Biodegradable hemp plastic as a model for bioplastics, sourced from marijuana byproduct

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Abstract

Over the years, Canadian dependency for plastics have increased due to its inexpensive and versatile properties, regardless of its contributions to an unsustainable lifestyle. Bioplastics, derived from renewable biomass, can serve as a substitution for traditional plastic products (Singhvi & Gokhale, 2013). In October 2018, the Canadian federal government legalized recreational use of *Cannabis indica* (marijuana) (Government of Canada, 2018). This leads to the accumulation of unused marijuana byproducts that lack tetrahydrocannabinol (THC), which could be repurposed to produce bioplastics. This proposal is based on the biodegradable plastic model of *Cannabis sativa* (hemp), a current source of bioplastics (Robles, Urruzola, Labidi, & Serrano, 2015). Since both marijuana and hemp belong to the Cannabis species, the physical properties of marijuana bioplastic composites can be analyzed to assess its similarities with hemp. As a preliminary step, supercritical extraction of THC from marijuana byproduct will form a fiber free of psychoactive components (Rovetto & Aieta, 2017). A general procedure for plant fiber extraction will be used for both hemp and marijuana which will then be combined with polylactic acid to form bioplastic composites. Using the following composite property tests: water absorption, tensile strength and biodegradability on both composites – the quality of marijuana bioplastics can be determined and refined to meet accepted standards. By following this approach, the negative impacts of current plastic usage can be addressed with a sustainable yet viable solution.

Background

Currently, the byproducts of marijuana, the stalk and fan leaves, must be disposed after harvesting the plant for THC and cannabinoids, which are concentrated in flower buds. However, annual Canadian marijuana demand is projected to be ~1 million kg annually upon legalization (Deloitte, 2018). Furthermore, since more than half of the marijuana plant is unused in its production of consumer goods, this entails even greater amounts of byproducts in Canada by the end of 2019 (Government of Canada, 2018). Hemp is an industrially grown plant belonging to the Cannabis species with negligible amounts of THC (Sawler, Stout, Gardener, Hudson, & Vidmar, 2015). Since marijuana is a related species to hemp, its byproducts have a large potential to be repurposed for biodegradable plastic.

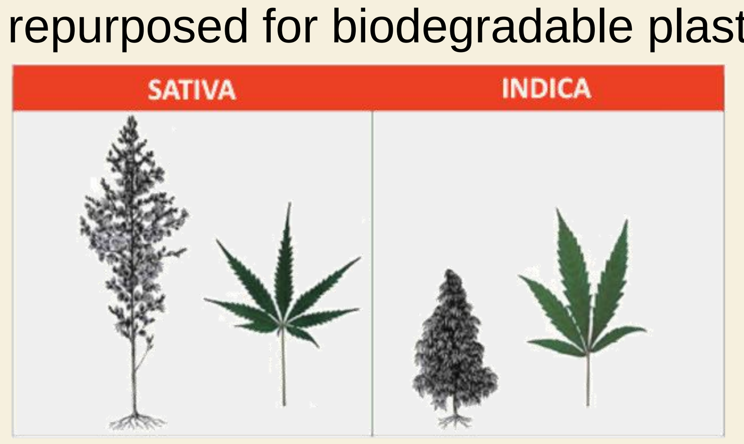


Figure 1: The phenotypic attributes of *Cannabis sativa* and *Cannabis indica* comparing height and leaf traits (Hemp vs Marijuana, 2015).

Objective

This experiment will investigate the viability of using marijuana byproducts as a biomass source for bioplastic composite production. Marijuana will undergo THC extraction as a preliminary step. Hemp and marijuana will be converted to a plastic composite for analysis of its three properties – biodegradability, water absorption, and tensile strength.

Methodology

THC extraction from byproduct

The plant material will be first dried at 70°C for 24 hours and ground in a commercial grinder. Following this, the plant material will enter a supercritical carbon dioxide extraction system set at 328 K similarly used by Rovetto and Aieta in 2017. The crude extract will contain THC and other cannabinoids in addition to n-alkanes and wax esters (Attard et al., 2018). This makes the remaining biomass residues free of THC and also more ideal for further processing into plastic (Attard et al., 2018; Attard et al., 2015).

