Hemp (*Cannabis sativa*) - An Underexploited but Promising Oilseed with Multifarious Properties and Applications: A Review

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ABSTRACT

Hemp commonly known as *bhang* belongs to the *Cannabaceae* family. Due to the psychoactive effect, it is often stigmatised; however, recently the Government of Uttarakhand has legalised the cultivation of hemp in the state with <0.3 % 9-tetrahydrocannabinol levels. Hence this review provides comprehensive details on how the whole plant of hemp can be potentially used in various industries. Researchers identify hemp as a rich source of nutrients. Specifically, hemp seeds are being celebrated due to the presence of fatty acids, amino acids, and antioxidants. The presence of these nutrients makes hemp seeds a valuable ingredient in functional foods. Additionally, several studies recognised hemp for several health benefits *viz.,* managing neurological disorders, preventing several cancers, easing skin problems and promoting better mental health. Alongside the health benefits, the hemp plant is recognised to have diverse applications in other industries such as cosmetics, textiles and construction. However, due to the legal constraints and local stigma large and nation-wide cultivation of hemp is difficult but extensive research into the cultivation and processing of hemp can help to leverage this plant for the associated benefits.

Keywords: Hemp; Fatty acids; Hemp seeds; Antioxidants; Medicinal benefits; Hemp products

NOMENCLATURE

THC   : Δ-9-tetrahydrocannabinol
CBD   : Cannabidiol
PUFA   : Polyunsaturated fatty acids
ALA   : Alpha-linolenic acid
LA   : Linoleic acid
HI   : Hypoxic-ischemic
RA   : Rheumatoid arthritis
PTSD   : Post-traumatic stress disorder
EFAs   : Essential fatty acids

1. INTRODUCTION

Cannabaceae is a family of flowering plants that includes the genus of *cannabis*. *Cannabis* plants also have been used for medicinal, recreational, therapeutic, and religious purposes for thousands of years. Cannabis sativa is referred to as hemp and is the most widely grown and studied cultivar in India. In India, there are 3.1 crore cannabis product users in the age range of 10 to 75 years or 2.8 % of the total population[2]. It is used to make biodegradable plastics, textiles, food, paper, lighting oil, animal feed, and other products (Figure 1).

The common names of Indian hemp around the globe are *Bhang, Charas, Ganja* (India); *Bang* (Egypt); *Bhango, Gaanjaa* (Nepal); *Canapaindica, Marijuana* (Italy); *Marihuana, Marijuana* (France); Hash, Hemp,
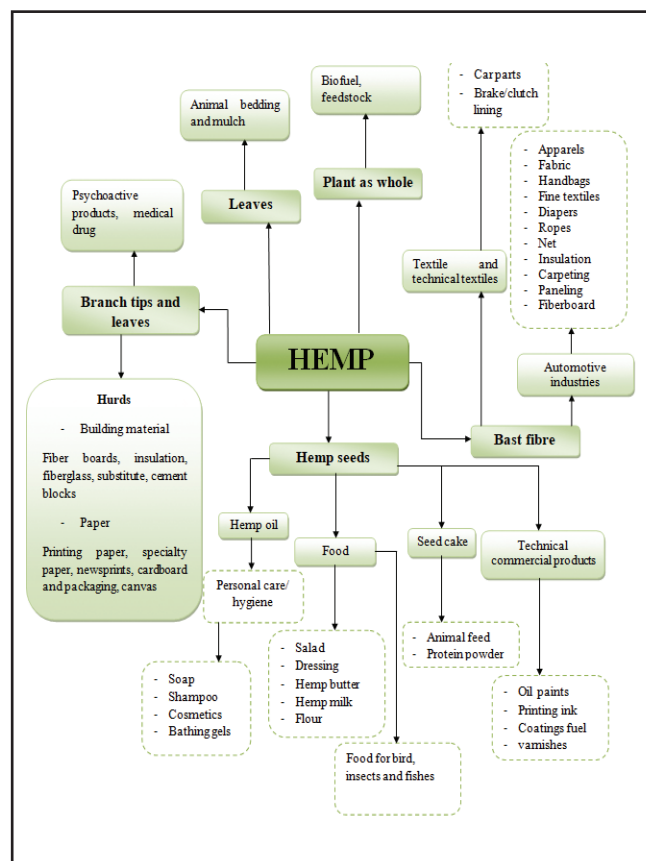

Figure 1. Overview of hemp plant use.

