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(54) **PARENTERAL FORMULATIONS**

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(57) **ABSTRACT**

The present invention relates to parenteral cannabinoid formulations, and more particularly to cannabinoid containing intravenous (IV) formulations. Preferably the parenteral containing formulation comprises a cannabinoid; an isotonic agent; a surfactant; and one or more stability enhancers. Furthermore the cannabinoid may be selected from one or more of cannabichromene (CBC), cannabichromenic acid (CBCV), cannabidiol (CBD), cannabidiolic acid (CBDA), cannabidivarin (CBDV), cannabigerol (CBG), cannabigerolpropyl variant (CBGV), cannabicyclol (CBL), cannabinol (CBN), cannabinol propyl variant (CBNV), cannabitriol (CBO), tetrahydrocannabinol (THC), tetrahydrocannabinolic acid (THCA), tetrahydrocannabivarin (THCV) and tetrahydrocannabivarinic acid (THCVA).

PARENTERAL FORMULATIONS

[0001] The present invention relates to parenteral formulations, and more particularly to cannabinoid containing intravenous (IV) formulations.

BACKGROUND TO THE INVENTION

[0002] Parenteral formulations, also called injectable formulations, may be used to deliver a drug intravenously, subcutaneously, or intramuscularly. The drug may be formulated as a liquid or it may be lyophilized.

[0003] When looking to solubilize an active pharmaceutical ingredient (API) together with excipients to produce an injectable formulation, a formulation chemist would generally follow a structured approach, as set out by e.g. Strickley, *Pharmaceutical Research*, Vol 21, No 2, 2004 (Table VIII). Thus, depending on the solubility of the API, the skilled person would first look at simple aqueous isotonic solutions and progresses through more complex approaches using: pH control, the addition of co-solvents, the use of pH adjustment in combination with co-solvents, complexation; organic solvent/surfactant combinations for dilution with an aqueous diluent to an oil in water emulsion and ultimately, the use of liposomes.

[0004] Thus, an ideal immediate release injectable formulation is aqueous and isotonic with physiological fluids such as saline, dextrose (5%) or lactated Ringer's with a pH of 7.

[0005] Where the API is not soluble, the skilled formulation chemist, as outlined above, would look to increase solubility through pH change and/or adding a co-solvent. Typical organic solvents used in IV formulations include ethanol, dimethylacetamide (DMA), glycerin, polyethylene glycol (PEG 300) and propylene glycol. The combination of both pH modification and co-solvent is a very powerful solubilization strategy, and if a drug is not solubilized using such an approach the next step would be to use complexing agents, such as, cyclodextrins. If this doesn't work the drug is considered "challenging" whereupon surfactants are used. Typical surfactants for intravenous infusion formulations include polyethoxylated castor oil e.g. Cremophor EL, PEG-60 Hydrogenated Castor Oil e.g. Cremophor RH60 and polyoxyethylene-sorbitan-20 mono-oleate e.g. Polysorbate 80. When this fails, oil in water emulsions or liposomes are usually the last option. Oil in water emulsions are however rarely used in commercial products.

[0006] Cannabinoids are highly lipophilic with the consequence that delivering them efficiently is challenging.

[0007] They include cannabichromene (CBC), cannabichromenic acid (CBCV), cannabidiol (CBD), cannabidiolic acid (CBDA), cannabidivarin (CBDV), cannabigerol (CBG), cannabigerol propyl variant (CBGV), cannabicyclol (CBL), cannabinol (CBN), cannabinol propyl variant (CBNV), cannabitriol (CBO), tetrahydrocannabinol (THC), tetrahydrocannabinolic acid (THCA), tetrahydrocannabivarin (THCV) and tetrahydrocannabivarinic acid (THCVA). This list is not exhaustive and merely details the cannabinoids which are identified in the present application for reference. So far, over 100 different phytocannabinoids have been identified and these cannabinoids can be split into different groups as follows: Phytocannabinoids; Endocannabinoids; and Synthetic cannabinoids.

[0008] Approved cannabinoid containing medicines have to date been delivered orally e.g. Nabilone and Dronabinol, or via the oromucosal route e.g. Nabiximols.

[0009] IV formulations of cannabinoids have of course been prepared for research purposes, where they can be manufactured for immediate use, but such formulations are not suitable for use as medicines due to e.g. poor stability.

[0010] Parenteral formulations of Marijuana constituents are disclosed in the *Journal of Pharmaceutical Sciences*, Vol 61, No 7, 1106-1112 1972 (incorporated by reference). This document discloses emulsions for parenteral use consisting of (i) sesame oil (10-15%) plus Polysorbate 80 (0.4-1%) in saline containing up to 4% tetrahydrocannabinol or (ii) sesame oil (5-10%), plus polyvinylpyrrolidone (PVP) (4-5%) containing approximately 1% cannabinoid. The document notes that the ratio of emulsifier to cannabinoid proved critical to obtain stable emulsions. The document teaches that aqueous cannabinoid containing systems for parenteral administration must incorporate some type of emulsifier and states the limitations (in formulating cannabinoids) falls into three categories:

[0011] (a) The low concentration of cannabinoid achieved dictates the volume of formulation that must be given;

[0012] (b) The concentration of emulsifier, and number of treatments, introduce the hazard of vehicle toxicity; and

[0013] (c) The lability of the formulation may require frequent preparation of the injectable.

[0014] The document goes on to comment on each of these limitations.

[0015] More specifically (Table 1 therein) shows the solubility of tetrahydrocannabinol (THC) in a range of solvents, with solubility ranging from 1 g/ml in ethanol to 0.28 g/ml in Polysorbate 80 (a paste).

[0016] With reference to the emulsion characteristics, various solvent/emulsifier/diluent combinations were examined. The studies (Table 2 therein) demonstrated that "small" quantities of solubilizer or emulsifier provided stable emulsions, whereas e.g. "relatively high" concentrations of cannabinoid with 10% Polysorbate 80 yielded emulsions which were stable only for a few minutes. It is further stated that small quantities of organic solvents failed to provide suitable cannabinoid suspensions (e.g. propylene glycol and glycerol formed a 2 phase system upon dilution with saline) and the most successful emulsions comprised stock solutions (1 ml) of cannabinoid in sesame oil (100-400 mg/ml) to which Polysorbate 80 and 8-9 ml of isotonic saline were added and emulsified by sonication. Other useable emulsions were obtained with cannabinoid in sesame oil and 5-10% Polyvinylpyrrolidone (PVP) or 1% polyoxalene (stable for 3-6 hours).

[0017] The discussion section included a review of various IV formulations used in animal studies. These included sesame oil-saline; propylene glycol; Polysorbate-saline; polyethylene glycol 300 and 10% PVP-saline.

[0018] The conclusions were that suspending agents like Polysorbate offered useful aqueous systems, but species sensitivity presented a formidable difficulty, whereas emulsions with natural oils and emulsifiers afford a good approach to injectables for chronic studies.

[0019] WO 2016/147186 discloses cannabis based emulsion formulations. It takes a cannabinoid containing oily phase comprising phospholipids and mixes this phase with a water phase, comprising glycerol to form a pre-emulsion which is microfluidised to form a micro-emulsion. The micro-emulsion can be administered by a range of routes

including intranasal, transdermal, intravenous, oral, and topical. In contrast, the parenteral formulation of the present invention does not comprise phospholipids and are based on the selection of the given surfactant and isotonic agent together with a stability enhancer.

