

Co-Product Opportunities

Lessons Learned

A look back at bio-based products



GP Bellingham, WA (lignin source)

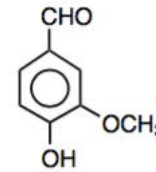


Monsanto Seattle Vanillin Plant

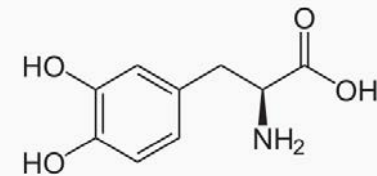
- Plant Operated from 1946 to 1991
- Highly profitable, made ~30% of world supply in 1980's
- Merck and Hershey were largest customers
- Inability to consistently sell co-product caused shutdown
- Replacement process was synthesis from crude oil



High pH, Cu catalyzed reaction. Liquid/Liquid extraction, distillation, crystallization, drying



Vanillin



L-Dopa
(Blood Pressure)

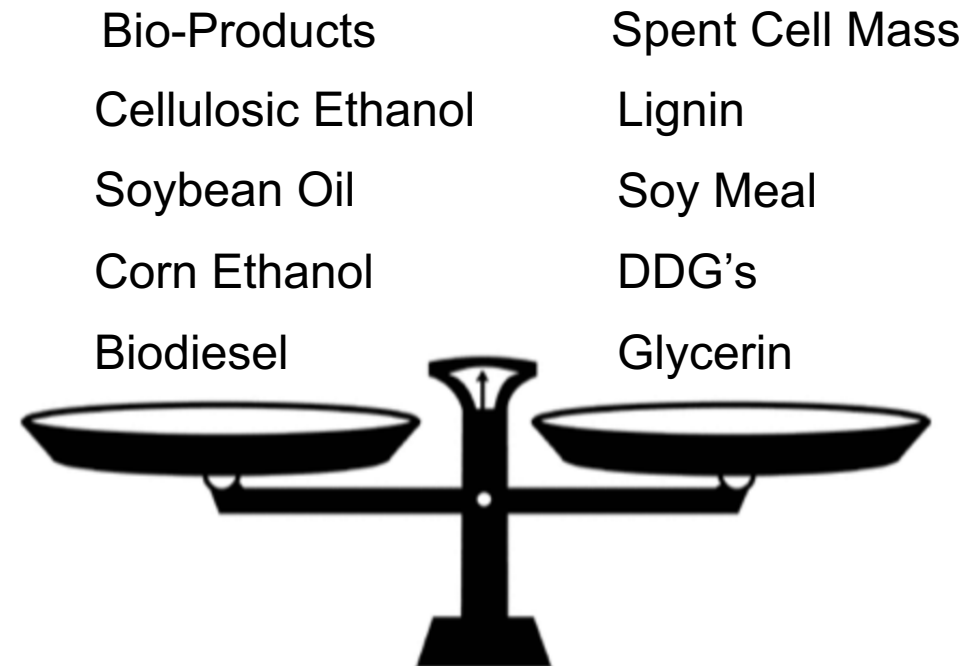


Recent perspective



What do bio-processes have in common?

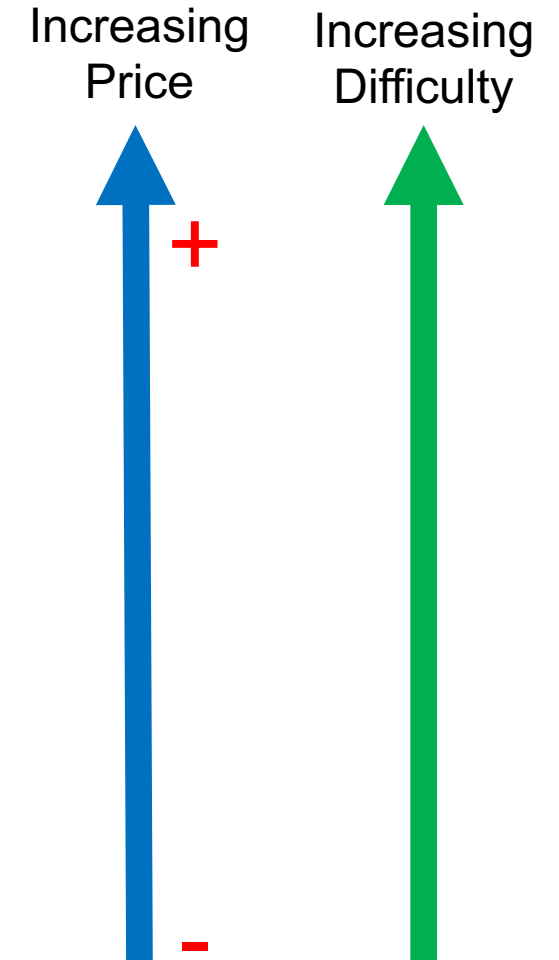
Co-products cause a difficult balancing act



Residual Biomass/Cells

Hierarchy of Options

- Nutritional value (human or animal food)
- Ingredient for bio-based products (plastics, etc.)
- Anaerobic digestion
- Burned for heat value
- Wastewater treatment
- Landfill disposal



Co-product Considerations

Is the co-product better than what is out there now?