Indian hemp (United Kingdom); *Marihuana, Marijuana* (Mexico)[3]. The two most prevalent psychoactive substances present in hemp are Δ-9-tetrahydrocannabinol (THC) and cannabidiol (CBD). THC is psychoactive while CBD is a non-psychoactive compound. Hemp which is used for drug consumption is distinguished by elevated levels of THC that are often difficult to distinguish morphologically from fibrous hemp which has low levels of THC and is used for consumption. Hemp that is harvested for consumption should contain THC levels less than 0.2 % by weight (whole plant)[4] and Uttarakhand Govt. has also issued notification for the commercial cultivation of varieties having < 0.3 % THC[39].

A roughly five-fold rise in licensed cultivators from 2018-2019 and the increase of 27 % in licensed cultivators between 2019 to 2020 demonstrate the interest in hemp. It was estimated that in 2019, nearly 87 % of hemp cultivation was dedicated to the production of CBD[5]. Hemp has promising use in multiple industries including plastics, textile, personal care, health, feed, furniture, construction, and food and beverage[6]. The fruit of hemp is filled by a seed that is small, light brownish-grey in colour. The edible parts of plants are stalks, leaves, and seeds and are used for a variety of culinary reasons. Hempseed represents an important source of essential fatty acids, fibers, minerals, and vitamins, along with a good amount of essential amino acids, it also contains highly digestible proteins that are albumin and edestin, and they are also a good source of plant-based protein (methionine, lysine and cysteine), lipids, and because of their nutritional properties hemp seeds and their products are achieving growing popularity as food for humans[40]. The larger part (>90 %) of hempseed oil is comprised of polyunsaturated fatty acids that are known for their favorable effects against inflammatory conditions, cancer, and, cardiovascular diseases[7].

The study aims to provide a comprehensive review of *Cannabis sativa* as a versatile oilseed crop, focusing on its nutritional properties, including essential fatty acids, proteins, and antioxidants. It evaluates hemp's potential health benefits, such as its effects on cardiovascular health, cancer, neurological disorders, skin diseases, and mental health. Additionally, it explores the current and emerging hemp applications in industries like food, medical, cosmetics, textiles, and construction, while identifying challenges and future prospects related to regulation, technology, and consumer adoption.

2. NUTRITIONAL PROPERTIES OF HEMP AND ITS SEEDS

Extensive research has unveiled numerous compounds exhibiting promising biological activity, elevating Cannabis to the status of one of the most extensively studied plants in history. In a recent study, several compounds like cannabinoids, terpenoids, glycosidic compounds, hydrocarbons, amino acids, non-cannabinoid phenols, nitrogenous compounds, fatty acids, proteins, and lipids were found in cannabis plant[8].

The swiftly digestible and abundant proteins albumin and edestin, which are copious with essential amino acids, make up the majority of hemp seed protein, making it suitable for both human and animal consumption. When consumed in a 3:1 ratio, the abundant PUFAs ALA; omega-3 and LA; omega-6 are considered to be beneficial and balanced for human nutrition[9]. Hemp seeds contain 20–25 % protein that is equal to a hen's egg white, 20–30 % carbohydrates, 25–35 % lipids, 10–15 % insoluble fibers, vitamins and minerals such as magnesium, potassium, phosphorus, sodium, calcium, and iron[10].

