AMITY UNIVERSITY CHHATTISGARH

Approving University Official(s): Vice-Chancellor-AUC
Responsible Office: Office of the Director Administration
Office of Risk Management Effective date:
Next review date:

POLICY ON SOLID WASTE MANAGEMENT

Policy Statement

Amity University Chhattisgarh (AUC) is committed to enhancing the health and wellbeing of its campus community, to increasing safety practices, to reducing consumption of energy and fuels, to minimizing emissions, and to reducing solid and hazardous wastes. Members of the University community are expected to integrate into their daily operations best practices to reduce, reuse, and recycle materials, consistent with Municipal, State, and Central rules and guidelines. This policy applies to the management of various types of generated solid and liquid wastes, as defined below. However, this policy does not apply to the management of domestic sewage, the mixtures of domestic sewage allowable for sanitary disposal, or the management of storm or irrigation water run-off.

Purpose

Amity University Chhattisgarh (AUC) endeavors to adopt practices that reflect a comprehensive approach to conserving resources and reducing and managing waste. Waste prevention, reuse, recycling, and composting are prioritized over landfill disposal. In order to minimize our environmental footprint; to provide guidance to the University community on best practices for reducing and recycling waste; and to promote adherence to environmental law, this policy establishes a sustainable, solid waste management program that communicates acceptable methods of handling, storing, recycling, and disposing of materials.

Audience

All members of the AUC community, including students, researchers, faculty, staff, visitors, contractors, and vendors.

Definitions

Electronic waste or e-waste: electronic materials or appliances that are at the end of their useful life. Electronic equipment often contains sensitive data and hazardous materials (lead, chromium, cadmium, mercury, beryllium, nickel, zinc, brominated flame retardants, etc.) whose disposal is regulated. Common electronic appliances include computers, printers, monitors, microwaves, telephones, televisions, laboratory appliances, and refrigeration units (freezers, refrigerators, and air conditioners).

Hazardous waste: any material that

(i) exhibits hazardous characteristics as defined by Central or State law,
(ii) is unusable or unwanted in any way, and
(iii) poses a potential hazard to individuals, the environment, or public health. Hazardous waste includes, but is not limited to, chemical, radioactive, or potentially infectious waste. For a list of examples of hazardous waste and detailed information on its disposal, see the Hazardous Waste Disposal Guide (Central Pollution Control Board).

Municipal solid waste: everyday items used and then thrown away, such as product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, and appliances. Municipal solid waste is commonly known as trash or garbage.

Non-research area: an area on University property that is not a teaching or research laboratory.

Specially-regulated waste: a subset of hazardous waste comprising materials that are subject to specific regulations. Examples include potentially infectious medical waste (PIMW); other biological waste; sharps waste; asbestos waste; regulated polychlorinated biphenyl (PCB) waste; cutting oils and used oil; paint sludge; equipment cleanings; metallic dust sweepings; used solvents from parts cleaners; and off - specification, contaminated, or recalled wholesale or retail products.

Universal waste: a category of waste materials designated as hazardous, but containing materials that are common or widely generated in the environment. Universal waste includes batteries, pesticides, lamps, thermostats, and other mercury-containing equipment.

Policy Implementation

I. Waste management requirements

A. ***Adherence to applicable law and University procedures***. All members of the AUC community are expected to handle, store, recycle, and dispose of materials in accordance with applicable law and University procedures, including all laws, regulations, and guidance documents referenced in this policy (see "Related Information" below; unless otherwise noted, the versions of such laws, regulations, and procedures currently in effect are to be followed). Specific guidelines relating to different types of waste are identified below.

B. ***Municipal solid waste***. Waste streams such as non-hazardous wastes, recyclables, food wastes, and construction and demolition debris should be handled pursuant to Govt. of India (GoI- CPCB) - Recycling Guidelines.

C. ***Electronic waste***. GoI - law bans most forms of electronic waste from landfills in the state. All University-owned electronic waste will be recycled through Facilities Management's E-Cycling Program and consistent with CPCB - Recycling Guidelines.

D. ***Hazardous waste***. All University-generated hazardous waste must be labeled, handled, stored, and disposed consistent with the Office for Research Safety (ORS) - Guide, developed to ensure that the management and disposal of hazardous waste at AUC is conducted consistent with applicable law, including the Resource Conservation and Recovery Act (RCRA).

Additionally, specially-regulated waste must be labeled, handled, stored, and disposed consistent with any additional applicable laws, regulations, or University guidelines, including the ORS guidelines applicable to the management and disposal of biological/infectious, radioactive, and sharps waste.

E. ***Universal waste***. All University-generated universal waste must be labeled, handled, stored, recycled, and disposed consistent with AUC - Waste Guide.

Any questions regarding the categorization of different types of waste or the guidelines applicable to their management and disposal should be directed to either GoI -CPCB, ORS, or the Ministry of Environmental Health and Safety Management.

II. Implementation responsibilities

A. Department and vendor leaders are responsible for:
   - i. Reviewing operations to determine where waste can be reduced at its sources of generation;
   - ii. Acquiring, to the extent feasible and practicable, items that are durable, have minimal packaging, or are readily recyclable when discarded;
   - iii. Assessing purchasing decisions, making every attempt to purchase items only when needed and in amounts that are not excessive;
   - iv. Ensuring employees have access to compliant waste containers, including containers for recycling; and
   - v. Assuring only trained and certified employees, students, and vendors generate and label specially-regulated or hazardous wastes.

B. AUC faculty, staff, students, and vendor personnel are responsible for:
   - i. Separating defined waste types and placing identified waste materials in the appropriate containers; and
   - ii. Handling specially-regulated or hazardous wastes only if trained and certified to do so.

C. AUC's Office of Procurement and Payment Services is responsible for:
   - i. Prioritizing procurement of goods and services that have a less negative effect on human health and the environment;
   - ii. Promoting the purchase of durable and environmentally preferable products and prioritizing these purchases over procurement of single-use or disposable products; and
   - iii. Establishing contracts with vendors when necessary to responsibly handle University-generated waste.

D. AUC's Office of Facilities Management is responsible for:
   - i. Establishing policies for the management of construction and demolition and executing construction and demolition contracts that include specific construction debris recycling targets;

ii. Facilitating the removal of regulated refrigerants from refrigerators and freezers and maintaining the pertinent records required by law or regulation;
iii. Managing collection areas for the drop-off of universal waste in each building;
iv. Providing standard trash containers; and
v. Maintaining contracts with custodial service providers responsible for collecting non-regulated waste.

E. AUC Administration is responsible for:

i. Managing all activities and services related to municipal solid waste disposal;
ii. Maintaining up-to-date procedures for reuse, recycling, and composting, as well as records of all waste reduction and recycling activities on campus; and
iii. Providing standard recycling containers.

F. AUC's Office for Research Safety (ORS) is responsible for:

i. Maintaining up-to-date procedures and training on the proper disposal of hazardous, radioactive, biological, and potentially infectious wastes generated in teaching or research laboratories;
ii. Providing approved containers for the disposal of hazardous, radioactive, biological, and potentially infectious wastes in teaching or research laboratories; and
iii. Managing contracts for the disposal of all hazardous wastes and for hazardous waste emergency response services.

G. AUC's Office of Risk Management (ORM) is responsible for:

i. Maintaining procedures for the handling and disposal of hazardous and universal waste in non-research areas;
ii. Training all non-research employees handling hazardous waste about proper waste handling procedures, safe use of personal protective equipment, and emergency procedures; and
iii. Ensuring non-research departments follow all contractual hazardous waste and hazardous waste emergency response services requirements.

H. AUC's Office of Human Resources, through its HR Learn system (TCS-ion), serves as a records repository of completion of required trainings for those employed by AUC. For various reasons, ORM or ORS may maintain other training records outside of the HR Learn system (TCS-ion).

Consequences of Violating this Policy

AUC faculty, students, or staff who fail to comply with the laws, regulations, and ordinances referenced in this policy could be subject to disciplinary action under University policies and procedures, including termination of employment or academic dismissal. The University may terminate its relationship with any third-party contractor who violates this policy. Individuals who knowingly and deliberately release hazardous materials in violation of law could also be subject to criminal penalties.

