



Enhancing Hop flavor and brewing efficiency with microwave-assisted extraction



MILESTONE
HELPING
CHEMISTS



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Milestone

SUMMARY

- Hops in the brewing process
- Dry hopping challenges
- Introducing True Hopping approach
- Why True Hopping
- Q&A session



... NAMES—Lupuli conii, ...
... Hops, Wild-hops, ...
... Lin. Pursh, Bigsby, ...
... Treaks, Bryony, Eberle, Maton, Rocher, ...
... Albert, Cox, Eberle, Maton, Rocher, ...
... Bigelow, fig. 60 and Seq.

Genus *HUMULUS*—Dioical, Staminate ...
... five leaved perigone, Stamina five, anthers ...
... Pistillate flowers strobilate: bracts before, ...
... one leaved, persistent entire, concave ...
... pistil, two styles ...



HOPS AND THEIR USE

DESCRIPTION—Root perennial. Stem ...
... forming a climbing vine, twining from right to left ...
... rough with minute reflexed prickles. Leaves ...
... smaller and floral ...

CURRENT USE

- Brewery (98%)
 - Alpha acids
 - Beta acids
 - Essential oil
- Medicinal
 - Sedative
 - Anti-inflammatory
- Nutraceutical
 - Hop pillows-sleep aid
 - Herbal teas
- Cosmetic



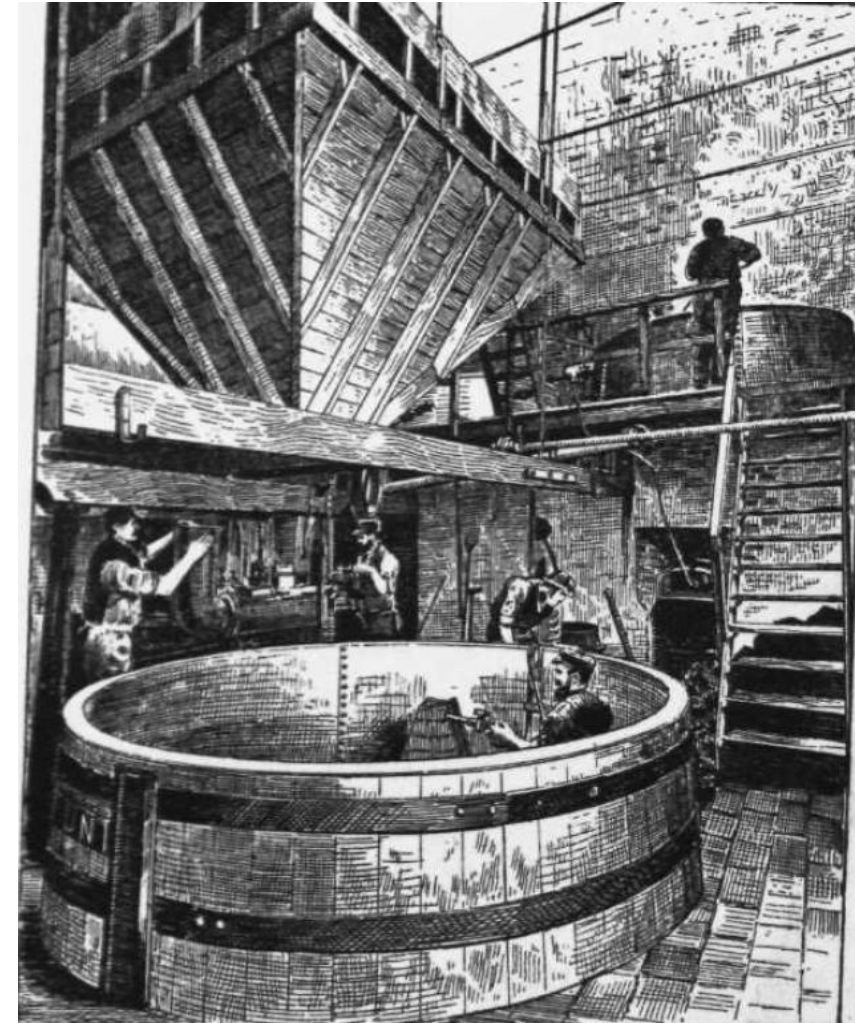
WHAT BEFORE HOP?