[0020] US 2007/0060638 discloses combination therapies of a cannabinoid receptor agonist and antagonist. It teaches the therapeutic compound may be administered parenterally mentioning dispersions can be prepared in, for example, glycerol, polyethylene glycol and mixtures thereof.

[0021] US 2013/0209483 teaches the use of CBD containing pharmaceutical compositions. Amongst many formulations disclosed are injectable formulations. The document teaches using sterile aqueous solutions or dispersions and mentions a number of suitable carriers.

[0022] WO 2008/144475 relates to CBD derivatives for treating cancer. It makes reference to various routes of administration, including parenteral. It further mentions the use of various solvents, isotonicity agents, antioxidants and chelating agents.

[0023] WO 2008/019146 discloses aqueous dronabinol containing formulations. The formulations are for delivery by a range of techniques. They include one or more co-solvents, typically organic co-solvents such as ethanol or polyethylene glycol, solubilizing agents may be included as may a range of other components including surfactants, antioxidants and isotonicity agents.

[0024] The formulation of injectable cannabinoid formulations therefore presents a major challenge to the skilled person. Achieving good solubility, low toxicity and stability cannot be underestimated.

[0025] Despite this, the Applicant has developed a stable (non-oil based) aqueous parental cannabinoid containing formulation using surfactants which contain the desired cannabinoid in amounts enabling effective subject dosing in combination with one or more stability enhancers. The stability enhancers include one or more antioxidant(s) and chelating agent(s).

BRIEF SUMMARY OF THE DISCLOSURE

[0026] In accordance with a first aspect of the present invention there is provided an aqueous parenteral cannabinoid containing formulation comprising:

[0027] (i) a cannabinoid;

[0028] (ii) an isotonic agent;

[0029] (iii) a surfactant; and

[0030] (iv) one or more stability enhancers.

[0031] Preferably the cannabinoid is selected from cannabichromene (CBC), cannabichromenic acid (CBCV), cannabidiol (CBD), cannabidiolic acid (CBDA), cannabidivarin (CBDV), cannabigerol (CBG), cannabigerol propyl variant (CBGV), cannabicyclol (CBL), cannabinol (CBN), cannabinol propyl variant (CBNV), cannabitriol (CBO), tetrahydrocannabinol (THC), tetrahydrocannabinolic acid (THCA), tetrahydrocannabivarin (THCV) and tetrahydrocannabivarinic acid (THCVA).

[0032] More preferably still the cannabinoid is CBD or CBDV.

[0033] It may be a highly purified natural compound or a synthetically manufactured compound with a purity of greater than 98%, and more preferably still greater than 99%

[0034] For CBD or CBDV, the cannabinoid may be present in the formulation in an amount of from 0.3 to 50 mg/ml,

preferably 0.5 to 20 mg/ml, more preferably 1 to 7 mg/ml, and most preferably 3 to 5 mg/ml.

[0035] Preferably the isotonic agent is selected from: polyethylene glycol, glycerol, saline, and glucose and are used in amounts to provide an osmolality in the range of, 100-500 mOsMol/Kg, more preferably still, 200-400 mOsMol/Kg, more preferably still 285-310 mOsMol/Kg, and most preferably about 300 OsMol/Kg.

[0036] Most preferably the isotonic agent is glycerol and is present in an amount of 5 to 50 mg/ml, more preferably 10-30 mg/ml, and most preferably 20 mg/ml.

[0037] If the product is to be freeze dried then a bulking agent such as, mannitol, sucrose, and trehalose may be added.

[0038] The preferred surfactant is a non-ionic surfactant. Most preferred are (i) Polyoxyethylene (20) sorbitan monooleate, also called Polysorbate 80 (Tween 80), (ii) Macrogol 15 hydroxystearate which is a mixture of mainly mono esters and di esters of 12-hydroxystearic acid and macrogols obtained by the ethoxylation of 12-hydroxystearic acid. The number of moles of ethylene oxide reacted per mole of 12-hydroxystearic acid is 15. Proprietary versions include Solutol HS15, Crodasol HS and Kolliphor HS 15 and (iii) Polyoxamers which are triblock co-polymers of a central hydrophobic chain of polyoxypropylene flanked by two hydrophilic chains of polyoxyethylene. Proprietary brands include Pluronic.

[0039] PVP (K12 or K17) may also be used as a solubiliser.

[0040] A most preferred surfactant is Macrogol 15 hydroxystearate (Kolliphor HS15). This may be used in an amount of from 5 to 500 mg/ml, more preferably 10 to 100 mg/ml, and most preferably at about 50 mg/ml.

[0041] Preferred stability enhancers comprise one or more antioxidants selected from ascorbic acid, monothioglycerol, cysteine HCl and Glutathione.

[0042] Particularly preferred is ascorbic acid which may be used in amounts of from 0.5 to 10 mg/ml, more preferably 1 to 5 mg/ml, and most preferably about 2 mg/ml.

[0043] Alternatively, monothioglycerol may be used, also in an amount of from 0.5 to 10 mg/ml, more preferably 1 to 5 mg/ml, and most preferably about 2 mg/ml.

[0044] It is most preferable to use monothioglycerol and ascorbic acid in combination in the amounts indicated above for each anti-oxidant.

[0045] Preferably the stability enhancers comprise, in addition to antioxidants, a chelating agent from disodium EDTA and calcium disodium EDTA. These are preferably used in amounts of from 0.1 to 10 mg/ml, more preferably 0.5 to 5 mg/ml, and most preferably about 1 mg/ml.

[0046] Preferably the formulation has a pH between 3 and 6, most preferably about 4.

[0047] The formulation may take the form of a bolus formulation or an infusion formulation which may be diluted in use with, for example an isotonic glucose solution.

[0048] The preferred formulations preferably provide a shelf life of at least 12 months without refrigeration, more preferably 18 months without refrigeration and most preferably still 24 months without refrigeration.

[0049] The preferred formulations are most preferably stable in climatic zones I and II for up to 18 months at 25° C., and stable in climatic zones III and IV for up to 12 months at 30° C.

[0050] The formulation may be packaged for use in a vial, ampule, syringe, infusion bag or other container.

[0051] The formulation should be sterile and may be sterilised by filtration.

[0052] The term “about” is defined according to the invention as meaning plus or minus 10% of the amount stated.

[0053] According to a second aspect of the present invention there is provided a method of preparing an aqueous parenteral cannabinoid according to the invention comprising preparing a stock solution of a cannabinoid in a surfactant; preparing an aqueous solution comprising the isotonic agent and one or more stability enhancers; and slowly adding the aqueous solution to the stock solution of the cannabinoid in the surfactant.

[0054] Preferably the cannabinoid is CBD or CBDV, the surfactant is macrogol 15 hydroxystearate, the isotonic agent comprises glycerol, and the stability enhancers are ascorbic acid, monothioglycerol and calcium disodium EDTA.

[0055] Preferably the Macrogol 15 hydroxystearate is heated to about 40° C., and CBD or CBDV is added at about 60° C.; the water is sparged with nitrogen, heated to about 60° C. and glycerol, monothioglycerol, EDTA and ascorbic acid added; and then the resulting aqueous solution is slowly added to the solution of CBD or CBDV in Macrogol 15 hydroxystearate.