Biohydrogen production/Biofuels:

Funding details:

Ramalingaswami re-entry Project:

Principle Investigator: Dr. Sudheer Pamidimarri

Funding agency: DBT-India

Starting data: August 2019

Project title Hydrogen gas production by engineered Escherichia coli utilizing crude glycerol and lignocellulosic biomass

Funding amount: 113.6 Lakhs [5 Years].

Expected outcome:

- The project is intended to develop zero-emission strategy for the production of green fuel (H_2).
- Waste biomass will be utilized to produce H_2 fuel.
- Low cost fuel production can reduce the cost of H_2 production up to 40-fold compared to present commercial value.
- Metabolic flux engineering technology intended to develop will have application in production of many industrially important chemicals.

Industrial project

Project title: Designing and fabrication of facile molecular systems for synthesizing stable bioactive peptides/proteins with pharmaceutical significance derived from green algae and marine biota.

Principle Investigator: Dr. Sushma Chauhan

Funding amount: 3,60,000 Rs.

Expected Outcome:

- Aims to identify novel bioactive peptides/proteins having pharmaceutical significance from marine biota.
- Genetic engineering technology for the synthesis of antimicrobial peptides will be developed.
- A technology for the development of stabilized peptides by backbone cyclization is proposed to develop in this study.

Funding via fellowship

DBT-JRF Fellowship: Tanushree Madavi

1st year : 31,000 + 16% HRA = 35,960 X 12 months = **4,31,520 Rs + 30,000 contingency**

2nd, 3rd and 4th year: 35,000+16% HRA = 40,600 X 12 months = **4,87,200 + 30,000 contingency**

Report:

Project title Hydrogen gas production by engineered Escherichia coli utilizing crude glycerol and lignocellulosic biomass

Hydrogen (H2) is considered as the cleanest energy since upon combustion H2 results in no carbon footprint is released to environment. Biological hydrogen is generated by the green process utilizing microbial fermentation process. H2 is clean energy credited with zero emotions and globally at present H2 is the most promising in the succession of fuel evolution, with several technical, socio-economic, and environmental benefits. H2 gas is safer to handle than domestic natural gas and is now universally accepted as an environmentally safe, renewable energy resource and an ideal alternative to fossil fuels. Microbial cell factories, unlike their chemical or electrochemical counterparts; H2 generation is catalyzed by microorganisms in an aqueous environment at the ambient temperature and atmospheric pressure is a complete green process. E. coli being an enteric bacterial species is naturally capable of producing low levels of hydrogen is a native microbial fuel cell for H2 production. The present study includes the development of engineered E. coli with fabricated metabolic flux-controlled system is forecast to have efficient H2 production which is a novel tool will replace physical knockout system with translational control gene silencing system. This will help in diverting metabolic flux rate towards H2 production. Moreover, this study will utilize the lignocellulosic biomass and crude glycerol generated during biodiesel production. In comprehensive prospective the total strategy will be carbon neutral and/or negative for the sustainable generation of biohydrogen (Figure 1). In this study we initiated the work with the physical knockout system for the production of the H2, and successfully enhanced H2 production in knockout E. coli. Designing and implementation of translation-controlled gene silencing is in under progress (Figure 2).

Publications:

1) Madavi, T.B., Chauhan, S., Jha, M., Choi, K.-Y. and Sudheer D.V.N.P*, Biohydrogen machinery: recent understandings, their genetic fabrication and future prospects. Chem. Eng. Technol (2021) In-press (IF: 1.74)
2) Pamidimarri DVN Sudheer, Sushma Chauhan, Wooyoung Jeon, Jung-Oh Ahn, Kwon-Young Choi, Monooxygenase-mediated cascade oxidation of fatty acids for production of biopolymer building block, Biomass Conversion and Biorefinery, (2021) (In press) (IF: 4.9)
3) Seo AP, Shashi KB, Hyun AP, Seo YK, Sudheer DVNP*, Yand Y-H, Chio KY*, Bacillus Subtilis as a robust host for biochemical utilizing biomass. Critical Review in Biotechnology (2021) 41,(6) 827-848 (IF: 8.2)
4) Sudheer DVNP*, Sushma Chauhan and Velramar B, Bio-hydrogen: technology developments in microbial fuel cells and their future prospects. Book title: Biotechnology for Biofuels: A Sustainable Green Energy, Edt. Nitish Kumar, (2020) Springer Nature, USA.
5) Sushma C, Velramar B, Soni RK, M Mishra M and Sudheer DVNP*, Biofuels: sources, modern technology developments and views on bioenergy management. Book title: Biotechnology for Biofuels: A Sustainable Green Energy, Edt. Nitish Kumar, (2020) Springer Nature, USA.
6) Sushma C, Balasubramanian V, Rakesh KS, Mohit M, Vargobi M, Tanushree Ba M, and Sudheer DVNP, Genetic Engineering and Fabrication of Microbial Cell System for Biohydrogen Production; Book title: Biohydrogen: Developments and Prospects; Chapter6, Edt. Sonil Nanda and Prakash Sarangi, (2021) Apple Accadamic Press, Taylor and Francis, UK. (In-press)
7) Sushma C, Balasubramanian V, Sneha K et al, Sudheer DVNP*, Engineered microbial systems for the production of fuels and industrially important chemicals, Biorefinary Advances: Production of Fuels and Platform Chemicals; Edt. Prakesh K.S. (2021) Wiley Scrivener Publishing LLC, US. (In-press)

Figure 1. Bio-hydrogen production by engineered *E. coli* from crude glycerol and lignocellulosic biomass. The schematic representation of carbon neutral/negative process for the production and utilization of bio-hydrogen as green fuel.