The nutrient and cannabinoid content of various anatomical regions of the hemp plant is very variable. The leaf contains 19.97 % fat, whereas seeds are between 25 % to 35 %, dehulled hempseed has 47 % and hemp hulls contain 10 %. Fiber is found to be very high in hulls that come up to 65 %, followed by the leaf to be 18.95 %, the stem being 23.13 %, seeds 20-30 % and dehulled hempseed at 8 %. Protein level is found at a high percentage in the leaf at 23.78 % and in dehulled hempseed at 36 %. The seed has around 20 % to 25 %, while the stem contains 17.20 %. Ash content, on the other hand, will be highest in the leaf, reaching 11.18 %, followed by the seed with 7 %, and then dehulled hempseed with 6 %. Lastly, the stem contains 6.78 %. There is a relatively equal moisture content in the plant from 5 % to 6 %, except for the leaf, which has 6.87 %. It contains 1.1 % to 2.1 % cannabinoids in leaves, 0.005 % to 0.008 % in the stem, and 0.001 % to 0.004 % in the root. THC ranges from 0.57 % to 0.93 % in leaves, 0.003 % in seeds, and 0.0038 % to 0.0064 % in the stem. CBD is present to the extent of 0.02 % in the leaves and seed, while trace amounts are seen in the stem (0.0001 %) and root[19].

3. HEALTH BENEFITS OF HEMP

In Asia, particularly in India, hemp was utilised as medicine before the Christian era. It is well known for its medical therapies. It has a variety of medical benefits including analgesic, euphoric, stomachic, narcotic, anodyne, antispasmodic, and sedative effects. More than 25 diseases can be treated by using hemp leaves alone, and they were also used to treat tumors and cancerous ulcers. Cannabis drinks have been used to cure a wide variety of gastrointestinal and rheumatic ailments. It is also used in common household medication for conditions like pain management, malaria prevention, and improvement of nervous diseases. Ayurvedic medicines have also used cannabis for hunger stimulation, sleep aid, excitability, aphrodisiacs, and analgesia[3].

In a recent study, THC and CBD both were found to lower accumulated lipid levels and adipocytes in models of hepatosteatosis[14]. Hemp-derived CBD can help to lessen chronic pain by influencing the activity of endocannabinoid receptor activity[12]. Another study stated that hemp seed oil is beneficial for people with diabetes, lupus, cancer, rheumatoid arthritis, depression, asthma, and hypertension. Hemp seed extracts also demonstrate high anti-aging and antioxidant properties.

3.1 Cardiovascular Health

In a study, it was discovered that heart capacity to recuperate from ischemia-reperfusion appeared to be closely connected to the PUFA in hemp seeds, according to an assessment of post-ischemic heart performance[16]. They discovered that adding hemp seed to rats' diets significantly raised plasma levels of LA and ALA, which subsequently results in slowing down platelet aggregation. Findings also indicated that fewer clots are formed, which affects how frequent reduction of myocardial infarctions and strokes occur. Similar results were obtained, after investigating the effects of incorporating hemp seed into the diet of rabbits over eight weeks. Increased plasma PUFA levels prevent hypercholesterolemia and indirectly reduce the risk of myocardial infarction and platelet aggregation[17]. The optimal proportion of unsaturated fatty acids, specifically linoleic acid (18:2 omega-6) and linolenic acid (18:3 omega-3) within hemp oil is approximately 2/3:1. They are known to have a cardio-protective effect and make up more than 800 % of hempseed oil[36].

3.2 Cancers

Consideration of how cannabinoids work and how they might be used to address certain problems has advanced significantly. A study demonstrates the anti-cancer properties of Cannabis phytochemicals, evidence suggested that treatment of prostate, brain, breast, pancreatic, colon cancer, and skin may be done by phyto-, endo-, and synthetic cannabis[25]. Cannabinoids are thought to have a part in regulating cellular pathways that result in anti-metastatic, anti-proliferative, pro-apoptotic, and anti-angiogenic responses, according to both in-vivo and in-vitro models[19].In a test tube study, CBD is induced to human breast cancer cells to die, and it showed positive result[14]. Additionally, it has been discovered that cannabinoids can also stop glioma stem-like cells from differentiating and proliferating, which may help treat gliomas challenging nature. The most effective cytotoxic agent against breast cancer cells was CBD extract, which also caused substantially less damage to healthy cells[21].