[0056] The resulting formulation is sterilized by filtration and the formulation is aseptically filled into a vial, ampule, syringe, infusion bag or other container.

[0057] This may be performed in a 4-glove general purpose filling isolator under nitrogen.

[0058] In accordance with a third aspect of the present invention there is provided a method of treating a subject comprising administering an aqueous parenteral cannabinoid formulation according to the invention.

[0059] Preferably the aqueous parenteral cannabinoid formulation is delivered by injection. Preferably the subject is a human.

[0060] The aqueous parenteral cannabinoid formulation is for use as a rescue formulation. Preferably the rescue medication is for use as a neuroprotectant or anti-convulsive.

[0061] The rescue medication may be used to treat newborn hypoxic-ischemic encephalopathy (NHIE), status epilepticus or stroke.

[0062] In a fourth aspect of the present invention there is provided an aqueous parenteral cannabinoid formulation according to the invention for use in the treatment of conditions requiring the administration of a neuroprotectant or anti-convulsive medication.

[0063] Preferably the aqueous parenteral cannabinoid formulation is used in the treatment of newborn hypoxic-ischemic encephalopathy (NHIE), status epilepticus or stroke.

DETAILED DESCRIPTION

[0064] Embodiments of the invention are further described hereinafter with reference to the following Examples and experiments. Initial investigations focused on CBD as a model cannabinoid and assessed a range of solvents or diluents alone or in combination with surfactants.

[0065] The solvents/diluents/surfactants investigated in a solubility screening study are set out in Table 1 below:

TABLE 1

Excipient
t-butyl alcohol (≤99%)
Ethanol (99.8%)
Glycerol (99.0-100%)
Glucose (99.5%)
Mannitol (Pearlitol PF)
Macrogol 15 Hydroxystearate Solutol HS15 (Kolliphor HS15)
Macrogol 15 Hydroxystearate, Super refined Crodasol HS HP-SO-(MH)
PEG 400 (GPR RECTAPUR)
Povidone K12 (PF)
Povidone K17 (PF)
Sodium Chloride (GPR RECTAPUR)
Sucrose (≤99.5%)
Synperonic PE/F68 Flakes, super refined
Trehalose (≤99%)
Tween 80-LQ-(Cqq), super refined

[0066] The methodology for the solubility screening was as follows:

Solubility Screening

[0067] 8 mg of API (CBD) was weighed into a 2 ml clear glass vial and 0.5 or 1 ml of solution was added. All the vials were sonicated for 5 minutes and then left on a roller mixer, mixing for 48 hours. The roller mixer was covered with aluminium foil to prevent light exposure.

[0068] After 24 hours, the vials which showed good API solubility visually (i.e. no solid seen) had more API added and this process was repeated until the samples were saturated or ceased, if saturation condition could not be met after adding a substantial amount of API.

[0069] After 48 hours, all samples were centrifuged, and the supernatants taken (250 or 500 µL) using a Gilson pipette and added into a 10 ml volume flask. Methanol was used to make up the volume and the samples were tested by HPLC. Sample numbers 5, 9 and 10 were assayed using visual observation as the amount of API that could be added was so high.

[0070] The assay results are shown in Table 2 below:

TABLE 2

Sample No.	Sample ID	ASSAY CBD (mg/ml)
1	ETOH (0.5% v/v)	0.0496
2	ETOH (1% v/v)	0.0426
3	ETOH (3% v/v)	0.0054
4	ETOH (5% v/v)	0.0244
5*	ETOH (100% v/v)	>1000
6	PEG400 (5% v/v)	0.1596
7	PEG400 (15% v/v)	0.1946
8	PEG400 (25% v/v)	0.1617
9*	PEG400 (100% v/v)	>400
10*	t-butyl alcohol (TBA), (100% v/v)	>600
11	Glycerol (10% v/v)	0.0029
12	Glycerol (20% v/v)	0.0437
13	Glycerol (40% v/v)	0.0859
14**	Glycerol (100% v/v)	—
15	Saline (0.45% w/v)	0.0021
16	Saline (0.9% w/v)	0.0551
17	Glucose (5% w/v)	0.0008
18	Glucose (10% w/v)	0.2379
19	Mannitol (5% w/v)	0.0009
20	Mannitol (10% w/v)	0.0148

TABLE 2-continued

Sample No.	Sample ID	ASSAY CBD (mg/ml)
21	Sucrose (5% w/v)	0.0202
22	Sucrose (10% w/v)	0.0822
23	Trehalose (10% w/v)	0.0124
24	Trehalose (5% w/v)	0.0600
25	Polysorbate 80 (0.5% w/v)	3.2600
26	Polysorbate 80 (1% w/v)	6.0415
27	Polysorbate 80 (3% w/v)	22.9779
28	Polysorbate 80 (5% w/v)	30.6529
29	Crodosal HS (0.5% w/v)	2.6529
30	Crodosal HS (1% w/v)	5.4462
31	Crodosal HS (2% w/v)	5.0344
32	Crodosal HS (3% w/v)	6.3465
33	Crodosal HS (4% w/v)	7.5569
34	Crodosal HS (5% w/v)	7.9983
35	Pluronic F68 (1% w/v)	0.1403
36	Pluronic F68 (2% w/v)	0.5209
37	Pluronic F68 (3% w/v)	0.5042
38	Pluronic F68 (5% w/v)	1.0654
39	PVP K12 (1% w/v)	0.0615
40***	PVP K12 (2% w/v)	0.1746
41	PVP K12 (3% w/v)	0.0639
42	PVP K12 (5% w/v)	0.0157
43	PVP K17 (1% w/v)	0.0031
44	PVP K17 (2% w/v)	0.0433
45	PVP K17 (3% w/v)	0.0409
46	PVP K17 (5% w/v)	0.2360

*Solubility data acquired by visual observation (all the others were acquired by HPLC).

**Sample not tested because of sampling problem.

***High assay result probably due to sampling problem.

[0071] According to the solubility results, ethanol (100%), PEG400 (100%) and TBA (100%) showed the highest solubility for CBD. Polysorbate 80 (Tween) and Crodosal

HS, at all concentrations tested, also showed better solubility compared to the other solutions tested. The use of Pluronic F68 also gave solubility improvement to CBD to a limited extent. The solubility of CBD in solutions containing different bulking agents such as sucrose, mannitol and trehalose was also investigated. Very limited solubility improvement was noticed. Saline (0.45% and 0.9%) and Glucose (G5 and G10) solutions were tested. Better solubility of CBD was seen in Glucose G10. Two polymers (PVP K12 and K17) were tested. A slight solubility improvement was seen. A linear relation of solubility and PVP concentration was observed for PVP K17 solutions; however, this linearity was not seen in PVP K12 (it should be noted that a sampling problem might have happened during measurement of sample 40 during HPLC analysis). TBA showed good CBD solubility in this study which suggests it could be used as a potential solvent for a lyophilised formulation.

[0072] It was observed that whilst pure ethanol and PEG400 resulted in the highest solubility of CBD, the aqueous solutions containing different amount of ethanol and PEG400 did not result in high CBD solubility. Even though the amount of PEG400 and ethanol was increased to 50% in water, the 10 mg of CBD added did not dissolve completely. This phenomenon was probably due to the poor aqueous solubility of CBD.