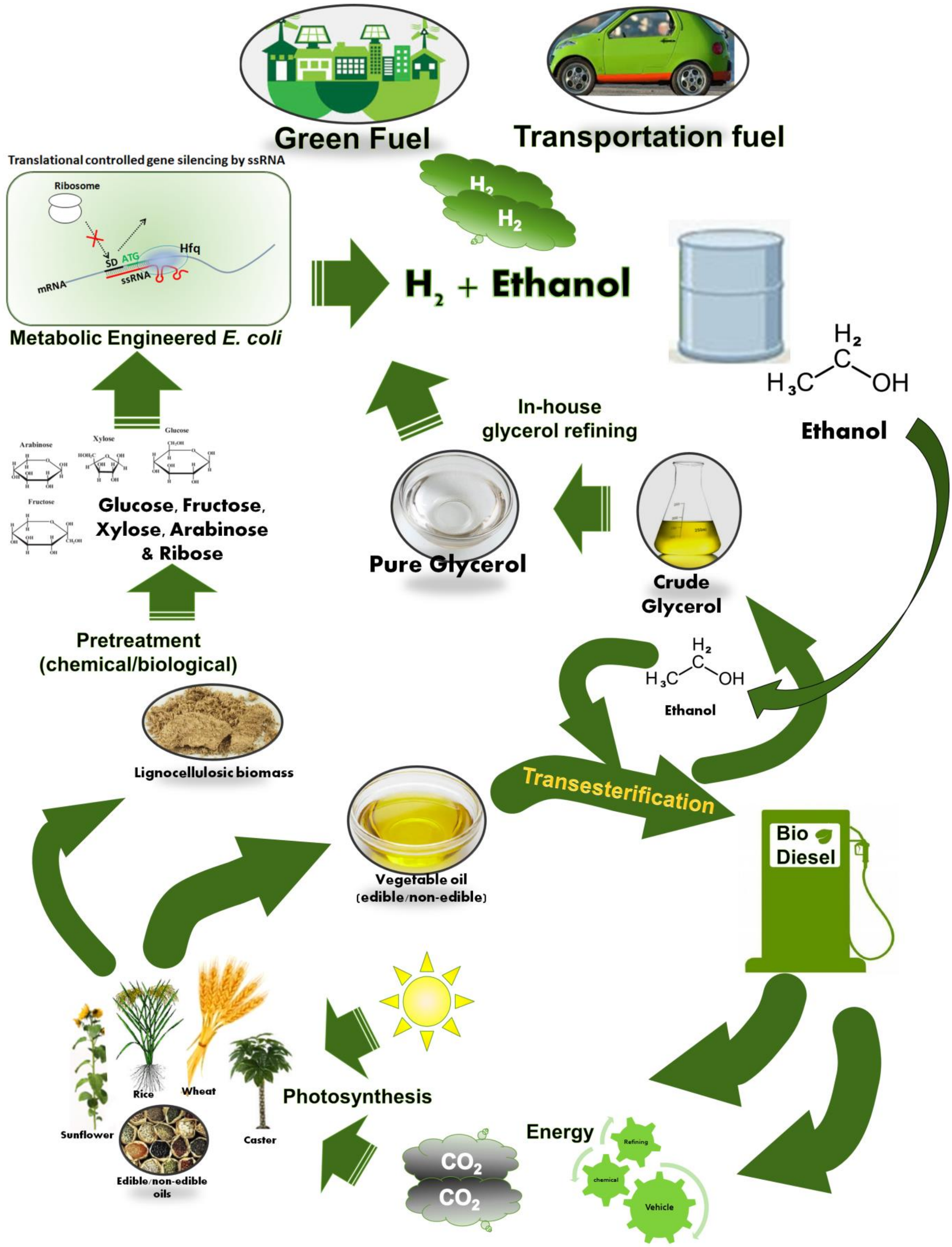
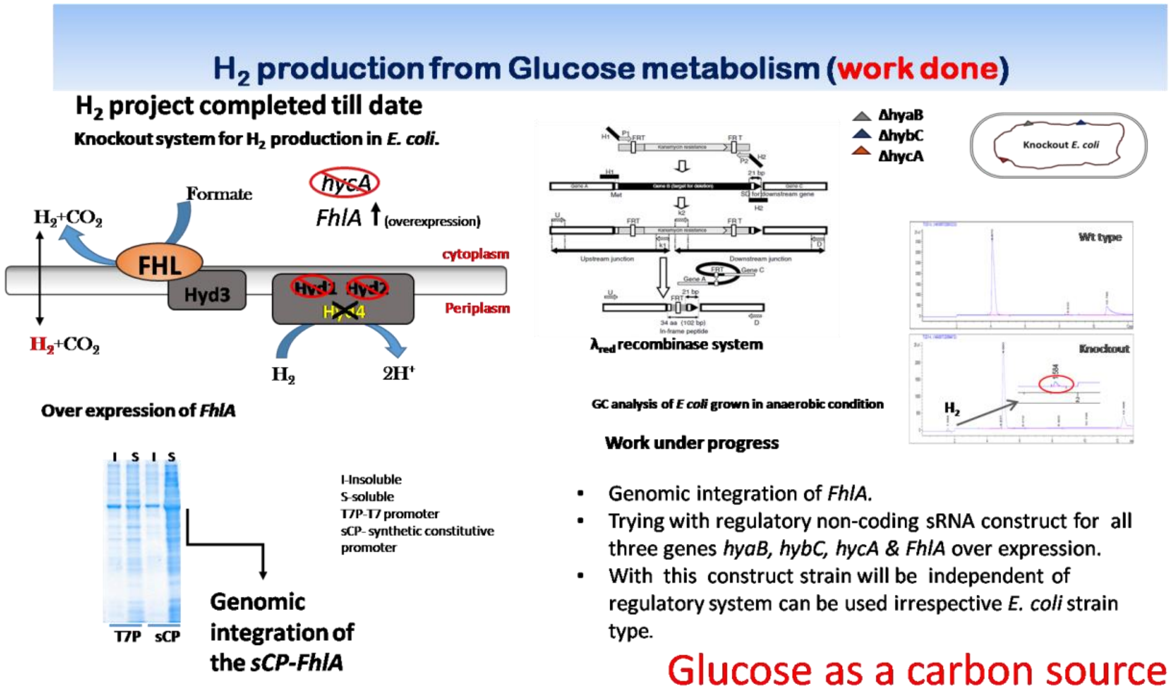


Figure 2. Enhanced H_2 production via Physical knockout of *hyd2, hyd 2, hyd4* and *hycA* in *E. coli* (W3110) .



1) Velarization waste biomass to biofuels and biochemicals

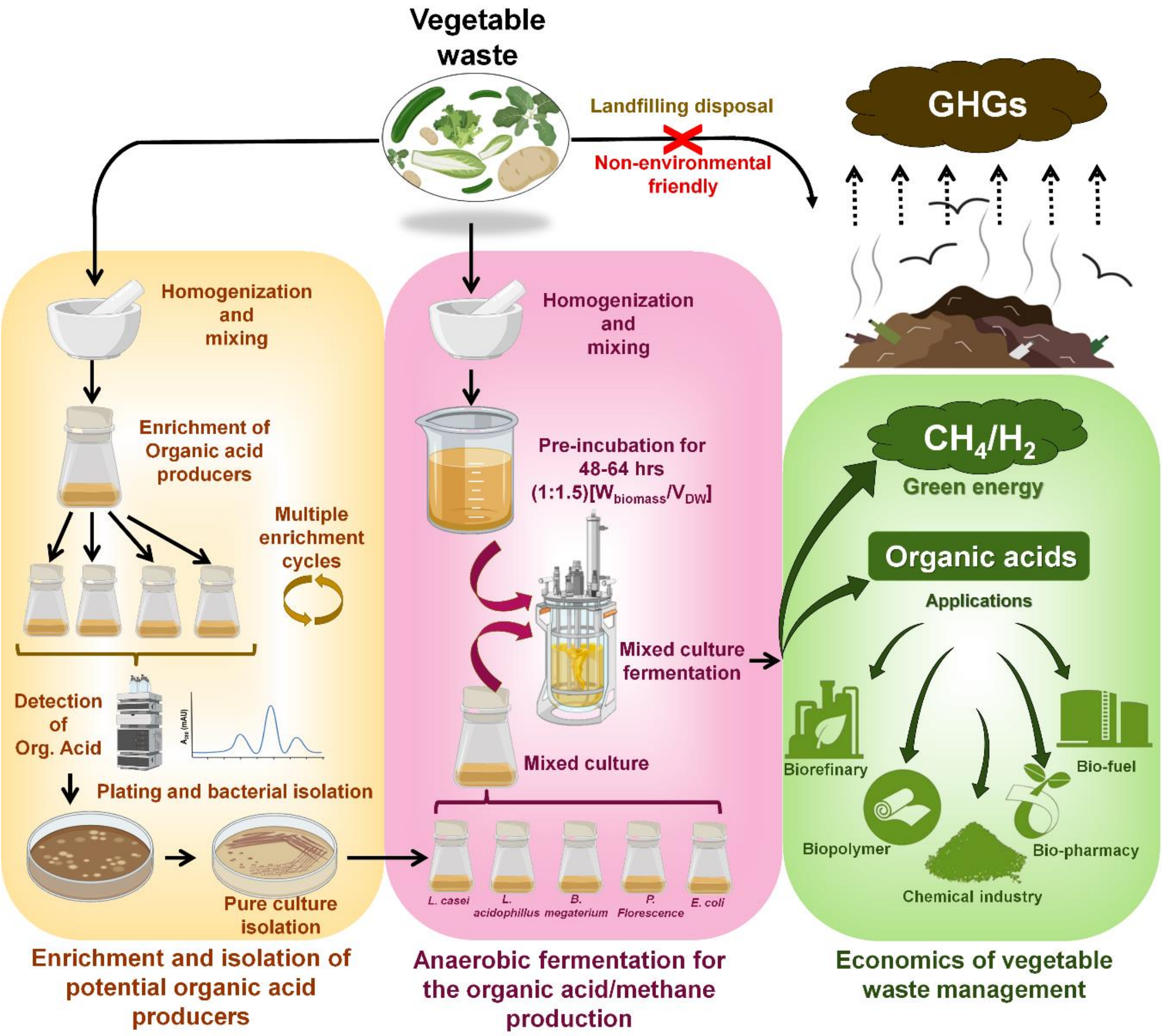
In recent years the keen interest of industries shifted from depending on traditional hydrocarbon-based carbon building blocks towards green synthesis via microbial fermentation. Organic acids come under the carboxylate platform and act as biobased chemical building blocks that can help in the green synthesis of many valuable chemicals. The library of organic acids such as acetic acid, oxalic acid, lactic acid, propionic acid, butyric acid, fumaric acid, malic acid, succinic acid, itaconic acid, citric acid, glucaric acid, and gluconic acid, can be derived from microbial fermentation and acts as chemical raw material These organic acids have applications as feedstocks in the synthesis of chemicals whose utilities start from food additives and act as raw material to produce polymers, synthetic intermediates, pharmaceutical agents, metal chelator, nylon, polyester production, therapeutics, fragrance/aroma ingredients, and in the synthesis of biodegradable polymers, complexing agents and also used as green solvents.