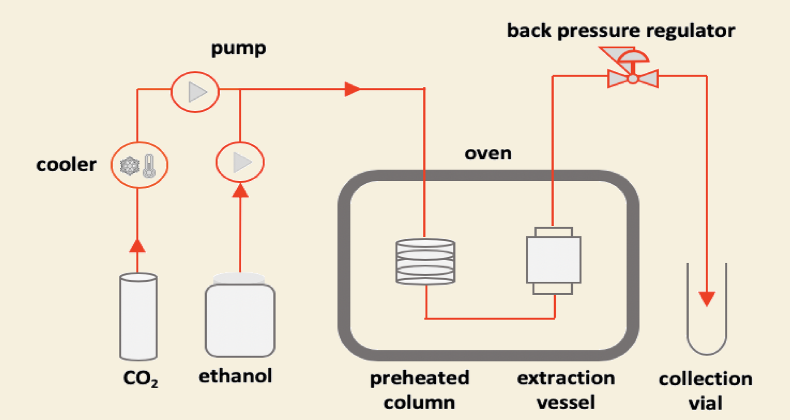
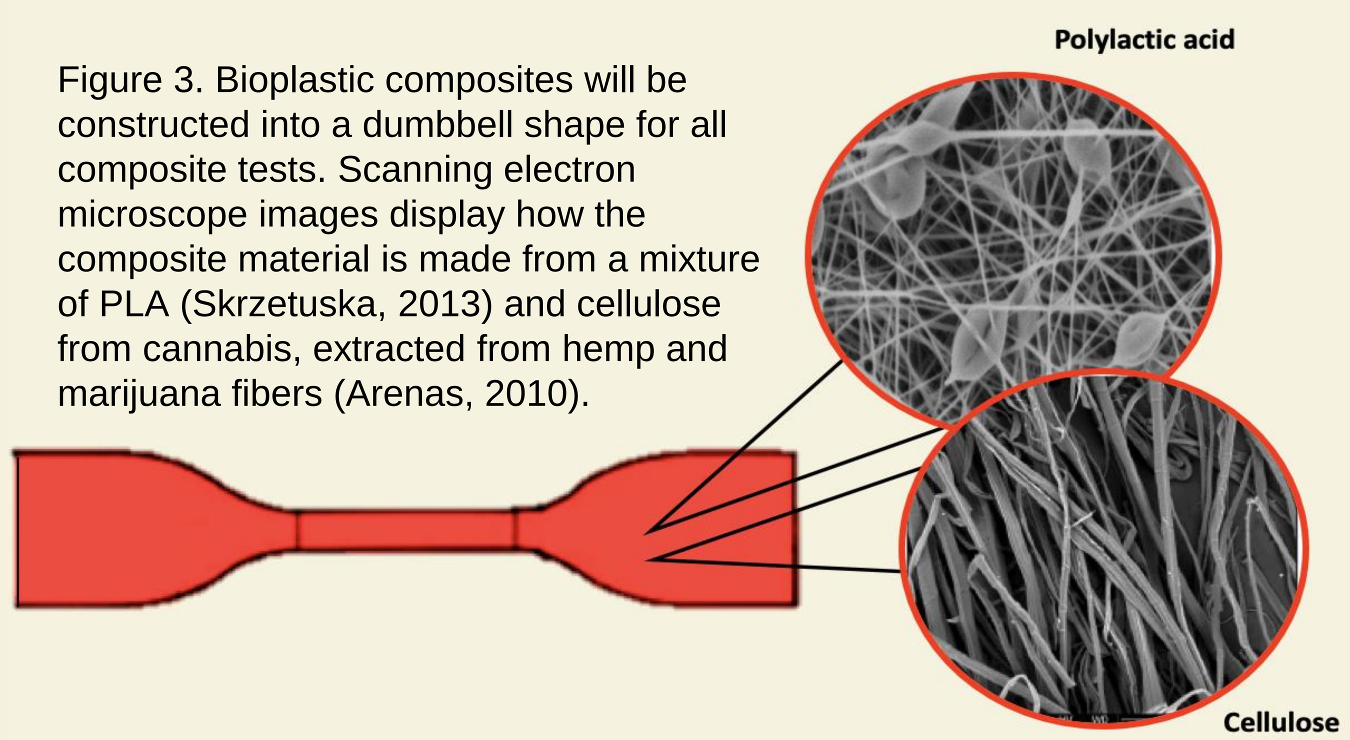


Figure 2: Supercritical CO2 extraction system which stores marijuana byproduct in the extraction vessel. THC and other cannabinoids will enter the collection vial (Juliasih, Yuan, & Sago, 2015).