3.3 Disorders Affecting the Central Nervous System

Numerous phytocannabinoids have demonstrated the potential to ameliorate neurodegenerative disease symptoms and lessen compromising damage. HI brain injury occurs from a lack of oxygen supply to the brain, and results in neurological impairments like epilepsy, developmental delay, and decreased motor and cognitive function. According to a study, when CBD was given to HI-induced mice, increased neuroprotection was observed[22]. Treatment with CBD improves recovery in mice with pre-existing brain ischemia, protects against emotional and cognitive deficits, white matter damage, hippocampus tissue deterioration, and reduces glial cell reactivity[23]. Epilepsy, the most common neurological condition, has also benefited from CBD. THC/CBD oromucosal spray helped patients with neuropathic pain, which can be difficult to manage with traditional drugs. The spray was effective in reducing neuropathic pain, according to a study using a placebo control[24]. MS patients were given a comparable spray, and it was found to significantly lessen their discomfort, pain, and sleep disturbances[25]. Children suffering from post-traumatic stress disorder have safely utilised CBD oil as a treatment for insomnia and anxiety[13].

3.4 Rheumatoid Arthritis

Hemp seed oil has been historically utilised in traditional Chinese folk medicine for addressing RA[26]. It is an autoimmune inflammatory disease, primarily distinguished by inflammation and hyperplasia of the synovial tissues[27]. In a study, CBD has a favorable effect on arthritic pain. When CBD was applied topically to rats: inflammation biomarkers, synovial membrane thickness, joint swelling, pain scores, immune cell infiltration, and pain scores all drastically decreased in a dose-dependent manner[28].

3.5 Dermatitis and Skin Diseases

Along with other skin-related conditions, eczema can also be effectively treated using hemp seed oil. Clinical research discovered that participants who consumed hemp seed oil regularly had significantly fewer eczema symptoms, such as skin dryness and itching[29].

3.6 Sleep Disorders and Mental Health

Hemp helps in enhancing the quality of sleep while lowering tension, pain, and anxiety. In both pre-clinical as well as clinical trials, concentrated hemp CBD has demonstrated antianxiety/anxiolytic properties, attributed to its calming impact on the limbic and paralimbic regions of the brain, effectively reducing anxiety[30]. It's important to note that CBD anxiolytic effects are only persuaded at lower concentrations; at higher concentrations, it may have panicogenic or anxiogenic effects[31]. Negative memories in people can be helped by CBD, and it can also be used to treat PTSD's anxiety-related symptoms without having any negative side effects[32]. CBD had antidepressant effects and decreased the exhibition of anhedonia in male and female genetically depressed rats[33].

4. PRODUCTS PREPARED USING HEMP AND ITS SEEDS

A large variety of new food items, such as pasta, salad dressings, tortilla chips, snack items, and frozen desserts, are entering the market that contain hemp seed and its oil. Hemp oil is used as a component in healthcare items and nutraceuticals that add EFAs to the diet. It is also considered to be a perfect topical ingredient in lip balms, lotions, shampoos, conditioners, soaps, and shaving products[15]. More than 25,000 products are available in the market that contain hemp, including textiles, rope, clothes, furniture, cosmetics, and industrial oils. Hempseed oil is the primary consumable form of hemp and exhibits promising applications in the realm of cosmetics as a potential sunscreen[35]. A seasoning sauce was also created

using fermented hemp seeds[26]. Since the last decade, the range of hemp seed products has increased and it includes a variety of food and beverages, alternative protein sources, nutritional supplements, and medications. This can be attributed to the exceptional nutritional and pharmacological qualities inherent in hemp seeds[34].

Some certified functional foods that have excellent nutritional qualities also include hemp seed flour and oil, due to their high concentrations of nutrients. The most commonly used functional food made by using hemp flour is bread. Some studies showed that hemp flour influences the antioxidant properties and protein content of bread[11].

Hemp is gaining new opportunities as a fiber crop in the production of biomaterials for the construction industry, insulation products, advanced nonwoven materials for automotive composites applications, and geo-textiles; fabrics for landscaping, mulching, erosion control, tree planting, and hemp logs idea for combustion in coal and wood stoves. Some recent uses of hemp fibres include the bioremediation of heavy metal ions through bio-absorption in aqueous solutions and the creation of new nano-structural polymers[37]. Since hemp seed can be easily incorporated into foods like energy bars, baked products, and flavoured yogurt, it has been employed as a source of dietary fibre and plant protein[38]. The raw leaves, sprouts, and blossoms of the hemp plant are suitable for consumption in juice or salads, even though the seeds are the part that is most frequently consumed[1].