The production of various organic acids from vegetable waste *via* a facile and cost-effective method utilizing characterized synthetic microbial consortia is designed in our study. Five bacterial species with the ability to produce organic acids from vegetable waste biomass were isolated and identified as *Lactobacillus casei*, *Lactobacillus acidophilus*, *Bacillus megaterium*, *Pseudomonas florescence* and *Escherichia coli*. Using these cultures, mixed acid fermentation was developed and was demonstrated to produce various organic acids. The total organic acids accumulated using optimized fermentation conditions was found to be 72.44±3.43 g L^{-1}. The acetic acid was produced as major acid accumulated up to 25.27±1.26 g L^{-1}, followed by lactic acid 19.11±1.73 g L^{-1}. Efforts were also put forth to check the ability to produce methane by the anaerobic digestion process. Up to 14.97mL g^{-1} biomass methane was produced during the anaerobic digestion process. The technology developed in this study is a carbon-neutral process for managing vegetable food waste with economic benefit. The developed technology will have great economic potential and add value to vegetable food waste management. Concept of waste management demonstrated in the above study is illustrated in figure 1.

Publications:

8) Mishra M, Chauhan C, Balasubramianian V, Sudheer P *, Facile bioconversion of vegetable food waste into valuable organic acids and green fuels using synthetic microbial consortium, Korean Journal Chemical Engineering (2021), 38(4), 833-842 (IF: 3.30).

Fig. 1: Process of biofuel and biochemical production via waste biomass (vegetable waste) management.



Annexure 1: publications first pages

1)

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Sushma Chauhan[1,‡]
Meenakshi Jha[1]
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Sudheer D. V. N. Pamidimarri[1,*]

Biohydrogen Machinery: Recent Insights, Genetic Fabrication, and Future Prospects

The increase in global carbon footprints forced mankind to look for alternative carbon-free fuels. Biohydrogen is an ideal fuel, free of carbon footprint, which has the potential to replace fossil fuels. Its high energy content per gram has a great commercial value. Bacteria, cyanobacteria, and algae are developed with various cellular machineries for hydrogen production. Detailed information on these hydrogen-producing cellular machineries, their mechanism of catalysis, and modern genetic engineering and fabrication studies for the enhancement of hydrogen production are reviewed and discussed.

Keywords: Biohydrogen, Biophotolysis, Dark fermentation, Genetic engineering, Hydrogen production

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1 Introduction

Over the years, the usage of non-renewable hydrocarbon-based fuels and their arbitrary usage policies by various nations led to the rise of the global carbon footprint, and its consequences are now being perceived in the form of global climate change. Moreover, globally the demand for energy is increasing exponentially. The depleting hydrocarbon resources are pushing mankind to look for carbon-free energy resources [1]. Besides hydroelectricity, wind, solar energy, hydrogen (H_2) fuel is non-carbonaceous energy with zero emission. H_2 holds a high-energy content per weight (120.9 kJ g^{-1}), which is nearly three-fold higher than that of conventional gasoline (48.3 kJ g^{-1}) and natural gas (44 kJ g^{-1}). On combustion, H_2 produces only water and the present infrastructure is amendable for future H_2 applications.

The characteristic features of H_2 are suitable for various applications like metal refinement, space exploration, metallurgy, petroleum refinement, and synthesis of many commodity chemicals and, most importantly, as transportation fuel [2]. H_2 seems to be a prospective alternative fuel of choice, which can replace hydrocarbon-based fuels. Though H_2 by nature is a zero-emission fuel, unless the process of H_2 production is zero/neutral emission in nature, it cannot be considered as green fuel or carbon-free energy.

Presently, commercial production of H_2 occurs via physicochemical or electrochemical methods and both are reported not to be carbon-neutral [3]. Unless the production method is carbon-neutral, the benefit of H_2 utilization cannot be extracted by replacing hydrocarbon-based fossil fuels [3]. Hence, in this context, the microbial cell apparatus which can generate H_2 with neutral emission is gaining significance. Moreover, the process of biological H_2 production is completely renewable. Thus, microbial H_2 synthesis is expanding the interest in the scientific community to understand and gain knowledge regarding the cellular apparatus and mechanism of H_2 production.

Through evolution, many biological cells evolved with various cellular apparatus with the ability to produce H_2 which could be utilized by cells for various metabolic processes or as a by-product during the synthesis of essential cellular biomolecules. Among these, various fermentative bacteria, photosynthetic cyanobacteria, and some algae are recognized as efficient cell factories that could generate enough quantities of H_2 fuel with minimal bioenergy input. From a physiological point of view, hydrogenases (H_2ases)/nitrogenases (N_2ases) which are the major enzyme complexes producing H_2 in the cells, act as redox safety valves neutralizing excess of reducing power and regeneration of coenzymes. Besides, these apparatus function as redox buffer units protecting cells from oxidative bleach.

The H_2 producing apparatus is crucial rather than subsidiary and must be maintained in balance for the good health of the cell. Hence, for H_2 production enhancement or optimization, and for fabrication, a comprehensive knowledge of these cellular apparatus is needed. To date, many reviews are published considering microbial hydrogen production [4–10]; however, comprehensive information on cellular apparatus and their conclusive mechanism is scarce in the literature. In this review, major attention is given to discuss various cellular machineries

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3)

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REVIEW ARTICLE

Check for updates

Bacillus subtilis as a robust host for biochemical production utilizing biomass

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ABSTRACT

Bacillus subtilis is regarded as a suitable host for biochemical production owing to its excellent growth and bioresource utilization characteristics. In addition, the distinct endogenous metabolic pathways and the suitability of the heterologous pathways have made *B. subtilis* a robust and promising host for producing biochemicals, such as: bioalcohols; bioorganic acids (lactic acids, α-ketoglutaric acid, and γ-aminobutyric acid); biopolymers (poly(γ-glutamic acid, polyhydroxyalkanoates (PHA), and polysaccharides and monosaccharides (N-acetylglucosamine, xylooligosaccharides, and hyaluronic acid)); and bioflocculants. Also for producing oligopeptides and functional peptides, owing to its efficient protein secretion system. Several metabolic and genetic engineering techniques, such as target gene overexpression and inactivation of bypass pathways, have led to the improvement in production titers and product selectivity. In this review article, recent progress in the utilization of robust *B. subtilis*-based host systems for biomass conversion and biochemical production has been highlighted, and the prospects of such host systems are suggested.

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KEYWORDS
Bacillus subtilis; bioorganic acids; biopolymer; biosugar; surfactant; surfactin; functional peptides

Introduction

The development of sustainable chemical and energy production in an ecofriendly manner has become important as an alternative to fossil fuels and to mitigate global climate change. However, the energy production paradigm relies on petrochemical-based chemical reactions and conversion processes. However, owing to climate change and strict regulations on the management of hazardous substances, research on biotransformation technologies that can replace chemical reactions is ongoing. Of course, the two processes themselves have different intended products and applications, and there is a high possibility that synergies can be created. In particular, biotransformation reactions based on biological processes play a unique role that cannot be replaced by chemical processes [1].

The use of microorganisms in fermentation, bioproduction, and biotransformation processes has a long history and has recently developed radically because of technological advances in the screening, cultivation, and genetic engineering of various strains of microorganisms [1]. In particular, in the process of securing energy through soil-based plant cultivation, many useful microorganisms derived from soil have been found and identified [2,3].

Bacillus subtilis, a representative soil microorganism, is a Gram-positive bacterium well known for forming spores [4]. It is a generally recognized as a safe (GRAS) species that has been intensively studied and utilized for the production of a variety of biochemicals [5]. It can metabolize a vast array of substrates ranging from glucose to budgetary carbon feedstocks such as food, pulp, and agricultural waste [5,6]. The absence of an outer membrane and well-characterized secretion pathways in *B. subtilis* facilitates the efficient relocation of proteins into the extracellular space [7]. Therefore, *B. subtilis* has been one of the most powerful cell factories for the extracellular production of enzymes and peptides. In addition to efficient protein production, these

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*Those who contributed equally.