[0073] Based upon the above, Applicant selected a Macrogol 15 hydroxystearate as the preferred surfactant, and investigated the effect of different antioxidants, chelating agents and isotonic agents on short term stability (1 week, 2 week and 1 month).

[0074] A number of test formulations are illustrated in Table 3 below:

TABLE 3

Sample No.	CBD (mg/ml)	Solutol HS15 (% w/v)	NaCl (% w/v)	Glucose (% w/v)	Glycerol (% w/v)	Disodium EDTA (% w/v)	Ascorbic acid (% w/v)	Mono-thioglycerol (% w/v)	Cysteine HCl (% w/v)	Glutathione (% w/v)
1	5	5	—	—	—	—	—	—	—	—
2	5	5	—	5	—	0.2	1	—	—	—
3	5	5	—	5	—	0.2	—	1	—	—
4	5	5	—	5	—	0.2	—	—	0.5	—
5	5	5	—	5	—	0.2	—	—	—	0.5
6	5	5	—	5	—	0.2	1	1	—	—
7	5	5	—	—	20	0.2	1	—	—	—
8	5	5	—	—	20	0.2	—	1	—	—
9	5	5	—	—	20	0.2	—	—	0.5	—
10	5	5	—	—	20	0.2	—	—	—	0.5
11	5	5	—	—	20	0.2	1	1	—	—
12	5	5	0.9	—	—	—	—	—	—	—

[0075] The relative chemical stability of these formulations are shown in Tables 4 (CBD) and 5 (placebo) below which show respectively the stability of CBD as an assayed % and as a % impurity.

TABLE 4

Formulation	CBD (mg/ml)	T0		T1w		T2w		T1m		Appearance
		Assay (mg/ml)	% Assay	Assay (mg/ml)	% Assay	Assay (mg/ml)	% Assay	Assay (mg/ml)	% Assay	
1	5.00	4.94	98.83	4.87	99.00	4.79	95.79	4.76	95.11	Clear
2	5.00	4.98	99.55	5.00	100.01	4.96	99.17	5.03	100.55	Brown
3	5.00	5.03	100.51	4.95	99.09	4.72	94.31	4.50	89.96	Clear
4	5.00	4.88	97.66	4.88	97.62	4.91	98.18	4.96	99.25	Turbid

TABLE 4-continued

Formulation	CBD (mg/ml)	T0		T1w		T2w		T1m		Appearance
		Assay (mg/ml)	% Assay	Assay (mg/ml)	% Assay	Assay (mg/ml)	% Assay	Assay (mg/ml)	% Assay	
5	5.00	5.00	100.10	4.95	99.04	5.00	100.10	5.03	100.63	Clear
6	5.00	5.03	100.58	4.92	98.43	4.72	94.32	4.46	89.12	Clear
7	5.00	4.82	96.44	5.09	101.86	4.91	98.92	4.93	98.60	Brown
8	5.00	4.90	97.96	5.08	101.52	4.69	93.74	4.50	90.07	Clear
9	5.00	4.89	97.77	5.08	101.55	5.15	103.06	4.98	99.58	Turbid
10	5.00	4.99	99.81	5.02	100.32	5.09	101.83	4.96	99.19	Clear
11	5.00	4.91	98.29	4.93	98.68	4.90	97.35	4.95	98.27	Clear
12	5.00	4.88	97.69	4.12	82.40	3.98	79.64	3.28	65.67	Clear

TABLE 5

Formulation	T0		T1w		T2w		T1m	
	Impurity $\leq 0.045\%$	Total impurity	Impurity $\leq 0.045\%$	% Total impurity	Impurity $\leq 0.045\%$	% Total impurity	Impurity $\leq 0.045\%$	% Total impurity
Std	0.53	0.67	0.77	0.89	0.55	0.72	0.46	0.57
1	0.81	1.03	3.67	3.81	3.39	3.54	5.92	5.96
2	0.57	0.78	0.49	0.61	0.85	0.96	1.00	1.17
3	0.54	0.76	3.03	3.11	2.66	2.75	10.87	10.89
4	0.52	0.74	0.82	1.04	1.4	1.81	1.86	1.93
5	0.46	0.71	0.54	0.67	1.21	1.4	0.61	0.73
6	2.91	3.06	8.99	9.09	8.38	8.56	15.6	15.63
7	0.46	0.7	0.47	0.57	1.18	1.37	0.57	0.68
8	0.46	0.74	1.58	1.74	3.96	4.11	9.25	9.3
9	0.47	0.74	0.82	1.06	1.16	1.41	1.81	1.85
10	1.89	2.16	0.46	0.6	1.48	1.59	8.54	0.64
11	1.82	2.07	0.47	0.59	1.08	1.25	0.56	0.62
12	0.47	0.77	11.67	11.92	17.56	17.6	25.69	25.73

[0076] The results show the best formulations are formulations 2, 4, 5, 7, 9, 10 and 11.

[0077] According to the HPLC data, the formulations containing the antioxidants: ascorbic acid, cysteine HCl, and glutathione showed better assay and impurity results after 1 month at 40° C. and 75% relative humidity (RH) compared to the control formulations (1, 12). The formulations 3, 6 and 8, (except for 11, which also contained ascorbic acid) containing monothioglycerol alone degraded significantly compared to the control formulation 1.

[0078] Formulation 12 which contained NaCl (as the isotonicity agent) showed the poorest stability with an assay of ~66% and total impurity of ~26%.

[0079] The physical stability of the formulations was also studied. The physical appearance of the active samples after storage at 40° C. and 75% RH was also monitored and the results are illustrated in Table 4. It will be noted that Formulations 2 and 7 (containing ascorbic acid alone) turned brown in colour after 1 month at 40° C. and 75% RH. These formulations were however not purged with nitrogen. This browning effect may however be due to the oxidation of the ascorbic acid itself. In contrast, Formulation 6 and 11, which contained ascorbic acid together with monothioglycerol did not discolour. Therefore there appears to be a positive protective effect seen when monothioglycerol is used in combination with ascorbic acid.

[0080] The active formulations 2 and 7 which contained ascorbic acid only did not change colour after 1 month at 40° C. and 75% RH which was probably because they were purged with N₂ for storage. This demonstrates the importance of a N₂ headspace environment in preventing oxida-

tion. Formulation 12 turned yellow after storage while the placebo one remained clear after storage at the same condition. This indicates that this change of colour was associated with the existence of CBD with NaCl.

[0081] Both placebos and active formulations 4 and 9 became turbid after storage, which was due to the precipitation of the cysteine HCl.

[0082] A summary of the physical appearance of all placebo and active samples is shown in Table 6.

TABLE 6

Sample	Placebo 40/75	Active fridge	Active 40/75
1	Clear	Clear - off yellow	Clear - yellow
2	Brown yellow	Precipitation	Brown yellow
3	Clear	Clear - off pink	Clear
4	Turbid	Turbid	Turbid
5	Clear	Clear - off yellow	Clear - off yellow
6	Clear	Clear - off pink	Clear
7	Brown yellow	Clear - off yellow	Brown yellow/hazy
8	Clear	Clear - off pink	Clear to hazy
9	Turbid	Hazy	Hazy
10	Clear	Clear - off yellow	Hazy
11	Clear	Clear - off yellow	Hazy
12	Clear	Clear - yellow	Clear - yellow

[0083] A summary of both the chemical and physical stability of the active formulations is shown in Table 7.

