Bioplastic(Petrochemical Plastic Substitutes): Price Burden and Path to Cost Reduction

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Introduction

- **Definitions**
  - Bioplastic: Biodegradable plastics are mostly(not all) made from renewable resources.
  - Bioplastic Products: Products made primarily from bioplastics that are certified biodegradable or compostable: US Standard ASTM D6400, European Norm EN 13432
- Identified **Problem**: 1% of 335 million tons of plastics produced annually are bioplastics, why is bioplastic market still small?
- **Questions** to be answered:
  1. Is the price of bioplastics a disadvantage to bioplastics when competing with traditional plastics in the market?
  2. What price reducing technology or innovations can be or is being adopted to reduce the cost of bioplastics?
  3. What indirect methods could help mitigate the cost reduction burden of bioplastics?

Identify the price burden: Bioplastic Products

- **Price Comparison**
  - BioBag vs. Conventional Plastic Products
    - Kitchen Waste Bag: Glad, Hefty®, Husky
    - Gallon Zipper Food Storage Bag: Ziploc, Glad, Great Value
    - Plastic Shopping Bag: Barnes Paper Company, SSWBasics, Universal
    - Produce Bag: SafePro 1220P, SafePro 1520
    - On average 2.9 times higher
- **Interview Evidence**
  - BioBag
    - Main component Mater-Bi™(starches, cellulose, vegetable oils and their combinations), higher raw material cost than petrochemical plastic
    - As demand increased, price has reduced, but “will never be as inexpensive as PE”
  - Distinctive Action #INVISIBLE BAG
    - HK company, biodegradable/compostable/water-soluble bag
    - Polyvinyl Alcohol(PVA), starch, glycerin, water, eco-friendly ink
    - 2-3 times price difference exist, worse in DA’s case as economies of scale is hard to achieve
    - Demand for PE drives down price, but not for PVA

Identify the price burden: Bioplastic Materials

Abb	Full Name	Company(if applicable)	Price($/lb)	Average Price($/lb)	Year	Price($/ton)	Price in Country	Biodegradable	Fossil Source	Natural Source
PHA	Polyhydroxyalkanoates	Metabolix	2.36-2.52	2.44	2014		US	1	0	1
Mater-Bi		Novamont	1.86-2.8	2.33	2014		EU	1	0	1
PS	Polystyrene		1.04-1.06	1.05	7/2014		US	0	1	0
PE	Polyethylene		0.98-1	0.99	7/2014	952.55	US	0	1	0
PLA	Polylactic acid	NatureWorks	0.82-1.1	0.96	2014		US	1	0	1
PVA	Polyvinyl Alcohol		0.938	0.938	2020	1875.15	US	1	1	0
PVC	Polyvinyl Chloride		0.78-0.8	0.79	7/2014		US	0	1	0
PP	Polypropylene		0.73-0.75	0.74	7/2014		US	0	1	0
PET	Polyethylene Terephthalate		0.5525	0.5525	11/2016		US	0	1	0

Cost Reducing Technologies: Polylactide Acid(PLA)

- **Production of Polylactic Acid(PLA)**:
  - Starch(Corn, Sugar, etc.) goes through hydrolysis to obtain individual glucose molecules
  - Glucose molecules are fermented with bacteria or fungi to form lactic acid monomers
  - Lactic acid monomers join chemically through condensation, water molecules are lost to form PLA
- **Application of PLA**:
  - Packaging: plastic bags, plastic containers, food wraps, etc.
  - Automotive & Healthcare Industry
- **To Reduce Price of PLA**:
  - Sisal Fibers (Wu 2011):
    - blend with PLA to form cheaper composites
    - Abundant natural fiber resource
    - Improve mechanical properties: lower melting point, higher tensile strength, & biodegradation rate

Cost Reducing Technologies: Polyhydroxyalkanoate(PHA)

- **Production of Polyhydroxyalkanoate (PHA)**:
    - Bacteria used for production of PHA(alcaligenes) come from sugar or lipids.
    - Bacterias are grown with nutrients such as carbon, nitrogen, sulfur, NaCl, etc.
    - Undergo bacterial fermentation with unbalanced conditions, to produce PHA for storage of energy
    - PHA is extracted and purified
- **Application of PHA**:
    - Commonly used plastic products: Utensils, shopping bags, toys, trashbags, etc.
    - Healthcare Industry: drug carriers, biodegradable implants, anticancer agents, etc.
- **To Reduce Price of PHA**:
    - Cheaper carbon substrate to reduce cost of biosynthesis
        - Plant oil: soybean oil, palm oil, corn oil
        - Waste streams from slaughtering cattle, organic fraction of municipal solid waste, sludge
    - Extraction:
        - Non-ionic surfactants as pre-treatment to extraction of PHA
            - Comparable yield as Chlorinated solvents(Chloroform)

Cost Reducing Innovations: UBQ™ & AirCarbon™

	Innovative Company 1: UBQ	Innovative Company 2: Newlight Technologies
Material Name	UBQ™	AirCarbon™
What is it?	A biodegradable plastic replacement	PHA-based thermoplastic
How is it made?	Residual Municipal Solid Waste is reduced to its basic components, then reconstituted to form the composite material UBQ™	Airstream containing greenhouse gas goes through Microorganism-based biocatalyst for separation of carbon and oxygen, molecules are re-assembled into a long chain thermoplastic
How does it reduce cost?	Patented modular conversion system can convert any RMSW to UBQ™, ever-growing and cheaper source, “won’t pay a penny more than their existing resin”	Microorganism-based biocatalyst provides 9X higher polymer conversion yield than previous conversion technology for methane to PHA
Applications	McDonald - Trays Central Virginia Waste Management Authority - Recycling Bins	Restore Foodware - Cutlery, straws Covalent Fashion - eyewear, wallets, handbags

Indirectly Mitigate Cost Burden

- Target Customers' WTP
  - Kainz (2016), Germany: label "Renewable Resources" increases WTP, label > text
  - Kaewphan et al. (2013), Thailand: 60% participants willing to pay more for bioplastic bags
  - Ellison et al. (2015): consumers are willing to pay $0.67-1.12 more for bioplastic pots
  - Klein et al. (2020), Germany: previous experience with bioplastics, higher Green Consumer Values increase consumers' preference for bio-based apparel

- Education & Collaboration
  - Klein et al. (2020), Germany: Only 12% of participants had experience with bioplastics
  - Iles et al. (2012): Sustainable Business Model for Chemical Companies
    - Reducing cost and increasing yields are not enough to secure success of bioplastics
    - Successful Example: DuPont(US)
      - Communication with customers: identify potential applications, customer needs
      - Create device for downstream manufactures to show their customers the material's ecological values(eco-label)
    - What's more to do:
      - Engage societal groups to define sustainability
      - Monitor bioplastics' improvement & communicate progress to societies

Conclusion

- Price gap exists for bioplastic materials and products, economics of scale assist conventional plastics in competitiveness of price
- Cost Reduction for bioplastics
  - Direct Solutions:
    - Cost Reducing Technologies
    - Innovations for cheaper plastic replacement
  - Indirect Solutions:
    - Target Consumers' WTP for environmentally friendly products
    - Education & Collaboration with customers

Thank you for listening!