Bioplastic production

The production of bioplastics varies based on the biomass used, however the general idea involves extraction of pure cellulose which can then be manipulated into its desired form (Pilla, 2011). Hemp-based and marijuana-based plastic composites will be created to compare their test results. Using high temperatures on both plants, the cellulose polysaccharide chains are separated from other components and elongated (Pilla, 2011). Using a centrifuge and hydrolyzation, the crystalline and amorphous sections of the mixture are separated. The nanocrystalline structures are combined with polylactic acid (PLA) to form a PLA bioplastic composite (Pilla, 2011)

Figure 3. Bioplastic composites will be constructed into a dumbbell shape for all composite tests. Scanning electron microscope images display how the composite material is made from a mixture of PLA (Skrzetuska, 2013) and cellulose from cannabis, extracted from hemp and marijuana fibers (Arenas, 2010).



Composite Tests

Biodegradability

Biodegradability is tested in soil and marine environments. A 5 g sample will be buried in soil of controlled natural environment and then weighed every three days for a three month period to identify percent weight loss. Then, 5 g samples of hemp and marijuana composites will be subjected to an open system with continuous natural seawater flow at fluctuating temperatures (12–22ºC) and pH (7.9–8.1), and weighed every week for a six month period (Thellen et al., 2008).

Water Absorption

The ASTM D570 standard testing will be used in which composites are dried in a 50ºC oven for 24 hours, cooled to room temperature and weighed. Then, they are immersed in distilled water, removed, dried and weighed. This occurs several times to identify changes in weight, indicating water absorption, to obtain a value used to compare with current mass-produced plastic (Chen et al.,2013).

Tensile Strength

ASTM D638 is a standardized test used to determine the tensile strength of plastics using a universal testing machine (ADMET, 2018). The composite will be moulded into a standard “dumbbell” shape and loaded onto tensile grips tol then be separated until the sample breaks. An extensometer and an appropriate software will be used to measure and calculate tensile strength (MPa), strain to failure (%),Young’s Modulus (GPa) and extension at breaking point (Gharagozlou, 2014).

Discussion

Previous research has shown that the structural properties of marijuana are not as strong as those of hemp, but their chemical compositions still exhibit similarities. Thus, the comparison of the marijuana to the hemp composite will allow the understanding of the extent that the marijuana composite may need to be reinforced in certain aspects to be feasible.
First, marijuana bioplastic can be modified to have short or long degradation periods from the results of the biodegradability test by varying ratio of marijuana to PLA. Tensile strength is determined primarily by the relationship between the fiber and matrix, and can be improved by adding additional biodegradable fibers, such as polyacrylonitrile or cellulose (Zhu et al., 2017). In addition, different matrix materials, such as the biodegradable polyester polycaprolactone, can increase hydrophobic properties of marijuana composites (Bajgai et al. 2008). A recent method to improve various composite properties is through the use of items less than 100 nm in length. Nanoclay in particular is an option that has been shown to enhance many properties including tensile strength as well as thermal and UV resistance (Lagaron & Lopez-Rubio, 2011).

Conclusion

Overall, the creation of marijuana bioplastic composites is the first step to understanding the potential of marijuana byproduct for large scale use. Analysis of biodegradability, water absorption, and tensile strength of hemp and marijuana composites with the same fiber to PLA ratio will allow quantification of improvements required for marijuana bioplastic to meet industry standards, while working towards a sustainable lifestyle.

Future Steps

This study only included macroscopic analysis of hemp and marijuana composites. Therefore, microscopic composite tests to study properties such as crystallinity and surface uniformity are suggested using scanning electron microscopy. Furthermore, only *C. sativa* and *C. indica* plants were addressed in this research. Other hybrids of Cannabis species present around the world should be further investigated.