5. FUTURE OUTLOOK

Hemp has a long history of cultivation for its therapeutic and dietary benefits throughout human civilisation. Initially restricted by government regulations, industrial hemp has gained legal recognition in recent times, revealing its significant value in the realm of foods and nutraceuticals. The potential of hemp and its seeds, as future functional food components is evident due to their advantageous functional and physiological properties. However, challenges such as limited consumer demand and stringent regulations have impeded the growth of hemp and products derived from hemp. Additionally, ongoing hemp research is in its nascent stages, grappling with various technological hurdles that demand resolution. Nonetheless, a promising horizon awaits, albeit with the need for future exploration.

To ensure the post-harvest security and quality of hemp plants, the development of efficient hemp drying techniques is paramount, striking a balance between processing throughput, efficiency, and minimal loss of bioactive constituents. The pursuit of secure, efficient, and economically viable extraction and purification technologies is indispensable. Such technologies must not only enhance the yield and selectivity of hemp but also guarantee the purity and safety of extracts destined for food applications.

Significant groundwork remains to be done before hemp and its seeds can seamlessly integrate as beneficial food additives. The establishment, implementation, and standardisation of national and international regulations by policymakers necessitate extensive scientific inquiry. The focus should be directed toward enhancing solubility and biocompatibility with other essential food components, alongside extending shelf life, stability, and bio-accessibility. These efforts are essential for the successful integration of hemp into a wide array of food product systems. An imperative task lies in educating consumers about the advantages and safety of hemp and its seeds, thereby expanding the potential user base. Anticipation is high that hemp will serve as functional food ingredients, enhancing human well-being and seamlessly integrating into daily life.

6. CONCLUSION

Hemp (*Cannabis sativa*) is a promising yet underutilised crop with multifaceted applications in nutrition, medicine, and industry. The seeds and oil deliver exceptional nutritional value in terms of high-quality proteins, essential fatty acids, and antioxidants, which makes them ideal components for functional foods and nutraceuticals. Bioactive compounds such as cannabinoids derived from the plant also show significant therapeutic potential against conditions like cardiovascular diseases, cancer, and neurodegenerative disorders. Hemp's strength potential is enormous, but mainstream food systems are held back by regulatory barriers, lack of consumer awareness, and various other technological problems. Only if research is being conducted on an ongoing basis in optimizing cultivation, processing, and extraction technologies, coupled with education regarding safety and benefits, can help unlock hemp's full potential. With its far-reaching benefits and sustainable applications, hemp can be a transformative force in enhancing human health and contributing to environmentally friendly practices in food and industrial sectors.

REFERENCES

1. Cerino, P.; Buonerba, C.; Cannazza, G.; D'Auria, J.; Ottoni, E.; Fulgione, A.; Stasio, A.D.; Pierri, B. & Gallo, A. A review of hemp as food and nutritional supplement. *Cannabis Cannabinoid Res.*, 2021, **6**(1), 19-27.
   doi: 10.1089/can.2020.0001
2. Owusu, N.O.; Arthur, B. & Aboagye, E.M. Industrial hemp as an agricultural crop in Ghana. *J. Cannabis Res.*, 2021, **3**(1), 1-8.
   doi: 10.1186/s42238-021-00066-0
3. Kuddus, M; Ginawi, I.A. & Al-Hazimi, A. Cannabis sativa: An ancient wild edible plant of India. *Emir. J. Food Agric.*, 2013, **25**(10), 736-745.
   doi: 10.9755/ejfa.v25i10.16400
4. Yang, Y.; Lewis, M.M.; Bello, A.M.; Wasilewski, E.; Clarke, H.A. & Kotra, L.P. Cannabis sativa (hemp) seeds, Δ9-tetrahydrocannabinol, and potential overdose. *Cannabis Cannabinoid Res.*, 2017, **2**(1), 274-281.
   doi: 10.1089/can.2017.0040