TABLE 7

Formulation	Assay (mg/ml)	% Assay	Impurity $\leq 0.045\%$	% Total Impurity	Physical appearance
1	4.76	95.11	5.92	5.96	Clear - yellow
2	5.03	100.55	1.09	1.17	Brown yellow
3	4.5	89.96	10.87	10.89	Clear
4	4.96	99.25	1.88	1.93	Turbid
5	5.03	100.62	0.61	0.73	Clear - off yellow
6	4.46	89.12	15.6	15.63	Clear
7	4.93	98.5	0.57	0.68	Brown yellow/hazy
8	4.5	90.07	9.25	9.3	Clear to hazy
9	4.96	99.58	1.81	1.86	White hazy
10	4.96	99.19	0.58	0.64	White hazy
11	4.91	98.27	0.56	0.62	White hazy
12	3.28	65.67	25.69	20.79	Clear - yellow

Conclusions

[0084] Macrogol 15 Hydroxystearate (e.g. Solutol HS15) as a surfactant was very effective at improving the solubility of CBD in water.

[0085] A number of antioxidants significantly improved the chemical stability of the formulations. The use of glutathione alone or ascorbic acid and monothioglycerol exhibit significantly improved both chemical and physical stability. Cysteine HCl also showed good chemical stability, however, precipitation of cysteine HCl was seen after storage.

[0086] Glycerol and glucose, but not sodium chloride, appeared to be the best isotonicity agents.

[0087] Based on the above the Applicant sought to optimise Formulation 11, with the intent of using the lowest amounts of stabilizing excipients to obtain a cannabinoid containing formulation with an osmolarity of approximately 300 mOsmol/Kg (range 200 to 400) exhibiting long term stability testing (1 year plus) without refrigeration. The optimized formulation is shown in Example 1.

Example 1: Optimised Formulation

[0088] Table 8 below illustrates the most preferred formulation where the API is cannabidiol (CBD).

TABLE 8

Product/Raw material	Generic	Broad range	Intermediate range	Quantity
CBD or CBDV	Cannabinoid	0.3-50	1-7	3 mg/mL (CBD) or 5 mg/mL (CBDV)
Macrogol 15 hydroxystearate Ph Eur (Kolliphor HS15)	Surfactant	5-500	10-100	50 mg/mL
Glycerol Ph Eur	Isotonic agent	5-50	10-30	20 mg/mL
Sodium calcium edetate Ph Eur	Stability enhancer	0.1-10	0.5-5	1 mg/mL
Ascorbic acid Ph Eur	Stability enhancer	0.5-10	1-5	2 mg/mL
1-Thioglycerol USP	Stability enhancer	0.5-10	1-5	2 mg/mL

TABLE 8-continued

Product/Raw material	Generic	Broad range	Intermediate range	Quantity
Water for Injection Ph Eur (1000 mL sterile pack)	Solvent	Q.S to volume	Q.S to volume	Q.S to volume

Method of Manufacture

[0089] The preferred formulation (Table 8 above) was prepared as per the steps indicated below:

[0090] 1. Heat Kolliphor HS15 to about 40° in an oven;

[0091] 2. Heat water to 60° C. in an oven;

[0092] 3. Weigh required amount of Kolliphor HS15 into a first container, ensuring no solidification of the Kolliphor HS15 occurs. Add CBD and stir maintaining a temperature of 60° C. Place back in the oven;

[0093] 4. In a second container weigh the required amount of Glycerol and monothioglycerol. Add 25% of the final volume of pre heated water;

[0094] 5. Then add the calcium disodium EDTA and ascorbic acid. Mix until fully dissolved then place back in the oven at 60° C.

[0095] 6. Add the content of the second container drop by drop to the first container whilst constantly stirring to prevent solidification; and

[0096] 7. Q-s to volume using desired vessel and mix without introduction of bubbles and air.

[0097] The formulation may then be spray dried or lyophilized such that it may be stored for a longer period. Such spray dried formulations could then be rehydrated with a sugar solution in order to provide the formulation in a different administration form or as a parenteral formulation.

[0098] The formulation of Example 1 was subjected to long term stability testing as set out in Experiment 1 below:

Experiment 1—Long Term Stability Study

[0099] This stability study was conducted on 1 batch of the IV formulation. The batch used was manufactured using a 1 L pilot scale manufacture and batch size, at GW Pharma Ltd. The batch was sub-divided (batches A-E, Table 9) to

provide sufficient samples for the different storage conditions and time-points. A placebo in a clear glass vial was put alongside this study.

TABLE 9

Batch	Description
A	Type I clear glass vial nitrogen purged (Active)
B	Type I amber glass vial nitrogen purged (Active)
C	Type I clear glass vial NO nitrogen purge (Active)
D	Type I amber glass vial NO nitrogen purge (Active)
E	Type I clear glass vial nitrogen purged (Placebo)
F (CBDV)	Type I clear glass vial nitrogen purged (Active)

[0100] The objective was to assess the long term stability (at least 12 months) of the formulation. Stoppers were gamma irradiated as per sterile manufacture and all vials containing the formulation were inverted and stored at different storage conditions (temperature and humidity—as per Table 10) to determine whether any potential extractables or leachables were present. The study stressed the formulation at 60° C. to accelerate any possible extractables or leachables that may occur.

TABLE 10

5 ± 3° C.
25 ± 2° C., 60% RH
30 ± 2° C., 65% RH
40 ± 2° C., 75% RH

Results

Batch A—all Temperatures

[0101] Overall throughout the 24 month study period there was no significant decrease in CBD content or pH of the samples as illustrated in Table 11. The formation of the degradant OH-CBD over various temperature and humidity conditions can be considered as an increasing trend of temperature as the results demonstrate that the increase in temperature 5-30° C. over 24 months is causing an increase in OH-CBD formation.

[0102] The degradants are below the acceptable limit. In terms of any extractables and leachables from the product stored inverted, there has been no detection or any anomalous peaks forming.

[0103] Batch A includes a nitrogen headspace sparge and the use of a clear glass vial and demonstrates acceptable stability over time.

Batch B—all Temperatures

[0104] Batch B has been tested to determine any differences between amber glass and clear glass vials and the results are shown in Table 12. The data showed no degradation or significant differences between storing in amber or clear glass vials.

Batch C—all Temperatures

[0105] Batch C has been tested at the same intervals as Batch A to determine any differences between nitrogen headspace sparging of the IV product and the results are shown in Table 13. A basic visual appearance test shows significant differences where batch C at the 6 month time point at 30° C. and 40° C. is it shows a yellowing of the solution which is also evident at the 9 and 12 month timepoint. Furthermore with the increase in temperature, 5-40° C. over 6 months, there is a decrease in the pH to <4. Furthermore as the temperature increases there is a rapid rise in the formation of OH-CBD compared to batch A which has had the nitrogen headspace sparge. A glance at the chromatography has also shown that all temperatures within Batch C have very rough baselines and degradation products are more prevalent than in Batch A suggesting that a headspace sparge is required for the stability of this product.

Batch D—all Temperatures

[0106] Batch D has been tested at the to determine any differences between amber glass and clear glass vials without the nitrogen headspace sparge in addition to comparing it to the corresponding purged sample in batch B. The results are shown in Table 14. The data shows that non-sparging the formulation, even within an amber glass vial, results in an increase in degradation. In general an overall trend comparing actives containing a nitrogen sparge maintains the pH of the solution >4 units compared to non-sparging which results in the pH decreasing <4 units.