- There was “gruit” beer: an herb mixture to provide flavor and bitterness
- Archbishop of Cologne, Germany held monopolistic rights to gruit
- It’s preservative quality enabled brewing, storing and eventual shipping of German lager style beer possible



FROM GRUIT TO HOPS

- The exclusive use of gruit was gradually replaced in favor of hops alone in Europe between the 11th century and the late 16th century
- In Germany, the Reinheitsgebot forced the use of only water, malt and hops for beer production in Bavaria since 1516
- In Great Britain, parliament banned the use of bitter hop alternatives in 1710 to ensure brewers did not try to avoid the new hop tax of a penny a pound

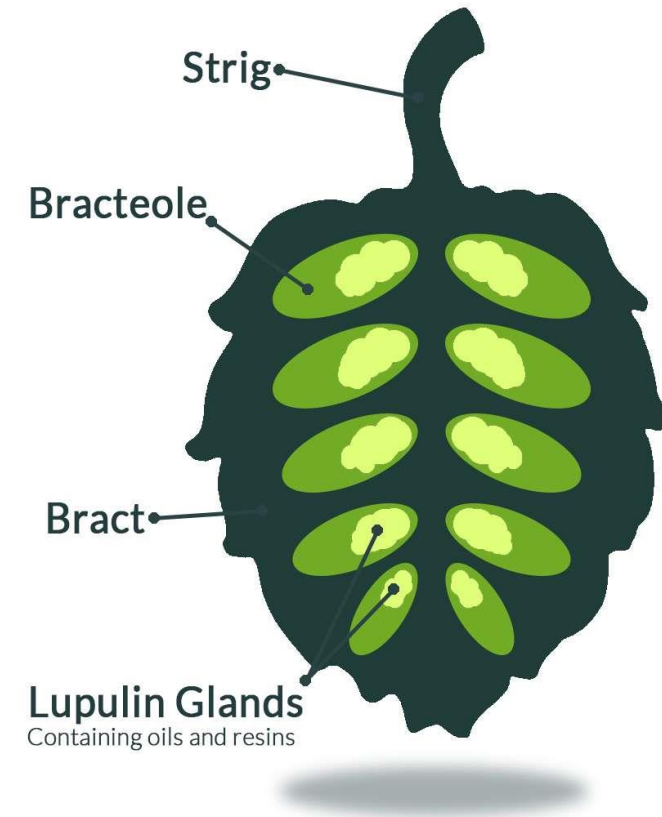




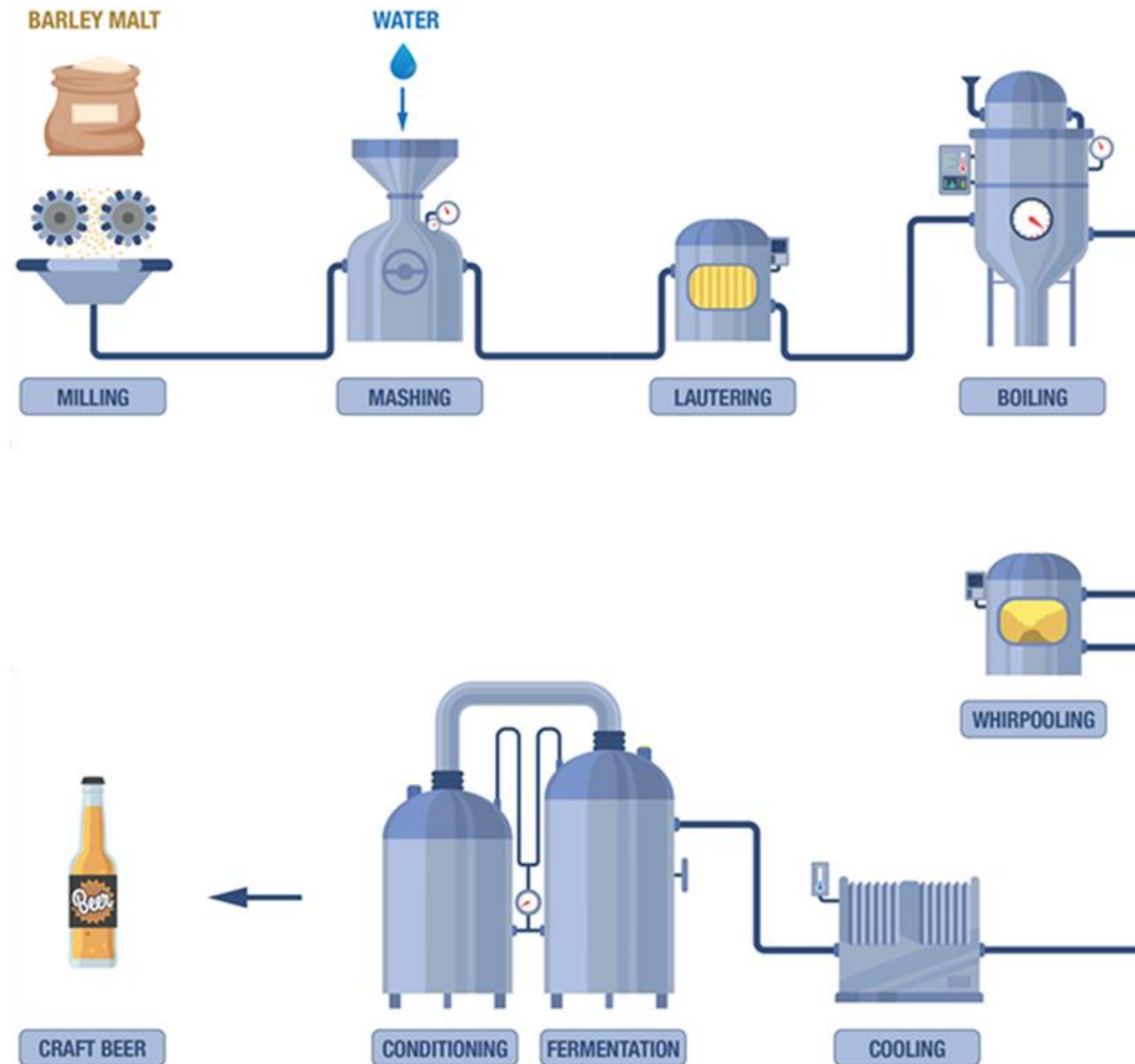
WHY HOP IN THE BEER?

