	7.12	8	6.56
100 g	6	3.69	5	3.71	4	4.39	3	3.77	4	3.63
200 g	n/a		1	1.62	n/a		n/a		1	1.77
500 g	6	2.51	5	2.47	3	2.79	4	2.56	3	2.58
1000 g	4	1.61	4	1.95	3	2.21	3	2.06	3	1.85

**Figure 1.** Number of synthetic cannabinoids listed for sale from Chinese vendors.

and unless you are an experienced user of this type of product I would strongly urge you not to order this, it will be too strong for you to enjoy and certainly not a drug you would want to take up as a new user.

Vendors from five countries offered larger quantities (≥ 500 g) of smoking mixes accounting for 12.2% (131/1075) of darknet listings for SC smoking preparations. For these larger volumes, Netherlands was cheapest with mean price 1.50 Euro per gram, followed by France 1.63, Germany 1.71, Spain 1.92, and UK 2.87.

There were 32 listed vape products containing SC from UK (11), Unknown (11), Germany (6), US (2), and Netherlands (2). Twelve contained SGT-25 (known as 5F-CUMYL-PINACA), one contained JWH-081 and 19 were branded vape products such as K2 and Kronik. Price was more variable but still lower for higher volumes 2.2 to 3.0 Euro per ml for ≥ 100 ml and 3.56–57 Euro per ml for 1–5 ml. The single SC listed item for blotters consisted of 10×3 mg blotters of JWH-018.

Discussion

The use of the darknet for the sale of illicit drugs is a rapidly emerging market. Data collected by the Global Drug Survey in 2012 of 9470 respondents from predominantly male population with mean age in 20s–30s from US, Australia, and UK revealed that 65, 53, and 40%, respectively had heard of the Silk Road [22]. MDMA, cannabis, and LSD were the most commonly purchased drugs. Their study found the most common reasons for buying drugs from Silk Road were wider range of products available, superior quality, convenience, and the use of vendor rating system. Those who avoided the Silk Road either reported adequate access to drugs or fear of being caught. Data from their follow-up survey [23] revealed in UK 25.5% ($n = 3118$) reported having obtained drugs on the darknet in the past 12 months. Lower rates were reported in the US, 13.2% of respondents ($n = 5655$), Germany 6% ($n = 20,298$), and Netherlands 6.7% ($n = 1433$). Finland had the highest rate of drug use from darknet but from a smaller sample size (41.4%, $n = 244$). According to EMCDDA, the three top European countries in order of revenue and weight of sales of drugs on the darknet are Germany, United Kingdom, and Netherlands with approximately 27, 21, and 18 million Euro, respectively [2]. Despite German markets having the most revenue, it appears more people in the UK access the darknet suggesting buyers and vendors may differ in location or reflect

quantities purchased per transaction. In our study, there were more darknet vendors selling SC in UK than Germany (20 vs 8) and a larger number of SC products (321 vs 184) implying countries vary in the type of drugs they buy on the darknet. Although it remains the largest number of synthetic cannabinoid products available on the darknet in Europe originate from these three countries (see Table 3).

Darknet markets are volatile—over the course of the study several darknet markets were either temporarily or permanently disabled and two markets switched to a referral-only system, meaning new buyers had to be referred by existing members. During the study, two new darknet markets selling SC emerged. At the final time point, 9 out of 11 darknet markets selling SC remained open with one of these no longer accepting new members. After the study, two of the largest darknet markets—Hansa and AlphaBay—were closed by law enforcement in June and July 2017. When AlphaBay was shut down, there were more than 350,000 listed illicit items including drugs and chemicals (approximately 200,000), firearms, and cybercrime malware with a conservative estimation of 1 billion US dollars transacted since the market was created in 2014 [2].

A geographical analysis of trafficking on a popular darknet market showed Chinese vendors specialised in selling NPS [24], and the European Drug Report also suggests Chinese laboratories are the source of many NPS [25]. This is consistent with our data, showing large number of SC available from China. These high purity SC are available in quantities up to 1 kg with the price per gram reducing with increasing quantity purchased. Given the large quantities available, detailed scientific information and frequent descriptions of laboratory tested high purity this suggests these are not being sold to individual end-users, especially given the typical micro- to milligram dosing for SC. It is likely that the larger quantity amounts are being marketed for others to be processed packaged and sold on locally through other channels. The increased scrutiny of SC exported from China may explain why some darknet vendors from EU such as Poland, Spain, and UK are exploiting less stringent shipping within the EU for sale of high purity preparations.

Ready-made smoking mixtures (“spice”) were the second major category of SC available on the darknet. These are most commonly available from Europe and North America with the majority of these offered in small volume packages of less than 50 g, suggesting that these are potentially being marketed more towards end-users of the product(s).

The main limitations of our study were darknet listings for SC correspond only to products offered for sale. As we did not purchase or analyse the compounds listed, we were unable to confirm definitively the SC present within the products. Given the anonymity afforded by the use of cryptocurrencies, it is difficult to determine actual sales. Some darknet sites such as Dream Market offer vendor details on “number of successful transactions” which can give some idea of sales over time, although it is often unclear the product or quantity of item sold. It is also possible SC listed on the darknet were not identified by our search methodology. This may have occurred if they had been inadvertently placed in a different drug category by the listing vendor. Finally, it is possible that some markets that existed in the time period were not included. The darknet allows for sites that are only accessible by those who have been given the direct addresses by the owners, and that are not indexed by search engines or manually curated lists. However, if these invite-only sites are similar to the publicly advertised invite-only sites, the invitations act as a “VIP” status to high level sellers who also advertise their wares on public markets.

Introduction of policies such as The Psychoactive Substances Act may impact the use of the darknet over time for NPS markets [26]. Given the rapidly changing environment of darknet drug markets, it is vital for policy makers to be aware of available substances as seen with the emergence of 5F-CUMYL-4CN-PINACA during the study. It will be interesting to see the effect of the closure of two large darknet markets (AlphaBay and Hansa) on the availability of SC on the darknet and whether vendors switch to other marketplaces, develop new marketplaces or utilise alternative sales platforms. Data on snapshots of the availability of NPS on the open web is routinely included in the Risk Assessment process of NPS at the EMCDDA. The development of methodology to determine the availability of NPS on the dark web will widen the scope of these assessments and ensure that the risk assessment process is guided by information which more accurately reflects the availability of NPS to users. The technological capacity to monitor drug markets needs to evolve alongside and in close, cross-disciplinary communication with toxicological and policy responses to this dynamic field.

Disclosure statement

PD is a Member of the Scientific Committee of the European Monitoring Centre for Drugs and Drug Addiction (EMCDDA) and the UK Advisory Council

on the Misuse of Drugs (ACMD); DW is an expert advisor to the EMCDDA and ACMD.

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