Batch E—all Temperatures

[0107] Batch E has been tested at the same intervals as Batch A and C to determine any placebo effects and interferences if any to the active IV product. The results are shown in Table 15. The placebo profile shows no degradation products. However increasing temperature from 5-40° C. results in the pH falling below 4. The placebo (Batch E) at 40° C. at the 6 month time point has shown cloudiness suggesting that the active (Batch A and C) is potentially stabilising the placebo formulation. Furthermore, at the 5° C. condition the 12 month timepoint shows placebo formulation showing cloudiness, which is not observed in Batch A or C at the 5° C. condition.

CBDV—all Temperatures

[0108] Overall throughout the 12 month study period there was no significant decrease in CBDV content or pH of the samples as illustrated in Table 16. The formation of the degradant OH-CBDV or THCV over various temperature and humidity conditions can be considered as an increasing trend of temperature as the results demonstrate that the increase in temperature 5-40° C. over 12 months is causing an increase in degradant formation.

[0109] Extrapolation to 18 months shows that the degradants will still be below the acceptable limit. In terms of any extractables and leachables from the product stored inverted, there has been no detection or any anomalous peaks forming.

TABLE 11

Test	Acceptance criteria	Comments (Batch A)				
		Initial	5° C. (12 months)	25° C. (12 months)	30° C. (12 months)	40° C. (12 months)
Appearance of Solution	Clear solution free from particulates	Complies	Complies	Complies	Complies	Complies
pH	>3.5	4.04	4.01	4.08	3.95	4.13
CBD Content (%)	Within $\pm 3\%$ of initial	100.0	100.6	101.1	101.3	102.3
Degradants (% of CBD content)						
CBE I	NMT 1.0%	0.00	0.00	0.00	0.00	0.04
OH-CBD	NMT 1.0%	0.05	0.05	0.09	0.14	0.25
Individual unspecified degradants	Monitor Above 0.1%	RRT 1.90: 0.08	RRT 1.90: 0.08	RRT 1.90: 0.09	RRT 1.90: 0.11	RRT 1.90: 0.17
Odour	For Information Only	Sulphurous/egg smell	A faint sulphurous smell	A sulphurous smell	A sulphurous smell	A faint sulphurous smell

Test	Acceptance criteria	Comments (Batch A)			
		Initial	5° C. (24 months)	25° C. (24 months)	30° C. (24 months)
Appearance of Solution	Clear solution free from particulates	Complies	Complies	Complies	Complies
pH	>3.5	4.04	3.94	4.02	3.85
CBD Content (%)	Within $\pm 3\%$ of initial	100.0	97.6	97.3	96.8
Degradants (% of CBD content)					
CBE I	NMT 1.0%	0.00	0.00	0.00	0.00
OH-CBD	NMT 1.0%	0.05	0.00	0.01	0.14
Individual unspecified degradants	Monitor Above 0.1%	RRT 1.90: 0.08	RRT 1.90: 0.08	RRT 1.90: 0.09	RRT 1.90: 0.11
Odour	For Information Only	Sulphurous/egg smell	A sulphurous smell	A sulphurous smell	A sulphurous smell

TABLE 12

Test	Acceptance criteria	Comments (Batch B)				
		Initial	5° C. (12 months)	25° C. (12 months)	30° C. (12 months)	40° C. (12 months)
Appearance of Solution	Clear solution free from particulates	Complies	Complies	Complies	Complies	Cloudy colourless solution
pH	>3.5	4.04	3.89	3.90	4.05	4.05
CBD Content (%)	Within $\pm 3\%$ of initial	100.0	99.5	99.5	100.1	100.3
Degradants (% of CBD content)						
CBE I	NMT 1.0%	0.00	0.00	0.00	0.00	0.00
OH-CBD	NMT 1.0%	0.07	0.05	0.09	0.13	0.24
Individual unspecified degradants	Monitor Above 0.1%	RRT 1.90: 0.07	RRT 1.90: 0.03	RRT 1.90: 0.07	RRT 1.90: 0.09	RRT 1.90: 0.13
Odour	For Information Only	Sulphurous/egg smell	A sulphurous smell	A sulphurous smell >5° C.	A sulphurous smell	A sulphurous smell

Test	Acceptance criteria	Comments (Batch B)			
		Initial	5° C. (24 months)	25° C. (24 months)	30° C. (24 months)
Appearance of Solution	Clear solution free from particulates	Complies	Complies	Complies	Complies
pH	>3.5	4.04	3.89	3.85	4.12
CBD Content (%)	Within $\pm 3\%$ of initial	100.0	97.4	97.9	98.2
Degradants (% of CBD content)					
CBE I	NMT 1.0%	0.00	0.00	0.00	0.00
OH-CBD	NMT 1.0%	0.05	0.00	0.01	0.1
Individual unspecified degradants	Monitor Above 0.1%	RRT 1.90: 0.08	RRT 1.90: 0.08	RRT 1.90: 0.09	RRT 1.90: 0.11
Odour	For Information Only	Sulphurous/egg smell	A sulphurous smell	A sulphurous smell	A sulphurous smell

TABLE 13

Test	Acceptance criteria	Comments (Batch C)				
		Initial	5° C. (12 months)	25° C. (12 months)	30° C. (12 months)	40° C. (12 months)
Appearance of Solution	Clear solution free from particulates	Complies	Complies	Complies	Clear faint yellow liquid	Cloudy yellow solution
pH	>3.5	4.05	3.95	3.81	3.82	3.79
CBD Content (%)	Within $\pm 3\%$ of initial	100.0	101.2	100.9	100.1	97.3
<u>Degradants (% of CBD content)</u>						
CBE I	NMT 1.0%	0.00	0.00	0.02	0.03	0.26
OH-CBD	NMT 1.0%	0.07	0.06	0.11	0.15	0.37
Individual unspecified degradants	Monitor Above 0.1%	RRT 1.90: 0.06	RRT 1.90: 0.08	RRT 1.90: 0.06	RRT 1.90: 0.12	RRT 1.90: 0.21 RRT 1.97: 0.13
Odour	For Information Only	Sulphurous/egg smell	A sulphurous smell	A sulphurous smell	A sulphurous smell >25° C.	A sulphurous smell

Test	Acceptance criteria	Comments (Batch C)			
		Initial	5° C. (24 months)	25° C. (24 months)	30° C. (24 months)
Appearance of Solution	Clear solution free from particulates	Complies	Complies	Complies	Complies
pH	>3.5	4.04	3.88	3.85	3.83
CBD Content (%)	Within $\pm 3\%$ of initial	100.0	97.0	95.8	95.2
<u>Degradants (% of CBD content)</u>					
CBE I	NMT 1.0%	0.00	0.00	0.00	0.00
OH-CBD	NMT 1.0%	0.05	0.00	0.01	0.14
Individual unspecified degradants	Monitor Above 0.1%	RRT 1.90: 0.08	RRT 1.90: 0.08	RRT 1.90: 0.09	RRT 1.90: 0.11
Odour	For Information Only	Sulphurous/egg smell	A sulphurous smell	A sulphurous smell	A sulphurous smell