5. Ellison S. Hemp (Cannabis sativa L.) research priorities: Opinions from United States hemp stakeholders. *Glob. Change Biol. Bioenergy*. 2021, **13**(4), 562-9.
    doi: 10.1111/gcbb.12794

6. Van der Poest Clement, E.; Jansen, F.E.; Braun, K.P. & Peters, J.M. Update on drug management of refractory epilepsy in tuberous sclerosis complex. *Paediatr. Drugs*, 2020, **22**(1), 73-84.
    doi :10.1007/s40272-019-00376-0

7. Saini, R.K. & Keum, Y.S. Omega-3 and omega-6 polyunsaturated fatty acids: Dietary sources, metabolism, and significance-A review *Life Sci.*, 2018, **203**(6), 255-267.
    doi: 10.1016/j.lfs.2018.04.049

8. Antonelli, M.; Benedetti, B.; Cannazza, G.; Cerrato, A.; Citti, C.; Montone, C.M.; Pivoesana, S. & Lagana, A. New insights in hemp chemical composition: A comprehensive polar lipidome characterisation by combining solid phase enrichment, high-resolution mass spectrometry, and cheminformatics. *Anal. Bioanal. Chem.*, 2020, **412**(11), 413-423.
    doi: 10.1007/s00216-019-02247-6

9. Schultz, C.J.; Lim, W.L.; Khor, S.F.; Neumann, K.A.; Schulz, J.M.; Ansari, O.; Skewes, M. A. & Burton, R.A. Consumer and health-related traits of seed from selected commercial and breeding lines of industrial hemp, Cannabis sativa L. *J. Agric. Food Res.*, 2020, **2**(12), 1-13.
    doi: 10.1016/j.jafr.2020.100025

10. Mikulec, A.; Kowalski, S.; Sabat, R.; Skoczylas, Ł.; Tabaszewska, M. & Wywrocka-Gurgul, A. Hemp flour as a valuable component for enriching physicochemical and antioxidant properties of wheat bread. *LWT*, 2019, **102**(3), 164-172.
    doi: 10.1016/j.lwt.2018.12.028

11. Devi, V. & Khanam, S. Comparative study of different extraction processes for hemp (Cannabis sativa) seed oil considering physical, chemical and industrial-scale economic aspects. *J. Clean. Prod.*, 2019, **207**(1), 645-657.
    doi: 10.1016/j.jclepro.2018.10.036

12. Shrivastava, A.; Kuzontkoski, P.M.; Groopman, J.E. & Prasad, A. Cannabidiol induces programmed cell death in breast cancer cells by coordinating the cross-talk between apoptosis and Autophagy CBD induces programmed cell death in breast cancer cells. *Mol. Cancer Ther.*, 2011, **10**(7), 1161-1172.
    doi: 10.1158/1535-7163.MCT-10-1100

13. Shannon, S. & Opila-Lehman, J. Effectiveness of cannabidiol oil for pediatric anxiety and insomnia as part of posttraumatic stress disorder: a case report. *Perm. J.*, 2016, **20**(4), 16-21.
    doi: 10.7812%2FTPP%2F16-005

14. Silvestri, C.; Paris, D.; Martella, A.; Melck, D.; Guadagnino, I.; Cawthorne, M.; Motta, A. & Di Marzo, V. Two non-psychoactive cannabinoids reduce intracellular lipid levels and inhibit hepatosteatosis. *J. Hepatol.*, 2015, **62**(6), 1382-1390.
    doi: 10.1016/j.jhep.2015.01.001

15. Piluzza, G.; Delogu, G.; Cabras, A.; Marceddu, S. & Bullitta S. Differentiation between fiber and drug types of hemp (Cannabis sativa L.) from a collection of wild and domesticated accessions. *Genet. Resour. Crop Evol.*, 2013, **60**(8), 2331-2342.
    doi: 10.1007/s10722-013-0001-5

16. Richard, M.N.; Ganguly, R.; Steigerwald, S.N.; Al-Khalifa, A. & Pierce, G.N. Dietary hempseed reduces platelet aggregation 1. *J. Thromb. Haemost.*, 2007, **5**(2), 424-425.
    doi: 10.1111/j.1538-7836.2007.02327.x