References

ADMET. (2018). How to Perform an ASTM D638 Plastic Tensile Strength Test. Retrieved November 23, 2018, from https://www.admet.com/how-to-perform-an-astm-d638-plastic-tensile-strength-test/
Arenas, J. (2010, July). Scanning electron microscope images of samples of hemp,... Retrieved March 5, 2019, from https://www.researchgate.net/figure/Scanning-electron-microscope-images-of-samples-of-hemp-kenaf-cotton-and-polyester_fig3_272151761
Attard, T. M., Bainier, C., Reinaud, M., Lanot, A., McQueen-Mason, S. J., & Hunt, A. J. (2018). Utilisation of supercritical fluids for the effective extraction of waxes and Cannabidiol (CBD) from hemp wastes. Industrial Crops and Products, 112, 38–46. https://doi.org/10.1016/j.indcrop.2017.10.045
Attard, T. M., Theeuwes, E., Gomez, L. D., Johansson, E., Dimitriou, I., Wright, P. C., … Hunt, A. J. (2015). Supercritical extraction as an effective first-step in a maize stover biorefinery. RSC Advances, (54), 43831–43838.
Bajgai, M. P., Aryal, S., Bhattarai, S. R., Bahadur, K. C. R., Kim, K.-W., & Kim, H. Y. (2008). Poly(ϵ-caprolactone) grafted dextran biodegradable electrospun matrix: A novel scaffold for tissue engineering. Journal of Applied Polymer Science, 108(3), 1447–1454. https://doi.org/10.1002/app.27825
Bilo, F., Pandini, S., Sartore, L., & Depero, L. E. (2018). A sustainable bioplastic obtained from rice straw. Journal of Cleaner Production, 200, 357–368. https://doi.org/10.1016/j.jclepro.2018.07.252
Chen, T., Liu, W., & Qiu, R. (2013). Mechanical Properties and Water Absorption of Hemp Fibers–Reinforced Unsaturated Polyester Composites: Effect of Fiber Surface Treatment with a Heterofunctional Monomer. BioResources, 8(2), 2780-2791–2791. https://doi.org/10.15376/biores.8.2.2780-2791
Deloitte. (2018). A society in transition, an industry ready to bloom - 2018 cannabis report. Retrieved from https://www2.deloitte.com/content/dam/Deloitte/ca/Documents/consulting/ca-cannabis-2018-report-en.PDF
Gharagozlou, Y. (2014). ASTM D638-10 Tensile Properties of Plastics. Retrieved November 23, 2018, from https://www.instron.us/en-us/testing-solutions/by-test-type/tension/astm-d638-10---properties?fbclid=IwAR2sHZrtZ2dnTMNxX-9w4i9rFmFxSzRJKEsnMY8gzLTNJzv8jr-Fc_OuRIc
Government of Canada. (2018, October 17). Consolidated federal laws of canada, Controlled Drugs and Substances Act. Retrieved November 22, 2018, from https://laws-lois.justice.gc.ca/eng/acts/c-38.8/
Hemp vs Marijuana. (2015). Retrieved from https://ministryofhemp.com/hemp/not-marijuana/
Juliasih, N. L. G. R. J., Yuan, L. C., Sago, Y., & Atsuda, Y. (2015, August). Supercritical Fluid Extraction of Quinones from Compost for Microbial Community Analysis. http://dx.doi.org/10.1155/2015/717616
Lagaron, J. M., & Lopez-Rubio, A. (2011). Nanotechnology for bioplastics: opportunities, challenges and strategies. Trends in Food Science & Technology, 22(11), 611–617. https://doi.org/10.1016/j.tifs.2011.01.007
Pilla, S. (2011). Handbook of Bioplastics and Biocomposites Engineering Applications. John Wiley & Sons.
Robles, E., Urruzola, I., Labidi, J., & Serrano, L. (2015). Surface-modified nano-cellulose as reinforcement in poly(lactic acid) to conform new composites. Industrial Crops and Products, 71, 44–53. https://doi.org/10.1016/j.indcrop.2015.03.075
Rovetto, L. J., & Aieta, N. V. (2017). Supercritical carbon dioxide extraction of cannabinoids from Cannabis sativa L. The Journal of Supercritical Fluids, 129, 16–27. https://doi.org/10.1016/j.supflu.2017.03.014
Singhvi, M., & Gokhale, D. (2013). Biomass to biodegradable polymer (PLA). RSC Advances, 3(33), 13558–13568. https://doi.org/10.1039/C3RA41592A
Skrzetuska, E. (2013, May). Visualization of the microscopic features of the poly(lactic... Retrieved March 5, 2019, from https://www.researchgate.net/figure/Visualization-of-the-microscopic-features-of-the-polylactic-acid-PLA-multi-walled_fig4_258196411
Thellen, C., Coyne, M., Froio, D., Auerbach, M., Wirsen, C., & Ratto, J. A. (2008). Processing, Characterization and Marine Biodegradation Study of Melt-Extruded Polyhydroxyalkanoate (PHA) Films. Journal of Polymers and the Environment. Retrieved from http://agris.fao.org/agris-search/search.do?recordID=US201301570498
Zhu, L., Wu, D., Wang, B., Zhao, J., Jin, Z., & Zhao, K. (2017). Reinforcing high-density polyethylene by polyacrylonitrile fibers. Pigment & Resin Technology, 47(1), 86–94. https://doi.org/10.1108/PRT-03-2017-0030