Hop Extract

Nick Angermeier (BE), Sung-Ting Chen (BE), Aiman Nawari (BE), and Scott Vanderbosch (BE)

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.

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 Overview

| Extraction solvent (liquid CO2, ethanol, petroleum ether). |
| Extraction time (number of cycles). |
| Moisture content of hops in leaching vessel. |
| Pulverization of hops before leaching. |

Design Alternatives

Process Alternatives
- Extraction solvent (liquid CO2, 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).

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

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

Percentage of Total Capital Investment: $181,760.70

Sponsor: Dr. Martin Okos