4)

Bio-Hydrogen: Technology Developments in Microbial Fuel Cells and Their Future Prospects

3

Pamidimarri D. V. N. Sudheer, Sushma Chauhan, and Balasubramanian Velramar

Abstract

The energy is the part of the human evolution; the innovation in the transportation and industrial evolution happened in this century made mankind to depend on fossil fuels invariably. The depletion of fossil fuel resources and global carbon footprint accumulation are worrying the global countries for the future environmental safety. The clear policies were amended to come out of releasing the global carbon footprint by many countries; even developing countries are making it compulsory for controlling or reducing greenhouse gases releasing in to environment. In this context hydrogen fuel is getting promising significance since it has high energy content per unit mass, and up on combustion it will not release any carbon footprint and considered to be complete green energy. Though there are many chemical and physicochemical methods available for the production of H_2, biological H_2 production will be superior since this method do not use harsh chemical process and do not need extreme conditions for the production. Hence, many research studies are put forward for the production of biological hydrogen production. In this book chapter we will have comprehensive discussion on these technologies developed for the hydrogen production till date. This chapter also included the next generation technologies which are in acceleration in engineering the strains for the enhancing the productivity and various other parameters like utilization of waste biomass and waste industrial affluent etc. This chapter also included with the list of aspects to be looked for the future development of H_2 as the next generation fuel energy.

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N. Kumar (ed.), *Biotechnology for Biofuels: A Sustainable Green Energy Solution*,
https://doi.org/10.1007/978-981-15-3761-5_3

5)

Biofuels: Sources, Modern Technology Developments and Views on Bioenergy Management

8

Sushma Chauhan, Balasubramanian Velramar, Rakesh Kumar Soni, Mohit Mishra, and Pamidimarri D. V. N. Sudheer

Abstract

Increasing energy demands and the rising global carbon footprint are forcing mankind to look for alternative green fuels. Fuels derived from biological sources are considered to be green fuels since they do not release toxic pollutants upon combustion. The global accumulation of the carbon footprint and accelerated demands on energy are pushing us to look for alternative green fuels based on renewable resources. Hence, identification of potential sources of green fuels produced by biological means and utilization of these resources for commercialization provide the context of the priorities for future energy needs. The two major concepts considered for next-generation green fuels are (i) fuels that do not increase the carbon footprint (e.g. hydrogen fuel) and (ii) utilization of photosynthetic processes to fix CO_2 and produce biofuels. Keeping these two priorities in mind, this chapter provides a detailed discussion of various biofuels available for mankind, which can replace traditional hydrocarbon-based fossil fuels. These biofuels could help in reducing the global carbon footprint. The chapter gives information about the various biological sources for production of biodiesel and microbial sources for production of liquid fuels. This chapter also discusses the concept of microbial fuel cells, the importance of biohydrogen, aspects of molecular engineering of organisms to enhance productivity, fabrication of microbial systems for production of biofuels and the prospects for biofuel production by utilizing modern biotechnology tools.

Keywords

Biofuels · Microbial fermentation · Biodiesel · Biohydrogen and microbial fuel cells

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8)

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Facile bioconversion of vegetable food waste into valuable organic acids and green fuels using synthetic microbial consortium

Mohit Mishra, Sushma Chauhan, Balasubramanian Velramar, Rakesh Kumar Soni, and Sudheer Deva Venkata Narayana Pamidimarri†

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(*Received 24 August 2020 • Revised 6 December 2020 • Accepted 23 December 2020*)

Abstract−The production of various organic acids from vegetable waste *via* a facile and cost-effective method utilizing characterized synthetic microbial consortia is described in this study. Five bacterial species with the ability to produce organic acids from vegetable waste biomass were isolated and identified as *Lactobacillus casei*, *Lactobacillus acidophilus*, *Bacillus megaterium*, *Pseudomonas florescence* and *Escherichia coli*. Using these cultures, mixed acid fermentation was developed and was efficient in producing various organic acids. The total organic acids accumulated using optimized fermentation conditions was found to be 72.44 ± 3.43 g L^{-1}. The acetic acid was produced as major acid accumulated up to 25.27 ± 1.26 g L^{-1}, followed by lactic acid 19.11 ± 1.73 g L^{-1}. Efforts were also put forth to check the ability to produce methane by the anaerobic digestion process. Up to 14.97 mL g^{-1} biomass methane was produced during the anaerobic digestion process. The technology developed in this study is a carbon-neutral process for managing vegetable food waste with economic benefit. The developed technology will have great economic potential and add value to vegetable food waste management.

Keywords: Carbon Footprint, Landfill Disposal, Organic Acids, Synthetic Microbial Consortia, Vegetable Waste Biomass

INTRODUCTION

In recent years the keen interest of industries shifted from depending on traditional hydrocarbon-based carbon building blocks towards green synthesis via microbial fermentation. Organic acids come under the carboxylate platform and act as biobased chemical building blocks that can help in the green synthesis of many valuable chemicals [1,2]. The library of organic acids such as acetic acid, oxalic acid, lactic acid, propionic acid, butyric acid, fumaric acid, malic acid, succinic acid, itaconic acid, citric acid, glucaric acid, and gluconic acid, can be derived from microbial fermentation and acts as chemical raw material. These acids range from C_2 to C_6 and are presently produced at the commercial level by microbial fermentation, occupying up to 5-10% of the total industrial production scale [1]. In recent years, higher chain diacids also have been reported *via* whole-cell biocatalysis utilizing vegetable oils with the help of recombinant strains [2,3]. These organic acids have applications as feedstocks in the synthesis of chemicals whose utilities start from food additives and act as raw material to produce polymers, synthetic intermediates, pharmaceutical agents, metal chelator, nylon, polyester production, therapeutics, fragrance/aroma ingredients, and in the synthesis of biodegradable polymers, complexing agents and also used as green solvents [1,4]. However, this adaptation is not in the desired acceleration to attain success at the commercial level. This hindrance is due to the cost incurred for the production of organic acids via microbial fermentation since biorefinery relies on costly culture media and the defined nutrients. Hence, researchers are looking to utilize low cost or waste biomass to produce organic acids; thus the production cost comes down and can attain commercial feasibility.

Urbanization is accelerating in larger cities, leading to the increased discharge of vegetable/food waste from the domestic and food industries. The vegetable/food waste discharge is presently a major urban issue because the protocols used in waste management elicit carbon emissions. Most of the nation's local governance primarily manages waste discharge *via* the landfilling method. Landfilling comes under the non-green disposal method as the wet solid waste, which includes the vegetables, food, kitchen waste generated by the domestic/commercial/food market/food processing industry, is rich in carbon and nitrogen sources along with the macro and micronutrients. Hence, is very much suitable for microbial growth [5,6]. In conventional landfilling disposal, the wet food waste upon the disproportionate microbial activity will result in methane and other greenhouse gases released into the environment. Hence, causing global carbon footprint accumulation [7]. According to the National Food and Agriculture Organization, up to 8% of global carbon footprint emission is due to improper vegetable/food waste management. Moreover, it is also responsible for local pollution, groundwater perturbance, and the release of toxic greenhouse gases through anonymous decomposing activities by the various microbiome. Hence, many countries with a high population density, e.g., the Republic of Korea, have banned landfilling disposal methods for vegetative food waste and/or domestic kitchen waste [8]. Thus, environmental research has shifted towards utilizing this waste to generate biochemical building blocks like organic acids. Organic acids can act as raw materials for the green synthe-

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ACTION PLAN
TO REDUCE PLASTIC IN CAMPUS

Going plastic-Free

Now here's a major challenge – a "Plastic-Free Campus". The ubiquitous presence of plastic in our daily lives might make this seem like an impossible task. Furthermore, plastics have played a huge role in technological innovation to do a lot of good for a lot of people. But, DO NOT BE DISCOURAGED! Your target is single-use, disposable plastic… and it's totally doable! Becoming plastic-free is a process that won't happen overnight, so keep in mind these key tips:

1. **Start small**, perhaps with a **Pilot Project**, and build on your successes

2. **Educate yourself** and others on the harms of plastics

3. **Rally support** from all types of stakeholders on the campus

4. **Make a plan** of action! While the implementation will be difficult, we and our peers have the power to reduce plastic pollution!