Even if the answer is yes, the fact it is new may extend timelines for adoption, especially if target customer is making an iso-certified product

Is there a consistent specification that can be met?

Whether you are selling as a high value product or sending to a break-even energy recovery option, you will need to be able to consistently meet a specification for the option to remain

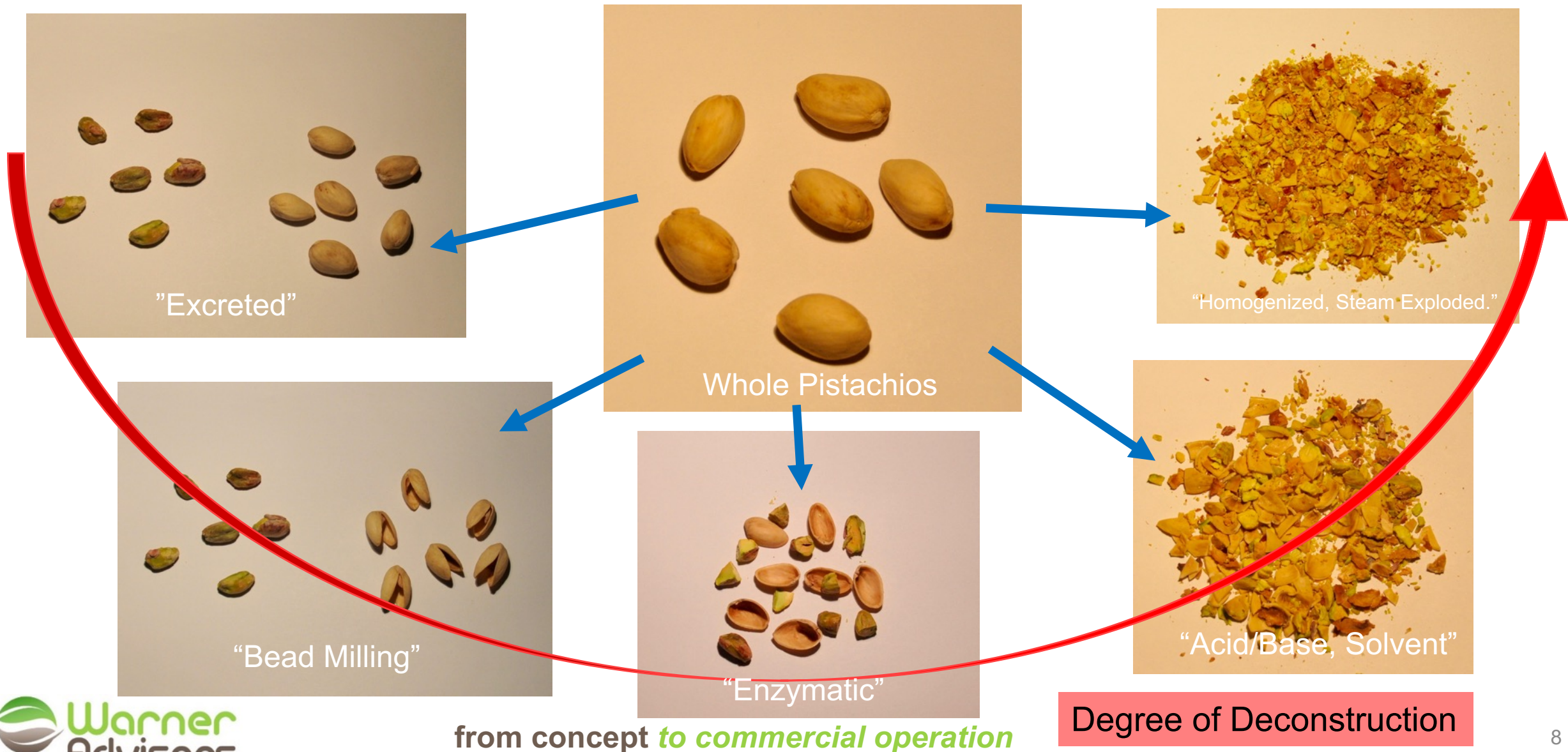
Co-product revenue can be significant

Often in the range of 10% of revenue from primary product. This can often be the difference between a venture being break-even or profitable

Plan for co-products as process is developed

- Upstream process has direct impact on co-product quality
- Degree of “deconstruction” impacts recovery and quality
- How biomass or organism is “deconstructed” matters
 - **Excretion** – product is taken without disrupting biomass/organism
 - **Light Deconstruction** – biomass or organism is partially deconstructed and product extracted. Large pieces of organism/biomass survive and product is reasonably accessible
 - **Robust Deconstruction** – biomass or organism is completely deconstructed to allow access to product. Resulting matrix can be complex to recover target product and de-value co-product

De-Construction Example



Lessons Learned

- The higher the degree of deconstruction of biomass, the lower on use hierarchy the co-product will likely be
- Need to plan for co-products up-front
- Impact of processing changes on co-product must be considered during process development
- Always have multiple outlets for co-products, including disposal
- Markets will shift and there will be a need to adapt
- Consider base-loading key options, not try to shift between “all or nothing” options as you may lose interest from some

Questions?

Mark Warner, PE

Founder – Warner Advisors LLC

mark@warneradvisorsllc.com

www.warneradvisorsllc.com