ANATOMY OF HOP CONES

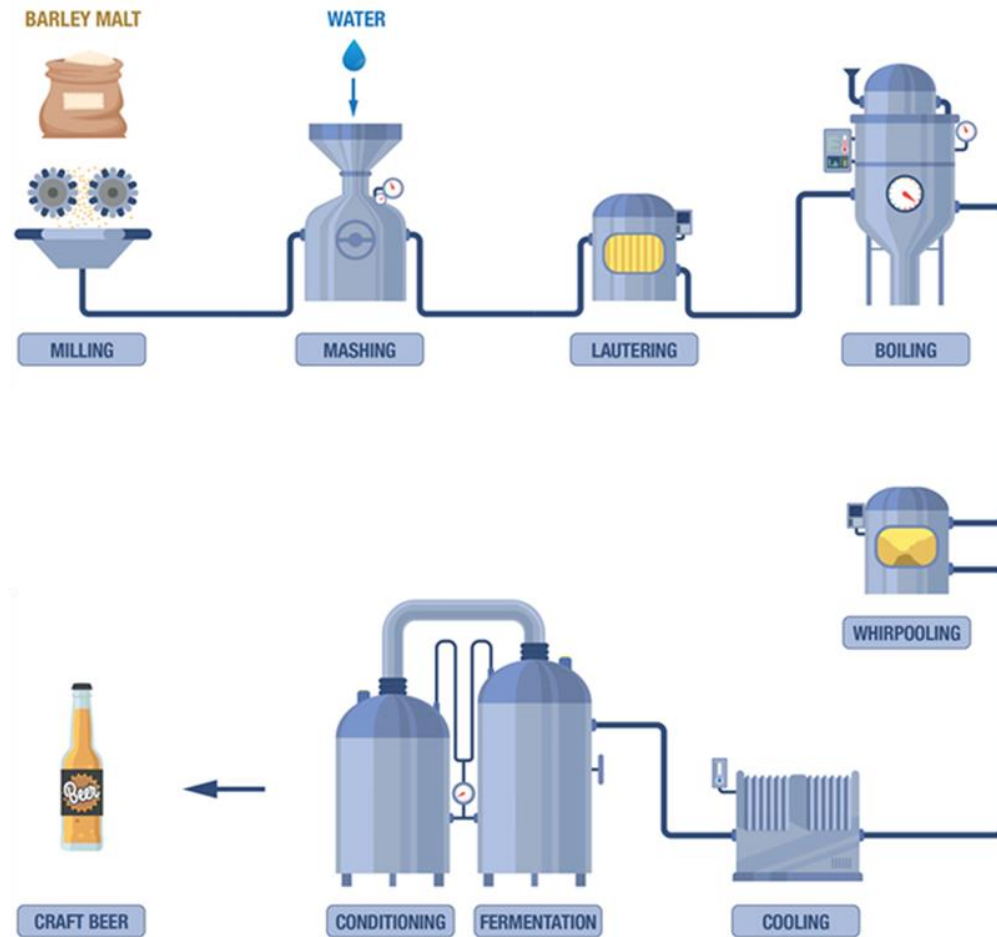
- α acids: contribute to the bitter flavor of beer, help prevent unwanted growth of bacteria, and enhance the ability of yeast to grow and ferment the wort to beer
- β acids: contribute very little to bittering, but have strong antimicrobial properties
- Essential oils: most valuable component, contribute aromas and flavors to beers