TABLE 14

Test	Acceptance criteria	Comments (Batch D)				
		Initial	5° C. (12 months)	25° C. (12 months)	30° C. (12 months)	40° C. (12 months)
Appearance of Solution	Clear solution free from particulates	Complies	Complies	Complies (yellow solution)	Complies (yellow solution)	Cloudy, yellow solution free from particulates
pH	>3.5	4.05	3.82	3.69	3.71	3.74
CBD Content (%)	Within $\pm 3\%$ of initial	100.0	100.1	100.6	100.1	97.0
<u>Degradants (% of CBD content)</u>						
CBE I	NMT 1.0%	0.00	0.00	0.04	0.07	0.17
OH-CBD	NMT 1.0%	0.07	0.06	0.12	0.17	0.43
Individual unspecified degradants	Monitor Above 0.1%	RRT 1.90: 0.06 RRT 0.46: 0.03	RRT 1.90: 0.07	RRT 1.90: 0.08	RRT 1.90: 0.09	RRT 1.90: 0.24
Odour	For Information Only	Sulphurous/egg smell	A faint sulphurous smell	A faint sulphurous smell	A faint sulphurous smell	A sulphurous disappeared after 15 minutes

Test	Acceptance criteria	Comments (Batch D)			
		Initial	5° C. (24 months)	25° C. (24 months)	30° C. (24 months)
Appearance of Solution	Clear solution free from particulates	Complies	Complies	Complies	Complies
pH	>3.5	4.04	3.9	3.85	3.85
CBD Content (%)	Within $\pm 3\%$ of initial	100.0	97.6	95.8	95.9
<u>Degradants (% of CBD content)</u>					
CBE I	NMT 1.0%	0.00	0.00	0.00	0.00
OH-CBD	NMT 1.0%	0.05	0.00	0.01	0.34

TABLE 14-continued

Individual unspecified degradants	Monitor Above 0.1%	RRT 1.90: 0.08	RRT 1.90: 0.08	RRT 1.90: 0.09	RRT 1.90: 0.11
Odour	For Information Only	Sulphurous/egg smell	A faint sulphurous smell	A sulphurous smell	A faint sulphurous smell

TABLE 15

Test	Acceptance criteria	Comments (Batch E)				
		Initial	5° C. (12 months)	25° C. (12 months)	30° C. (12 months)	40° C. (12 months)
Appearance of Solution	Clear solution free from particulates	Complies	Cloudy colourless liquid	Complies	Complies	Cloudy colourless liquid
pH	>3.5	4.10	3.96	3.86	3.98	4.05
CBD Content (%)	Within $\pm 3\%$ of initial	N/D	N/A	N/A	N/A	N/A
<u>Degradants (% of CBD content)</u>						
CBE I	NMT 1.0%	N/D	N/A	N/A	N/A	N/A
OH-CBD	NMT 1.0%	N/D	N/A	N/A	N/A	N/A
Individual unspecified degradants	Monitor Above 0.1%	N/D	N/A	N/A	N/A	N/A
Odour	For Information Only	Sulphurous/egg smell	A faint sulphurous smell	A faint sulphurous smell	A sulphurous smell	A sulphurous smell >30° C.

Comments (Batch E)

Test	Acceptance criteria	Comments (Batch E)				
		Initial	5° C. (24 months)	25° C. (24 months)	30° C. (24 months)	
Appearance of Solution	Clear solution free from particulates	Complies	Complies	Complies	Complies	
pH	>3.5	4.04	4.11	4.02	4.01	
CBD Content (%)	Within $\pm 3\%$ of initial	N/D	N/D	N/D	N/D	
<u>Degradants (% of CBD content)</u>						
CBE I	NMT 1.0%	N/D	N/D	N/D	N/D	
OH-CBD	NMT 1.0%	N/D	N/D	N/D	N/D	
Individual unspecified degradants	Monitor Above 0.1%	N/D	N/D	N/D	N/D	
Odour	For Information Only	Sulphurous/egg smell	A sulphurous smell	A sulphurous smell	A sulphurous smell	

TABLE 16

Test	Acceptance criteria	Batch F (CBDV)				
		Initial	5° C. (12 months)	25° C. (12 months)	30° C. (12 months)	40° C. (12 months)
Appearance of Solution	Clear solution free from particulates	Complies	Complies	Complies	Complies	Complies
pH	>3.5	4.15	3.99	4.06	4.04	4.06
CBDV Content (%)	Within $\pm 5\%$ of initial	100.0	100.4	100.9	99.9	99.5
CBD		3.1	3.1	3.1	3.1	3.1
CBD-4		0.1	0.1	0.1	0.1	0.1
<u>Degradants (% of CBDV content)</u>						
CBE I	NMT 0.5%	<0.5	<0.5	<0.5	<0.5	<0.5
OH-CBD	NMT 0.5%	<0.5	<0.5	<0.5	<0.5	<0.5

Conclusions

[0110] Batches A and F provides a shelf life based on the decision tree for evaluation of stability data (ICH guidelines) extended to 24 months.

[0111] Batch E is the corresponding placebo to Batch A and supports a store below 25° C. label.

[0112] As this product is intended for use in Climatic Zones I and II the intermediate condition will be used for assigning the shelf life based on the ICH decision tree.

[0113] Data for this formulation can support for an active formulation:

[0114] Climatic Zone I and II-24 months—Store below 25° C.

[0115] Climatic Zone III and IV-12 month—Store below 30° C.

[0116] In addition to the Stability study the formulation underwent a number of additional studies the results of which are set out below:

Experiment 2

Filtration Compatibility Study

[0117] A pre and post filtration study was carried out on the active and Placebo formulations.

[0118] The IV solution undergoes a bioburden reduction step after manufacture of the solution prior to filling using a Merck Millipore gold pack PVDF 0.22 µm filter. To determine compatibility of this filter a pre and post filtration sample was collected for both active and placebo batches. Assay, appearance, odour and pH was tested and the data is presented in Table 17.

TABLE 17

Test Description	Pre filtration Active	Post filtration Active	Pre filtration Placebo	Post filtration Placebo
Appearance	Clear colourless solution free from particulates	Clear colourless solution free from particulates	Clear colourless solution free from particulates	Clear colourless solution free from particulates
pH	4.05	4.01	4.08	4.12
Assay (CBD content)	3.0 mg/mL	3.0 mg/mL	ND	ND
Degradants	No change	No change	No change	No change
Odour	Faint egg like odour	Faint egg like odour	Faint egg like odour	Faint egg like odour

[0119] Results from the pre and post filtration study demonstrates that the CBD IV solution and placebo are compatible with the tubing and filter used.

Experiment 3

Pilot Photostability Testing

[0120] A sample of placebo and active was prepared and packaged in 20 mL clear glass vials containing the IV solution. Two vials of active and two vials of placebo were subjected to a minimum of 1.2 million Lux hours as part of

ICH Q1B testing. Additional vials were wrapped in foil as the control for the study.

Results

[0121] The experiment demonstrated no differences in appearance, pH, assay, degradants and odour between the control and test samples when exposed to 1.2 million Lux hours and the data is presented in Table 18.

TABLE 18

Test Description	Control	Active	Control Placebo	Placebo
Appearance	Clear solution free from particulates	Clear solution free from particulates	Clear solution free from particulates	Clear solution free from particulates
pH	3.91	3.89	3.86	3.86
Assay (CBD content)	3.0 mg/mL	3.0 mg/mL	ND	ND
Degradants	No change	No change	No change	No change
Odour	Faint egg like odour	Faint egg like odour slightly stronger than control	Faint egg like odour	Faint egg like odour slightly stronger than control

[0122] The solution throughout the study remained clear and free from particulates with a pH for both active and placebo of 3.9 with and without foil. The assay results show no significant differences between the exposed vial and the control vial wrapped in foil.