17. Prociuk, M.A.; Edel, A.L.; Richard, M.N.; Gavel, N.T.; Ander, B.P.; Dupasquier, C.M.C. & Pierce, G.N. Cholesterol-induced stimulation of platelet aggregation is prevented by a hempseed-enriched diet. *Can. J. Physiol. Pharmacol.*, 2008, **86**(4), 153-159.
    doi: 10.1139/Y08-011

18. Seltzer, E.S.; Watters, A.K.; MacKenzie, D.; Granat, L.M. & Zhang, D. Cannabidiol (CBD) as a promising anti-cancer drug. *Cancers.*, 2020, **12**(11), 1-26.
    doi: 10.3390/cancers12113203

19. Alexander, A.; Smith, P.F. & Rosengren, R.J. Cannabinoids in the treatment of cancer. *Cancer Lett.*, 2009, **285**(1), 6-12.
    doi: 10.1016/j.canlet.2009.04.005

20. Xu J.; Bai M.; Song H.; Yang L.; Zhu D. & Liu H. Hemp (Cannabis sativa subsp. sativa) Chemical composition and the application of hempseeds in food formulations. *Plant Foods Hum. Nutr.*, 2022, **77**(4), 504-513.
    doi: 10.1007/s11130-022-01013-x

21. Ligresti, A.; Moriello, A.S.; Starowicz, K.; Matias, I.; Pisanti, S.; De Petrocellis, L.; Laezza, C.; Portella, G.; Bifulco, M. & Di Marzo, V. Antitumor activity of plant cannabinoids with emphasis on the effect of cannabidiol on human breast carcinoma. *J. Pharmacol. Exp. Ther.*, 2006, **318**(3), 1375-1387.
    doi: 10.1124/jpet.106.105247

22. Castillo, A.; Tolon, M.R.; Fernandez-Ruiz, J.; Romero, J. & Martinez-Orgado, J. The neuroprotective effect of cannabidiol in an in vitro model of newborn hypoxic–ischemic brain damage in mice is mediated by CB2 and adenosine receptors. *Neurobiol. Dis.*, 2010, **37**(2), 434-440.
    doi: 10.1016/j.nbd.2009.10.023

23. Mori, M.A.; Meyer, E.; Soares, L.M.; Milani, H.; Guimarães, F.S. & de Oliveira, R.M.W. Cannabidiol reduces neuroinflammation and promotes neuroplasticity and functional recovery after brain ischemia. *Prog. in Neuropsychopharmaco. Biol. Psychiatry*, 2017, **75**(4), 94-105.
    doi: 10.1016/j.pnpbp.2016.11.005

24. Langford, R.M.; Mares, J.; Novotna, A.; Vachova, M.; Novakova, I.; Notcutt, W. & Ratcliffe, S. A double-blind, randomised, placebo-controlled, parallel-group study of THC/CBD oromucosal spray in combination with the existing treatment regimen, in the relief of central neuropathic pain in patients with multiple

sclerosis. *J. Neurol.*, 2013, **260**(11), 984-997.
doi: 10.1007/s00415-012-6739-4

25. Rog, D.J.; Nurmikko, T.J.; Friede, T. & Young, C.A. Randomised, controlled trial of cannabis-based medicine in central pain in multiple sclerosis. *Neurol.*, 2005, **65**(6), 812-819.
doi: 10.1212/01.wnl.0000176753.45410.8b

26. Rupasinghe, H.V.; Davis, A.; Kumar, S.K.; Murray, B. & Zheljazkov, V.D. Industrial hemp (*Cannabis sativa* subsp. *sativa*) as an emerging source for value-added functional food ingredients and nutraceuticals. *Mol.*, 2020, **25**(18), 1-24.
doi: 10.3390/molecules25184078

27. Choy, E. Understanding the dynamics: Pathways involved in the pathogenesis of rheumatoid arthritis. *Rheumatol.*, 2012, **51**(5), 3-11.
doi: 10.1093/rheumatology/kes113