THE BREWING PROCESS



THE HOP IN THE BREWING PROCESS



1) Addition in kettle

- α acids thermally convert in iso- α acids to get the right IBU
- Very inefficient for hop flavor
 - At 100°C nearly all the volatile oil are lost!

2) Late-hop addition

- Hops added in last 15 minutes of boiling/ whirlpooling/ sedimentation

3) Dry Hopping

- Dry-hopping is the cold, aqueous extraction of hops into beer
- Dry-hopping achieves a distinctive aroma that is notably different from kettle or late-hop additions

DRY HOPPING



- Dry hopping is a relatively inefficient process
 - Poor extraction efficiency of volatile oil into beer
 - Negatively impact brewing yield
 - All alpha-acids are wasted
- Highly hop-forward beers such as IPA, double IPA etc, require massive dry-hopping
 - Very low brewing yield
 - Very high costs

DRY HOPPING – EXTRACTION EFFICIENCY

	OIL STILL RETAINED ON SPENT HOPS [%v/v]	
Hop Variety	Range	Mean
Amarillo	35-68	57
Cascade	30-60	41
Centennial	39-65	51

Average extraction efficiency 30-40% at 3.5-4 g/L dry hopping

- Extraction media is water with a low alcohol content
 - Poor extraction efficiency of volatile oil into beer
- Approximately from 30 to 70% v/v of volatile oils remain in spent hops
 - Today wasted!
- High variability of oil still retained
 - Poor flavor standardization