What does it mean to go plastic-free?

Plastic has become an almost-unavoidable part of modern everyday life. It's affordable, easy to mass-produce, and ideal for many innovative technologies. Pledging to transition away from disposable plastics is pledging to end the consumption of single-use items destined for a landfill. It can start with an elevated education about the consequences of plastic production and consumption, and a removal of basic products like plastic bottles and bags, plastic film, and other unnecessary product packaging. While plastic alternatives can be costly, the long-term health and environmental benefits of going plastic-free far outweigh the initial monetary costs.

Navigating the Project

All campuses are different: what works at one school may require more attention, more push, or may not work at all, for ours. From the passing of bans that have essentially fallen into students' laps, to initiatives that resulted in unintended consumption of other plastic items. You will find that our University has a specific pace to be followed. Our student group working towards zero waste must explore the kind of attention our institution needs. Ask yourself these questions regarding single-use disposable plastics:

- What do you perceive to be the most concerning issues regarding plastic use on our campus?

- What single-use disposable plastic items are most prevalent on our campus?

- Which "problem" plastics should be a priority target?

- What form of action should we take: a ban, a reduced-price incentive for reusables, or simply more education entailing the consequences of plastic use?

Seven Reasons to go Plastic-Free

1. Single-use disposable plastics have a **massive carbon footprint**. Whether made from petroleum or plants, plastic manufacturing is not efficient due to the scale of production.
2. Both the production and disposal of single-use plastics often emit massive amounts of dioxins, a highly toxic by-product linked to increased cancer rates and other **human health effects**.

3. **Plastic lasts forever**: Plastic can never be broken down by natural processes; every particle of plastic that has ever been created still exists in a form toxic to all terrestrial and marine life.
4. Plastics can be **challenging to dispose of**. Not all localities have the infrastructure to recycle single-use plastics; thus, many recyclable plastics take up valuable landfill space. When not able to be recycled or landfilled, they are often sent to incinerators, emitting environmental toxins into the atmosphere.
5. Plastic **poisons our food chain**: It is increasingly found in the ocean and guts of marine life, extending to affect the health of human populations who rely on fish and other marine life for food sources.
6. Going plastic-free can **save you money**! Relying on reusable items enables you to avoid constant purchasing of disposable items.
7. Single-use plastic items perpetuate a **wasteful, throw-away culture**. Our society is far too valuable to be thrown away! Brought to you by PLAN and the Plastic Pollution Coalition.

Now that we've got the facts about issues surrounding plastic pollution, we want to help you take action! Among all of the following best practices to becoming plastic-free, we outline:

- **How to navigate our campus and local community infrastructure**
- **Existing initiatives, campaigns, and legislation targeting single-use plastics, and where to find information about plastic-free initiatives near us**
- **How to conduct a Plastic Audit, and use that information to make a plan of action**
- **Alternatives to specific single-use plastic items, and resources for further support!**

Preparing for Pushback

As mentioned, we may receive pushback about going plastic-free. Be prepared for critics to challenge us with these myths about plastic bag bans and going plastic-free:

Reusable bags spread bacteria: Some studies out there try to make the case that reusable bags encourage the spread of infectious disease through harbouring bacteria like E. Coli. The reality is that bacteria is found on EVERYTHING, including single-use plastic bags. If your reusable bag is dirty, give it a wash or wipe it down. It's also good practice to use separate bags for meat and produce.

Reusable bags are toxic: Any synthetically made product has the potential to contain unsafe amounts of heavy metals or other toxic compounds. Eco-friendly intentioned products are no exception to this. Likewise, reusable bags are no more likely to be toxic than their disposable counterparts. Navigating this is part of being an informed consumer!

Banning plastic bags means people will just use disposable paper bags instead: That is certainly a logical assumption, but paper bags can be the lesser of two evils. They are more easily recyclable AND have the ability to be composted. Oftentimes, bag bans will put charge a small fee onto other disposable bags, so that consumers are still encouraged to bring reusables.

Charging for single-use bags is just a scam for stores to make money: Fees applied to single-use bags are used to fund an establishment's procurement of more durable (thus, more expensive) bags to comply with the law. The consumer was never getting single-use bags for free in the first place; the cost of procuring them is often tacked onto the prices of products that the establishment sells.

Know Your Stuff:

Campus & Community Infrastructure

Start big and learn the status of the area surrounding our University in regard to any kind of plastic ban or legislation. This knowledge is a powerful tool in moving our campus to take steps. Once we know, we can act. The second half of this action plan covers who to talk to make change.

Local Laws and Regulations

As the general public becomes more aware of the dangers of single-use disposable plastics, new legislation is calling for sustainable alternatives. While not always obligated to follow suit, universities and colleges can adopt local regulations or ordinances if the campus population expresses support. These community laws can provide a baseline for new student campaigns, or a final push for on-campus initiatives.

So where do we find all this information?

There are a variety of resources to consult, including web resources from leaders in the plastic-free movement, to talking with city council representatives. Check out the following web resources to find out if bag bans and other plastic free initiatives exist in our area:

- Chico Bag's "Track the Movement" interactive map
- The National Conference of State Legislation site detailing passed and proposed plastic bans by the State
- The Plastic Bag Ban Report for bans nationally and worldwide
- The Surfrider Foundation
- Social media hashtags: #bagban, #banthebag, #plasticbags, #banthebead, #plasticpollutes, #bringyourown

Existing Campaigns:

AUC - Administration has banned polystyrene (Styrofoam™) in campus food establishments only to find that dining services had already begun taking steps to phase-out the material on their own accord. Students latched onto this discourse and kept close communication with dining services to consult them on what a polystyrene phase-out would look like. This group (Administration + Student groups from various streams) established a petition committee to draft effective policy language, and delegate the proposal out to individual campus food vendors. It was also helpful to have a community member who worked for World Centric, a company that manufactures compostable to-go ware, as a part of the petition committee to be able to attest to the affordability of compostable alternatives. Student organizers recognized that, had they drafted the proposal alone without input from a variety of campus representatives, they would have faced much more pushback. Ultimately, the combined force of Administration, students and dining hall operations made passing of the ban, and its subsequent implementation, more effective.

Existing Municipal Ordinances & Bans

City ordinance or District Authorities, prohibits the use of polystyrene to-go containers by all food service operations in Raipur. This is in an effort to reduce plastic debris and avoid the potential health impacts of single-use plastic products. The terms are as follows:

- prohibits the use of polystyrene (Styrofoam™) to-go containers by all establishments serving food in Raipur

- requires food vendors and restaurants to use only compostable or recyclable to-go food service ware

With the infrastructure already in place at the local level, the Amity University Chhattisgarh (AUC) implemented a similar policy mandating all private food vendors leasing space on campus to comply with the city ordinance, resulting in the ban of polystyrene on campus.

Existing Campus Policy and Operations

If University has limited recycling capacities for recovering single-use plastic items, there is all the more reason to eliminate these items on campus. However, for schools with recycling infrastructure, full blown bans of plastic items may not financially make sense to campus administration because of recycling rebates and other incentives that campus receives. Talk to Procurement Department as well as the department that handles waste management in our campus to determine if any financial incentives drive campus recycling operations. If this is the case for our campus, there are alternatives out there for our campus to mitigate its plastic footprint:

1) Decreasing campus-wide procurement and consumption of non-recyclable plastics

- polystyrene containers could be replaced with another material.
- Make some campus events or student org programs plastic-free.

2) Encouraging **individual behaviour change** for single-use plastic consumption.

3) Increasing **recycling participation** and reducing recycling contamination on campus.

University (In)Capabilities

AUC has been strategizing to purchase reusable dishware for all eateries on campus. We have even succeeded for one or more locations.

