

# Hop Extract

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## Problem Statement & Objective

To determine, through experimentation, the viability of producing hop extracts with hops that have been previously processed during the production of a fermented beer product. With the viability of producing hop extract from pre-processed hops proven, a process to produce hop extract on an industrial scale was designed. This scheme implements a zero waste, close loop, design, along with the optimization of equipment in order eliminate waste, maximize yield, minimize cost, and to achieve profitability within four years.

## Background Information

Hops contain four major compounds which contribute to the flavor profile of beer.

- Alpha and Beta acids: Contribute bitterness when isomerized, during heating. Sensitive to oxidation via light exposure.
- Oils: Contribute 'Hoppy' aroma, they are sensitive to heat.
- Polyphenols (Proanthocyanidins): Lend colloidal and foam stability in final beer product, by producing weak protein matrices. Sensitive to over heating.

The Boston Beer Company, Samuel Adams, generates 2.5 million pounds of hop waste annually, this waste is traditionally sent to farmers as fertilizer and livestock feed. On a brewery level 166,700 pounds of hop waste is produced per year.

Hop extracts are currently produced by companies like Kalsec® using fresh hops, with the indented purpose of replacing the use of fresh hops in the production of beer in industrial or home brewing settings. Prior art analysis shows spent hops are not currently being utilized in the production of hop extracts.

## Experimental Design

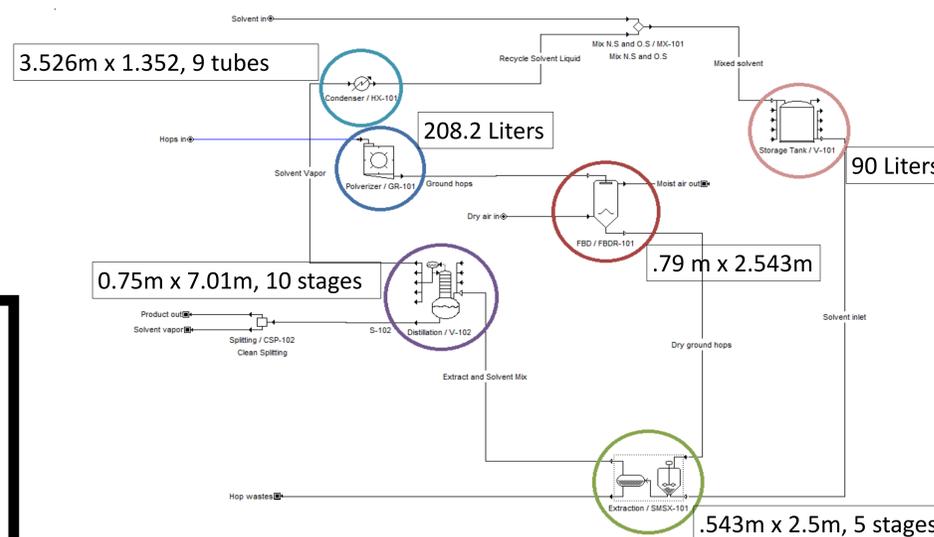
A Plackett-Burman experimental design was used to determine the significance of multiple various, presented based on their effect on the yield of hop extract produced.

Statistical analysis of the experimental data suggests that the only experimental factor tested that has significant effect on the production yield of hop extract was the type of solvent used in the leaching process with a confidence of 98.2%. All other factors were found to be statistically not significant, including the presence of a boiling step pre-extraction. This result allowed for further work to be done and for the production process to be designed in line with the objective stated above.

Pre-boiling	Pulverization	Solvent	Number of Leaching Cycles	Moisture Content (%)	dummy	Yield %
no	Yes	pet ether	7 cycle	50	-	0.323
no	No	pet ether	5 cycle	50	+	0.257
no	no	pet ether	5 cycle	0	+	0.1528
yes	Yes	pet ether	5 cycle	0	-	0.324624
yes	no	pet ether	7 cycle	0	-	0.415618
yes	Yes	pet ether	7 cycle	50	+	0.2515
no	no	ethanol	7 cycle	0	-	0.4464
no	Yes	ethanol	7 cycle	0	+	0.5378
no	no	ethanol	5 cycle	50	-	0.5155
yes	no	ethanol	7 cycle	50	+	0.4177
yes	No	ethanol	5 cycle	50	-	0.3961
yes	Yes	ethanol	5 cycle	0	+	0.5572



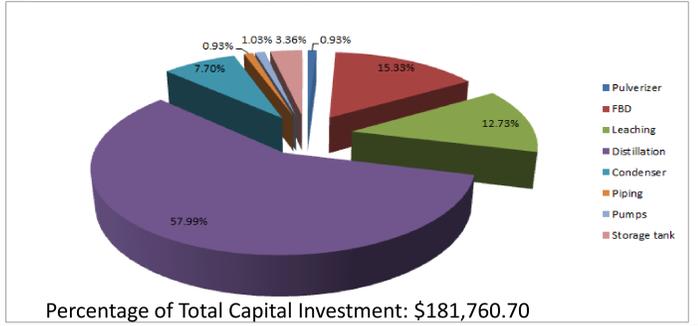
## Design Overview



## Economic Analysis

Yearly Cost: \$2,806,000  
 Yearly Revenue: \$3,548,000  
 Return on Investment: 25%  
 Sale price: \$13.52  
 Process requirement: 100% of hop waste are processed

## Break down of Equipment Costs



## Product Implementation

### Hop Extract locations

1. Replacement of bittering hops are added after wort has been filtered to add alpha and beta acids, bitter flavor.
2. Replacement of aroma (dry) hops are added at the end of the wort boiling in order to add heat sensitive oils, aroma.
3. Producer increasing hop profile in beer.
4. Consumer increasing hop profile in beer.



## Design Alternatives

### Process Alterations

- Extraction solvent (liquid CO<sub>2</sub>, ethanol, petroleum ether).
- Extraction time (number of cycles).
- Moisture content of hops in leaching vessel.
- Pulverization of hops before leaching.

### Future Design Iterations

- Multiples of each unit process for synchronized production.
- Removal of pulverization unit process.
- Optimization of process for specific hop varieties.

## Global Impacts & Sustainability

### Global Impacts:

- The use of hop extracts in beer making is counter to traditional production methods.
- Reduction of demand for imported fresh hops.
- Hop extracts expand multiple market sectors.
  - Holistic healthcare (supplements, and aroma therapy).
  - Industrial brewing (hop replacement and/or post sale flavor enhancer).
  - Craft and home brewing (increase of product diversity, brew kits).

### Sustainability of Process Design

- Environmentally friendly solvent disposal (ethanol).
- Post-Processed hops sold as mulch additive.
- Recycle spent hops as heat exchanger fuel source.

