Bean Processing:
Recycling and Conversion of Wastewater

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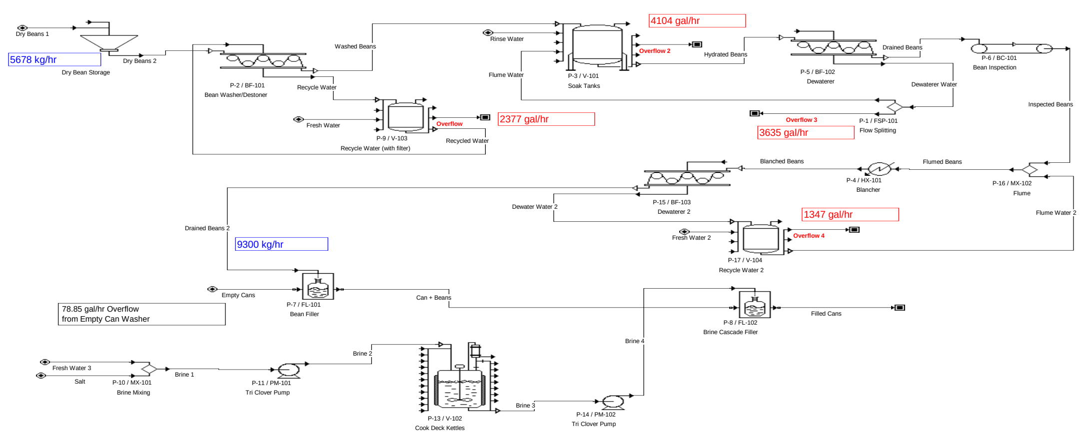
Objectives:

- Work with industry partner Morgan Foods to minimize wastewater in bean processing line
- Conversion of necessary wastewater to electricity via a microbial fuel cell

Existing Process Flow Diagram



Identification of Highest Points of Wastewater Generation using Mass Balances

PROBLEM STATEMENT:

1.) The United States' fruit and vegetable industry annually generates nearly 430 billion liters of effluent wastewaters, which is both an environmental and economic concern.

2.) Even stricter regulations by the EPA are expected.

The motivation for wastewater reduction is based on the money lost in product and water discarded in addition to the cost of not being able to increase wastewater treatment capacity. Due to this concern, a local canned food processor, Morgan Foods, was used as a prototype in a project designed to minimize wastewater in their bean processing line where effluent daily wastewater generation is 1.5 million gallons.

Equipment Location	Function	Wastewater Generated
Bean Soak Tank	Bean hydration	4104 gal/hr
Soak Tank Dewaterer	Remove bean soak water from stream prior to inspection	3635 gal/hr
Bean Washer/Destoner	Wash beans and remove foreign material	2377 gal/hr
Filler Dewaterer	Dewater beans prior to filling	1347 gal/hr
Empty Can Washer	Rinse cans prior to filling	79 gal/hr

Process Modifications to Minimize Wastewater

Soak Tank Water for Brine Solution

Use bean soak tank water to replace fresh water in brine solution

ADVANTAGES:
7.7% wastewater reduction
Retain nutrients discarded in soak tank water
Additional piping only capital requirement

DISADVANTAGES:
Potential quality impact on final product
Soak tank water quality
Composition uniformity of soak tank water

New Bean Inspection Table Location

Avoids dewatering beans for inspection and then rewatering for transport through blancher

ADVANTAGES:
11.8% wastewater reduction
Eliminates soak tank dewaterer
Reuses soak tank water vs. fresh water to flume beans
Can use existing bean inspection table in new location

DISADVANTAGES:
New location may violate HACCP requirement
Space constraints in proposed location
Effect of soak tank water vs. fresh water on blanching and fluming process
Capital investment for redesign

Reduce Washer/Destoner Fresh Water Input

Decrease fresh water input because dry beans arrive already pre-washed

ADVANTAGES:
10.4% wastewater reduction
Decreases fresh water usage
No capital investment

DISADVANTAGES:
Research needed to determine minimum amount of water required to effectively destone dry beans

Bean Inspection Table

Canning Operation

Compressed Air Can Washer

Replaces fresh water with compressed air to clean empty cans

ADVANTAGES:
0.46% wastewater reduction
Easy process modification
Decreases fresh water usage

DISADVANTAGES:
Compressed air availability
Consumer impression

Savings From Proposed Process Modifications

Justification of Capital Spending for Process Modifications

Based on 8 months of Morgan Foods' water bills, their cost of water is $0.000766/gal

The additional opportunity cost of inability to obtain enough water from local utility or the barrier to expansion of the wastewater treatment plant has not been included in the justification.