As we've just seen, there are a variety of ways to move towards a plastic-free campus. Existing laws and ordinances may serve to make the switch effortless, or may force us to get creative with our education and outreach efforts. Even if we are able to pursue a solid alternative to single-use plastic products, every alternative will have its own set of complications. For example, compostable products may not be compatible with the composting infrastructure of our campus or surrounding community. Furthermore, these operations might not even exist for us to consider compostable bio-ware as a sustainable plastic alternative.

Collaborating with Departments on Campus

Whether we are trying to pass a ban on campus, change procurement, or establish a reusables campaign, we will need backing from institutions. Remember to include others on campus who are affected by these initiatives. Some examples of important stakeholders to include in our initiatives are:

- dining service workers or food service provider representative: chefs, servers, cafe managers

- campus waste management service staff

- custodial staff

- procurement department staff

- student groups working for campus change: services groups, environmental groups

- professors, faculty, provosts, department chairs

- community members that may be affected remember, having a signature on a petition from a major campus faculty, agreeing to support our initiative or campaign, can go a long way.

TAKING ACTION

Conducting a Plastic Audit

The first step is to conduct a plastic audit. Check out and record the following:

- What plastics are used on campus and where do they come from?
- Which of these items are most frequently used?
- Where are single-use plastics disposed of?
- Who is using single-use disposable plastics on campus?

Plastic audits can be conducted through multiple approaches, and will set the stage for plan of action for a plastic-free campus. No matter which approach we choose, try to be transparent to students and other campus residents about why are we conducting a plastic audit - the sooner we start to educate and outreach the better.

VISUAL ASSESSMENT

Note and track all single-use plastics we see on campus, from trash receptacle contents, to what cafés and campus vendors are distributing to customers. Observe passers by walking to class: What are students carrying? Coffee cups with plastic lids or iced drink cups? Granola bars in plastic wrappers? A sandwich in a baggie or plastic wrap? While taking records of the plastics we observe, keep these questions in mind:

- What kinds of plastics are being thrown away?

- Roughly, what ratio of these are plastics that can be recycled?

- What/How much of that is material supplied by our campus?

- What/How much is being brought onto campus from outside sources?

- Who is associated with these outside sources and how will we communicate with them?

Observe the contents of vending machines on campus. How many in total are they and where are they located? What kinds of plastics appear in them? Which items have potential alternatives?

PROCUREMENT INVENTORY

A procurement inventory provides more verifiable data on campus plastic presence and insight into campus procurement practices. This will require communication with campus dining services, cafes and other eateries, and perhaps the procurement department through which these establishments purchase their products. Ask for a purchasing list and note the specifics of all of the single-use plastic products that are purchased, including:

- How much of the item is purchased
- How much the item costs per unit purchased (include shipping!)
- What company produces each product and/or the supply centre from which it is shipped
- What the product is made of and how it is packaged

This information will be useful for calculating any sort of cost-benefit analysis of plastic product alternatives that can be presented to campus administration. After taking an initial procurement inventory, we can further analyse the products that we have recorded by finding out if product vendors provide alternatives, and what the costs of these alternatives are in comparison to the materials that are currently being purchased.

Formulating A Plan

Once we have conducted a plastic audit identifying the major sources of single-use disposable plastics on your campus, where they come from, and who is using them, follow the steps below to formulate a plan for a plastic-free campus!

STEP 1: FIND YOUR TARGETS

Petroleum-Based Products & Bioplastics

There are many products advertised as plastic alternatives that are petroleum-based and still contain plasticizers, and thus pose similar health and environmental effects to traditional plastics. Try and advocate against these single-use items in our plastic-free initiatives. **Bioplastics are composed of “renewable biomass sources,”** like corn or vegetables oils, that are processed into a compound called polylactic acid (labelled as PLA #7). Their composition makes them less fossil-fuel-intensive in production and less hazardous in disposal. However, there is often a huge amount of energy sources put into growing the crops for the production of bioplastics. While bioplastics are designed to be “biodegradable”, this term does not guarantee that an item will fully break down in a compost system. Furthermore, the nature of bioplastics’ composition interferes with the operations designated for recycling regular plastics. In other words, we cannot mix bioplastics in with recyclables!

If implementing reusables is not feasible for our campus at the moment and we opt for single-use bio-plastics, we suggest using World Centric products. The majority of plant fibre products from World Centric are composed of wheat straw, a by-product of agricultural production that is often thrown away or burned.

Single-Use Plastics

Freedom from plastic should include all plastic items that would normally be disposed of after one use. This includes (but is not limited to) beverages in plastic bottles, items in plastic wrap or plastic containers, utensils, cups and lids, straws, stirrers, bags, and any disposable polystyrene (Styrofoam) products.

Beyond Bottles and Bags

Single-use plastic bottles and bags are just the first steps to becoming a plastic-free campus. Future purchases of plastic materials should be avoided, when possible, especially when the products are hard-to-recycle or unable to be recycled. For example, plastic shower curtains cannot be recycled and alternatives should be considered when old ones need to be replaced. Another target to be aware of is products containing plastic microbeads.

"Biodegradable" is not the same thing as "compostable"! If an object is biodegradable, that means that is capable of being decomposed by natural processes. This does NOT necessarily mean that the item will break down in a composting system to be used in a finished compost product. There is no time scale requirement for biodegradation - everything will biodegrade eventually. Compostable means that an item or product will break down completely within a given time. Compostable is a term with set requirements in regards to biodegradability, disintegration, and ecotoxicity:

1**) Biodegradability** - 60-90% will break down in 180 days

2**) Disintegration**- 90% of material will break down into pieces 2 mm or less in diameter

3) **Ecotoxicity**- when product breaks down, it will not leave behind heavy metals that are toxic to the soil above a standard level

Bioplastics and single-use compostable are often viewed as a feasible alternative for campuses who have access to composting operations. However, we encourage campus to abide by the waste hierarchy, to reduce and reuse before creating more waste that must be composted. Single-use compostable items still require resources and energy to be produced, packaged, and transported. Furthermore, many industrial composting facilities are opposed to large amounts of compostable plastics in their material, because the chemical makeup of #7 plastics can interfere with efficient decomposition of other materials

STEP 1: TARGETS LOCATIONS

While campus eateries are the common source of single-use disposable plastics on campus, there are many other source locations to take into account. Some are prime locations for single-use plastic reduction and some are hot spots of information from where we can continue to spread our message.

Promotional Areas:

Any place displaying school pride, like the campus bookstore or a sports venue, should also represent our campaign. Talking to campus vendors about selling reusable drinkware, like water bottles and coffee thermos; ask that cashiers and other store staff be trained to first ask customers if they need a plastic bag for their purchase, rather than offering it automatically. Look into the feasibility of installing water bottle filling stations**. Other ideas include**:

- not automatically offering straws for drinks, napkins, and other concessionary products at sporting events

- selling reusable bags at the bookstore with our campus logo

Residence Halls:

Residence halls are a prime location for targeting a large audience of potential plastic users on campus. In order for this to be successful, students need some means of utilizing plastic alternatives, especially those that already exist within dorm locations. For example, highlight existing water fountains and sinks in the building to sway students from purchasing bottled water.

Resident Advisors (RAs) are usually required to hold a certain number of programmed events each term. These events are a great opportunity to reinforce plastic-free habits and education. Reach out to residence hall staff to plan plastic-free program trainings for RAs at the beginning of each term.

Departments and Staff:

In addition to students, be sure that other members of campus are aware of plastic-free campus initiatives. If staff and faculty understand the effort to go plastic free, they can pass information onto students and campus visitors. Probably Plastic-free efforts can be incorporated into staff meetings, office operations, and class instruction so that these habits become a part of campus culture.

Events:

Events are a fun and inclusive way of extending the university's plastic-free initiatives to a larger audience. Events provide opportunities to:

- Recruit new volunteers and student groups to join in plastic-free initiatives

- Frame initiatives in a positive light, through fun and interactive activities

- Extend initiatives beyond everyday campus operations

- Advertise incentive programs that give discounts for bringing your own reusable items

Work with event planners to brainstorm procurement alternatives to purchasing single-use plastic materials and supplies. Brand these events as plastic-free in your invites, and make it explicit at the event itself. Connect with student clubs, groups and individuals coordinating events so they can join in and help cultivate a plastic-free culture.