28. Hammell, D.C.; Zhang, L.P.; Ma, F.; Abshire, S.M.; McIlwrath, S.L.; Stinchcomb, A.L. & Westlund, K.N. Transdermal cannabidiol reduces inflammation and pain-related behaviours in a rat model of arthritis. *Eur. J. Pain*, 2016, **20**(6), 936-948.
doi: 10.1002/ejp.818

29. Callaway, J.; Schwab, U.; Harvima, I.; Halonen, P.; Mykkanen, O.; Hyvonen, P. & Jarvinen, T. Efficacy of dietary hempseed oil in patients with atopic dermatitis. *J. of Dermatological Treatment*, 2005, **16**(2), 87-94.
doi: 10.1080/09546630510035832

30. Wright, M.; Di Ciano, P. & Brands, B. Use of cannabidiol for the treatment of anxiety: A short synthesis of pre-clinical and clinical evidence. *Cannabis Cannabinoid Res.*, 2020, **5**(3), 191-196.
doi: 10.1089/can.2019.0052

31. Blessing, E.M.; Steenkamp, M.M.; Manzanares, J. & Marmar, C.R. Cannabidiol as a potential treatment for anxiety disorders. *Neurother.*, 2015, **12**(4), 825-836.
doi: 10.1007/s13311-015-0387-1

32. Bitencourt, R.M. & Takahashi, R.N. Cannabidiol as a therapeutic alternative for post-traumatic stress disorder: From bench research to confirmation in human trials. *Front. Neurosci.*, 2018, **12**(7), 1-10.
doi: 10.3389/fnins.2018.00502

33. Shbiro, L.; Hen-Shoval, D.; Hazut, N.; Rapps, K.; Dar, S.; Zalsman, G.; Mechoulam, R.; Weller, A. & Shoval, G. Effects of cannabidiol in males and females in two different rat models of depression. *Physiol. Behav.*, 2019, **201**(3), 59-63.
doi: 10.1016/j.physbeh.2018.12.019

34. Vonapartis, E.; Aubin, M.P.; Seguin, P.; Mustafa, A.F. & Charron, J.B. Seed composition of ten industrial hemp cultivars approved for production in Canada. *J. Food Compos. Anal.*, 2015, **39**(5), 8-12.
doi: 10.1016/j.jfca.2014.11.004

35. Oomah, B.D.; Busson, M.; Godfrey, D.V. & Drover, J.C. Characteristics of hemp (Cannabis sativa L.) seed oil. *Food Chem.*, 2002, **76**(1), 33-43.
doi: 10.1016/S0308-8146(01)00245-X

36. Siano, F.; Moccia, S.; Picariello, G.; Russo, G.L.; Sorrentino, G.; Di Stasio, M.; La Cara.; Volpe. M.G & Volpe, M.G. Comparative study of chemical, biochemical characteristic and ATR-FTIR analysis of seeds, oil and flour of the edible Fedora cultivar hemp (Cannabis sativa L.). *Mol.*, 2018, **24**(1), 83-96.
doi: 10.3390/molecules24010083

37. Pejic, B.; Vukcevic, M.; Kostic, M. & Skundric, P. Biosorption of heavy metal ions from aqueous solutions by short hemp fibers: Effect of chemical composition. *J. Hazard. Mater.*, 2009, **164**(1), 146-153.
doi: 10.1016/j.jhazmat.2008.07.139

38. Montserrat-de la Paz, S.; Marin-Aguilar, F.; Garcia-Gimenez, M.D. & Fernandez-Arche, M. A. Hemp (Cannabis sativa L.) seed oil: Analytical and phytochemical characterisation of the unsaponifiable fraction. *J. Agric. Food Chem.*, 2014, **62**(5), 1105-1110.
doi: 10.1021/jf404278q

39. CSIR- National Botanical Research Institute. HEMP, *Cannabis sativa* **L**. : A potential under-utilised crop for next green revolution. Niche Creating Programme. https://nbri.res.in/cannabis/.

40. Galasso, I.; Russo, R.; Mapelli, S. & Reggiani, R. Variability in seed traits in a collection of Cannabis sativa L. genotypes. *Front. Plant Sci.*, 2016, **7**(688), 1-9.
doi: 10.3389/fpls.2016.00688

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