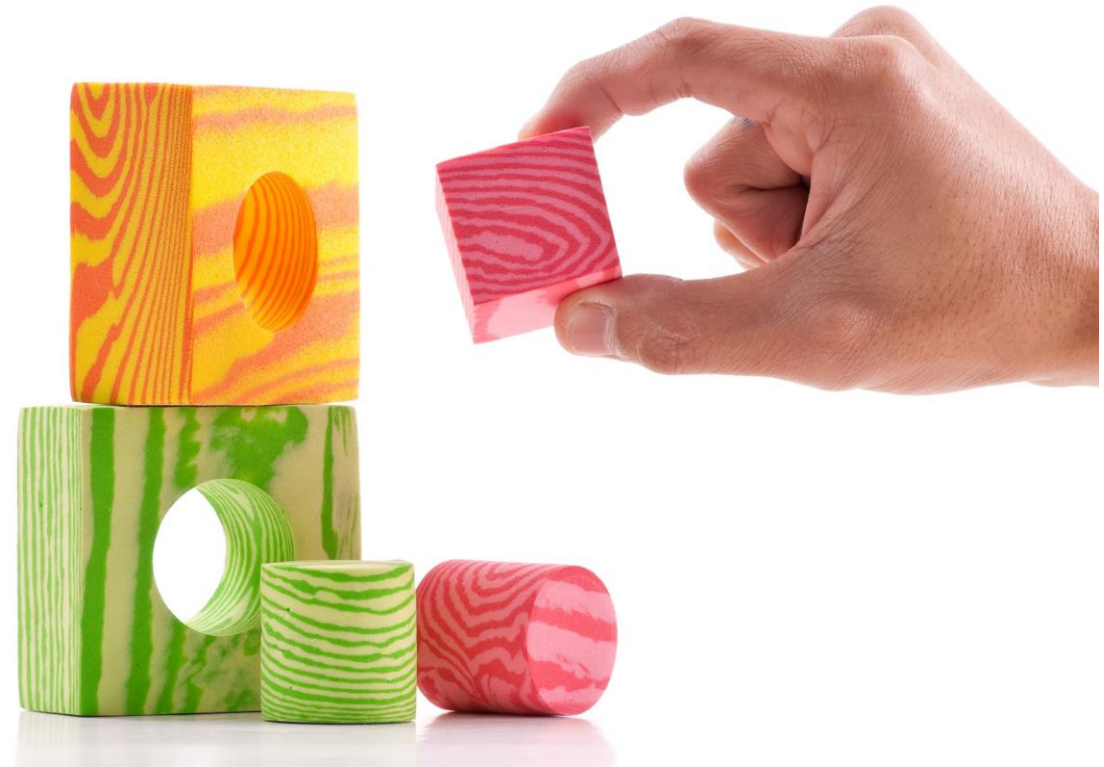
DRY HOPPING – BEER LOSS



- Hop pellets are highly hygroscopic
 - Hop pellets can absorb approximately 8-10 times its weight
 - Adsorption depending on beer styles such as IPA, double IPA etc, require dry-hopping at high rates, up to 15 g/L
- High beer loss
 - Approximately 10-25% w/w beer was lost during the process!
- All α acids are wasted

ADDRESSING DRY HOPPING CHALLENGES

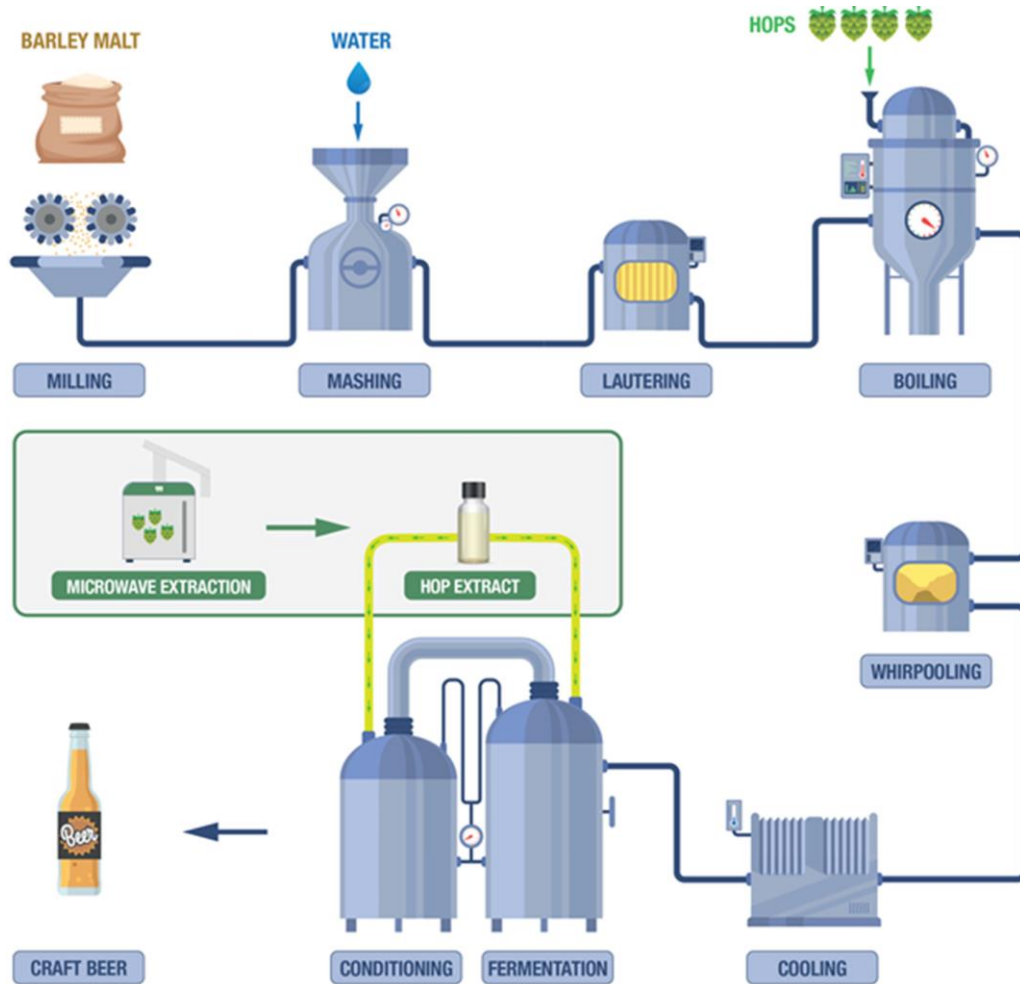
- Different addition strategies
 - Challenges in standardizing the process
 - More additional steps involved
 - Always a matter of equilibrium
- Use of additional equipment
 - Expensive
 - Maintenance is required
 - Compromise strategy
- Use of commercial extracts
 - Few varieties available
 - Restored with additional terpenes when quality is poor or extraction is partial