Pre-Planning:

- Coordinate plastic-free purchasing by communicating with the caterer or food service provider that there should be no single-use plastic packaging for the food
- Buy in bulk or opt for food and materials that are packaged in paper, as long as we have the ability to compost or recycle the material
- Serve beverages fountain-style or out of out pitchers
- Provide reusable cutlery and serving utensils
- Opt for reusable decorations, like cloth table covers or woven placemats, or consult the art or theatre department for old set pieces (any plastic decor should be reused for future events)
- In our event invites, encourage guests to bring their own reusable water bottles and coffee mugs - if it is a picnic type event, attendees can even bring their own plates, bowls and utensils!

During:

- Set up clear signage for refillable water stations, water fountains, and waste bins
- Use fun displays to advertise the event as plastic-free

- Have interactive games around the plastic-free movement, with reusable prizes!
- Monitor bins throughout the event to ensure waste streams are properly separated (i.e. compost, recyclables, landfill trash). We like to refer to this job as "Trash Talkers"
- Train event staff to talk about plastic-free and the sorting of material in an encouraging way – they should not feel like they are educating, rather than policing

Clean-Up:

- Do a final sweep of bins to ensure waste streams are properly separated (i.e., compost, recyclables, landfill trash)
- Follow up on our material. Make sure each bin is picked up/ dropped off in the proper location in a timely manner after the event
- Recycle or reuse any plastic that did end up at the event, such as cellophane on catered food or plastic bags from an outside vendor. All of this has the potential to be washed and reused for future events!
- Debrief with our team and the event organizers to assess what went well and what could be improved

NEXT STEPS:

ALTERNATIVES TO SINGLE-USE PLASTICS

First, we talk about Education. If people know the problem with plastics, they will be a lot more likely to assist and accept the change. Refusal is next, addressing those pesky disposable items so common at to-go eateries. Our next mission is to replace those single-use plastic items with – and encourage the use of – reusable items. We cover bottles and fountains, bags, dishware and reusable containers, cutlery and vending machines, finishing up with an analysis of different styles of positive and negative reinforcement. Thinking longer term, we go on to discuss procurement policies for campus-wide change. Finally, cross-disciplinary alternatives acknowledge that a Zero Waste campus must be a plastic-free campus.

1. Education as an Alternative

Transitioning our campus to becoming free of single-use disposable plastics requires tangible and trackable goals. Keep in mind that many of our successes might take qualitative forms, and may be hard to measure. There may be too much pushback from our campus to officially ban single-use plastics; if this is the case, all is not lost! We can still EDUCATE the student body on the dangers of plastics, and their ability to make a direct positive impact by choosing to live their personal lives without them. For example, the dining hall may still give out straws but that doesn't mean people have to take them. When students are given the ability to choose, rather than having behaviour dictated to them, they feel more empowered! Furthermore, with the ability to choose, students come to better understand the initiatives in place and why they matter… this new attitude is more likely to be sustained beyond their time at the university'

2. Refusing Single-Use Items or Providing Upon Request

Dining areas and eateries are prime locations for complementary single-use items making them a primary source for generating waste on campus. Working with these areas can be a huge stride in our plastic-free efforts. Rather than offering napkins, straws, plastic bags, coffee sleeves, and ketchup packets in a free-for-all fashion, eateries can offer these items by request only. Better yet, many of these items can be displayed in a self-serve, bulk fashion.

3. Encouraging Reusable Items

Whether or not our campus is able to implement a ban on single-use plastics, It is important to highlight existing infrastructure that assists campus residents in living plastic-free. Post maps and signs around dorms highlighting existing water fountains for students to refill reusable drink containers at no cost. You might also look into making these fountains more reuse-compatible with special gooseneck spouts for more efficient bottle filling. These retrofitted fountains often referred to as "hydration stations" can improve perceptions around drinking free, local water.

4. Alternatives Through Procurement

A ban prohibits a product or material from being purchased, sold, or used on campus. Once incorporated into campus policy through a ban, plastic-free initiatives will have more strength and stability. All campus vendors and contractors must abide by the language of the ban; this puts pressure on vendors working with major institutions like AUC campus to create plastic-free alternatives for the greater consumer population.

5. Cross-Disciplinary Alternatives

Plastic-free is just one component to overall campus waste reduction. Joining forces with other waste reduction initiatives on campus can strengthen our campaign. A plastic-free campus is by no means mutually exclusive from sustainability initiatives concerning food recovery and hard-to-recycle materials.

Prioritize Local

Sourcing locally for food and other items reduces the need for extensive packaging, cuts carbon emissions associated with transportation, and allows for more opportunity to negotiate sustainable alternatives with vendors.

Recycling

An efficient recycling infrastructure is important for managing any plastics that do end up on campus. By recycling plastics, products get a chance to become something else, making it not quite single-use. Try to raise awareness around campus recycling operations participation rates among students. We might make our Plastic Audit a part of a larger campus Waste Audit to gauge all of the different types of waste materials generated on campus and how they are being disposed of.

Composting

Switching to compostable to-go ware and packaging is a great first step but it must come along with a composting system that can handle not only the material but the volume produced.

Campaigning

There are a ton of resources both on and beyond campus that we can utilize to spread the word for our project or campaign. Collaborate with our advisor, or equivalent project "champion", about how to reach out to local, regional, national, and international groups who are implementing plastic-free initiatives on a larger scale. Support in all shapes and sizes is important - augment the impact of students in numbers with a shout out from campus staff and faculty, community leaders and organizers, and non-profit advocates!

Advertise our Campaign!

Signage and Flyering

- Use different types of font, bolding or underlining important words, to guide the reader's eyes and to break up the text

- Keep it short and simple. Anyone and everyone should be able to get the message with just a quick glance

- Use images to draw attention and help convey information

- Create a memorable logo or slogan for a campaign

- Use numbers on our visual - they can be powerful for putting things into perspective

- Signs should be at eye-level so students can't miss them

- Get help from art and graphic design students!

Social Media Platforms

Social media is a powerful way to spread the word about our program. We recommend creating a Facebook page and Twitter handle for your plastic-free campaign and projects. Perhaps designate this task to a single person on our campaign team. Work with our Campus Coordinator to utilize PLAN's national media presence in advertising our campaign!

Making Plastic-Free a Positive Experience

It's really important that the students of our campus leave having had a positive experience with plastic-free initiatives. The goal is not to burden individuals by making it difficult to follow these initiatives. Reducing plastic use is important, and the goal is for students to realize that being plastic-free is possible, easy, affordable, and can be done without missing out on anything.

Educating Visitors

Educating visitors is not an obstacle, but an opportunity! Chances are that our university rents or donates space to community and private groups for events, such as conferences or summer camps. These visitors are likely unaware of campus plastic policies and initiatives. Work with whomever on our campus maintains communication with these types of groups, such as Admissions, Conference Services, or Orientation Staff, to ensure that the best effort to inform people of our university's policies is communicated before the visit. This also includes educating guest speakers and performers. To make it easier for speakers, performers, and other traveling individuals or groups to comply with our campus policies, offer them advice from the Plastic Pollution Coalition's one-sheet on "Touring Plastic Free", available in the Plastic-Free folder in our Google drive. University tours are another major avenue to convey campus practices. Talk with the department in charge of campus tours about training orientation guides to be able to effectively explain the plastic-free initiatives our campus has adopted.

Maintaining the Importance of Recycling

Recall any waste or plastic audits we performed in the beginning stages of our project or campaign. We may have found that a lot of students throw away recyclable materials. This often happens with lack of education regarding recycling infrastructure on campus. It might also be caused by inadequate recycling infrastructure to begin with: if recycling bins are not in close-enough range to a trash can, some people may not make the extra effort to distinguish where they are throwing away their waste.

Going plastic-free won't happen all at once, so continue to give attention to recycling infrastructure and participation on campus. Be sure that bins for all different waste streams are present at disposal areas, and are clearly marked and distinguishable. We also may have found in our audit that there is a significant amount of plastic from off-campus sources. It is important to continue education of proper disposal of these items, as they will inevitably enter campus from time to time.

Finally, being plastic-free does not mean disregarding recycling entirely. Even with a reduction of single-use plastics, recycling can still serve as an appropriate disposal method for glass, aluminium and more difficult to dispose of plastic products.