Conclusion:

[0123] The product is not sensitive to light and a clear glass vial is suitable for storage and presentation of the CBD IV and Placebo solution.

Experiment 4

Compatibility in 5% Glucose Diluent

[0124] The proposed method of delivery for e.g. an IV product for neonatal hypoxia is slow bolus injection (Potentially via a catheter).

[0125] To test compatibility with a diluent, 30 mL of a 3 mg/mL CBD solution (90 mg) was injected into a 500 mL 5% glucose infusion bag and left for a period of 24 hours at ambient to determine any physical or chemical incompatibility.

[0126] 5 mL samples were removed from the infusion bag using a 5 mL syringe on the outlet valve at 0, 0.5, 1, 2, 4 and 24 hours after injection. At each time point the bag was inspected under a polarised light box to check for any precipitation. The results are illustrated in Table 19 below.

TABLE 19

	0	0.5	1	2	4	24
CBD (calculated mg/mL)	0.163	0.163	0.164	0.164	0.164	0.164
Appearance (Clear solution free from particulates)	Complies	Complies	Complies	Complies	Complies	Complies

[0127] At all time points the solution remained clear and free from particulates. There was some residual volume in the syringe and the needle that may account for the mass balance. CBD IV solution is compatible with glucose 5% for a period of 24 hours tested.

Conclusion:

[0128] The rationale for the 5% glucose infusion bag stems from the properties being very similar to the IV formulation with a pH of approximately 4 and an osmolality of close to 300 (maintaining isotonicity).

[0129] CBD IV solution is compatible with glucose 5% for a period of 24 hours tested. In addition, the pH remains unchanged over the 24 hour period and maintains pH of the glucose infusion bag of approx. 4.2.

Experiment 5

Particle Size

[0130] The preferred formulation was tested on a Malvern Zetasizer in order to measure the particle size of the micelles produced by the formulation.

[0131] Table 20 below details the average size of the particles of four batches of the formulation. As can be seen the particle size of all formulations is very consistent. All batches were shown to produce average micelle size of less than 20 nanometers. Such particle size may be important to enable faster uptake of the active agent into cells.

TABLE 20

Sample Details	Date of Manufacture	Date of Testing	Z-Average (d · nm)
3 mg/mL CBD IV	15 Dec. 2015	11 May 2017	15.03
3 mg/mL CBD IV	22 Sep. 2014	05 May 2017	17.02
DSP-14-09-01 25° C.			
3 mg/mL CBD IV	15 Apr. 2015	19 Apr. 2017	15.45
DSP-15-06-01 25° C.			
3 mg/mL CBD IV	03 Jun. 2015	03 May 2017	15.37

1. An aqueous parenteral formulation comprising:

- (i) a cannabinoid;
- (ii) an isotonic agent;
- (iii) a surfactant; and
- (iv) one or more stability enhancers.

2. The formulation of claim 1 wherein the cannabinoid is selected from: cannabichromene (CBC), cannabichromenic acid (CBCV), cannabidiol (CBD), cannabidiolic acid (CBDA), cannabidivarin (CBDV), cannabigerol (CBG), cannabigerol propyl variant (CBGV), cannabicyclol (CBL), cannabitol (CBN), cannabitol propyl variant (CBNV), cannabitriol (CBO), tetrahydrocannabinol (THC), tetrahydrocannabinolic acid (THCA), tetrahydrocannabivarin (THCV) and tetrahydrocannabivarinic acid (THCVA).

3. The formulation of claim 1, wherein the cannabinoid is CBD or CBDV.

4. The formulation of claim 1, wherein the cannabinoid is present in an amount of 0.3 to 50 mg/ml.

5. (canceled)

6. The formulation of claim 1, wherein the isotonic agent is selected from: polyethylene glycol, glycerol, saline and glucose.

7. The formulation of claim 1, wherein the formulation has an osmolality is in the range of from 100-500 mOsmol/Kg.

8. The formulation of claim 1, wherein the isotonic agent is glycerol, and wherein the glycerol is present in an amount of 5 to 50 mg/ml.

9. (canceled)

10. Formulation of claim 1, wherein the surfactant is a non-ionic surfactant selected from Polyoxyethylene (20) sorbitan monooleate, Polysorbate 80; Macrogol 15 hydroxystearate and Polyoxamers.

11. The formulation of claim 10 wherein the surfactant is Macrogol 15 hydroxystearate, and the Macrogol 15 hydroxystearate is present in an amount of from 5 to 500 mg/ml.

12. (canceled)

13. The formulation of claim 1 wherein the one or more stability enhancers comprises one or more antioxidants selected from ascorbic acid, monothioglycerol, cysteine HCl and Glutathione.

14. The formulation of claim 13 wherein the one or more stability enhancers is selected from ascorbic acid, monothioglycerol, and a combination thereof.

15. The formulation of claim 14 wherein when ascorbic acid is present, the ascorbic acid is present in an amount of from 0.5 to 10 mg/ml, and when monothioglycerol is present, the monothioglycerol is present in an amount of from 0.5 to 10 mg/ml.

16.-19. (canceled)

20. The formulation of claim 1 wherein the one or more stability enhancers comprises a chelating agent selected from: disodium EDTA and calcium disodium EDTA.

21. The formulation of claim 20 wherein the chelating agent is calcium disodium EDTA, and is present in an amount of from 0.1 to 10 mg/ml.

22.-29. (canceled)

30. A method of preparing the formulation of claim 1, comprising preparing a stock solution of a cannabinoid in a surfactant; preparing an aqueous solution comprising the isotonic agent and one or more stability enhancers; and slowly adding the aqueous solution to the stock solution of the cannabinoid in the surfactant.

31. The method of claim 30 wherein the cannabinoid is CBD or CBDV, the surfactant is macrogol 15 hydroxystearate, the isotonic agent is glycerol, and the stability enhancers are ascorbic acid, monothioglycerol and calcium disodium EDTA; and the method further comprises:

generating a solution of CBD or CBDV in macrogol 15 hydroxystearate by
heating the macrogol 15 hydroxystearate to about 40° C.; and
adding the CBD or CBDV at about 60° C. to the macrogol 15 hydroxystearate;
generating an aqueous solution by
sparging the water with nitrogen;
heating the water to about 60° C.; and
adding the glycerol, monothioglycerol, EDTA and ascorbic acid to the water; and
slowly adding to the solution of CBD in Macrogol 15 hydroxystearate to the aqueous solution.

32.-35. (canceled)

36. A method of treating a subject comprising administering the aqueous parenteral formulation of claim **1** to the subject.

37.-38. (canceled)

39. The method of claim **36**, wherein the formulation is administered as a rescue formulation.

40.-43. (canceled)

44. The method of claim **36**, wherein the formulation is administered for the treatment of one or more conditions requiring the administration of a neuroprotectant or anti-convulsive medication.

45. The method of claim **44**, wherein the one or more conditions are selected from newborn hypoxic-ischemic encephalopathy (NHIE), status epilepticus, and stroke.

46.-47. (canceled)

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