Process Modification	Reduction in wastewater (gal/yr)	$ saved/ 3 years
Soak Tank Water for Brine	5.32 million	**$12,207**
New Bean Inspection Table Location	809 million	**$18,573**
Compressed Air vs. Fresh Water for Can Washer	316,000	**$724**
Reduce Washer/Destoner Fresh Water Input	7.13 million	**$16,377**
GRAND TOTAL	**20.86 million**	**$47,881**

MICROBIAL FUEL CELLS

Maybe the bean processing overflow does not have to be considered "waste" water…

Why are microbial fuel cells such a HOT topic?

Microbial fuel cells are very stable for long periods of time so they have implications for use in locations difficult to access.

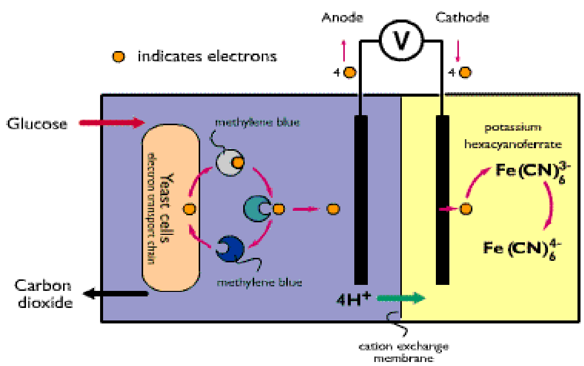
- Medical device implants
- Bottom of the ocean
- Military equipment in hostile territory

Microbial fuel cells run on renewable resources.

- Help eliminate dependence on fossil fuels
- Reduce wastewater generation

Ideal Bacteria: Rhodoferax ferrireducens

Why? Microbes can transfer electricity without the highly toxic electron shuttling mediators required in previous microbial fuel cell technology.



Mechanism of Current Production in Microbial Fuel Cell Using Yeast (Mediator Required)

How do microbial fuel cells work?

Pinto beans are 25% carbohydrates, which leads to a good source of glucose in the soak tank water.

$$C_6H_{12}O_6 + 6\ H_2O \rightarrow 6\ CO_2 + 24\ H^+ + 24\ e^-$$

Electrons are produced via the oxidation of glucose by the bacteria and are shuttled between carbon electrodes to generate a small electric current.

The anode and cathode compartments are both loaded with the glucose source then the bacteria is added to the anode side only.

ADVANTAGES:

•Ability of cell to recharge to near full power

•Low capacity loss during open circuit and prolonged storage

RESULTS:

9.47*10^{-7} kW/m^2 of electricity was generated with the microbial fuel cell using Geobacter metallireducens, a microbe similar to R. ferrireducens! Experimental results from literature have shown electricity generation of 9.61*10^{-4} kW/m^2.

CONCLUSIONS:

We have shown that R. ferrireducens has the potential to convert Morgan Foods' wastewater to a value added product. However, the data obtained thus far is preliminary, and experiments have yet to be optimized.

FUTURE WORK:

Future work will focus on the effects of the following factors on electricity generation.

•Electrode size

•Microbe concentration

•Glucose concentration in soak tank water

•Improved Anaerobic Conditions and Aseptic Technique

FEASIBILITY ANALYSIS:

The average electricity consumption of the wastewater treatment facility at Morgan Foods is 0.11 kW/hr.

How big would the microbial fuel cell electrode have to be to power this operation based on literature estimates of power production?

10,159 ft^2 OR 100.8 X 100.8 ft

Electricity to the wastewater treatment plant only costs Morgan Foods an average of $15 per month. This would not support the justification for constructing a microbial fuel cell of this size. Based on these results, it appears that microbial fuel cells may be better suited for smaller scale applications at this time.

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