INTRODUCING MILESTONE TRUE HOPPING



THE MILESTONE TRUE HOPPING PROCESS PRINCIPLE



- Head brewers select hops species and suppliers they trust
- Production of hops terpene extract with Microwave-assisted distillation
- Add terpene hop extract in conditioning and fermentation steps instead of directly using hops pellets

MICROWAVE ASSISTED DISTILLATION OF HOPS

- True-hopping uses solvent-free microwave extraction (SFME)
 - Based on Microwave-assisted hydrodistillation
 - Patented technology by Milestone
- High-quality terpene extracts from hops you trust
 - Fast and efficient extraction
 - No oxidation
 - Controlled isolation of strain-specific hop essential oils
- Water and energy saving



ETHOS X 2.0

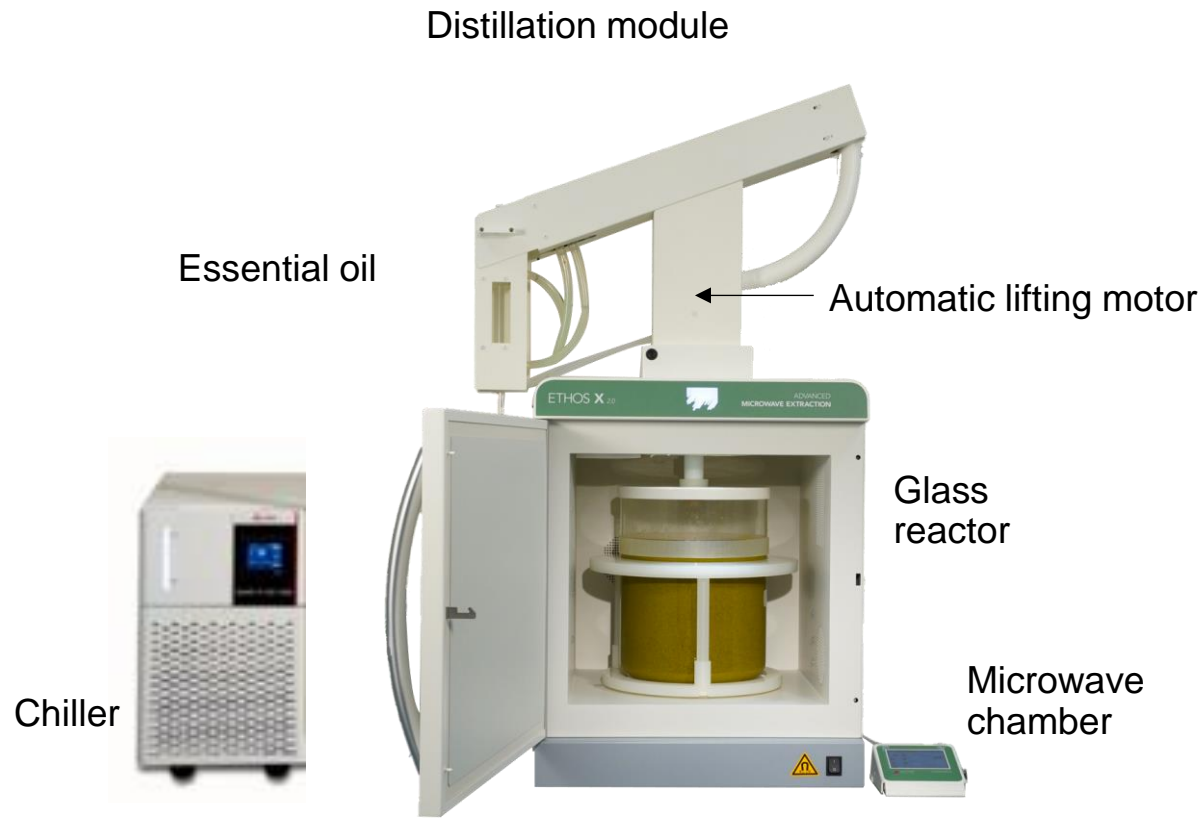
- Material processed per shift
- 3.5 - 4kg (0.8-1kg per run)
 - 2 hours/run



ETHOS XL

- Material processed per shift
- 10 - 12kg (3.5-4kg per run)
 - 3 hours/run

SOLVENT-FREE MICROWAVE EXTRACTION (SFME)



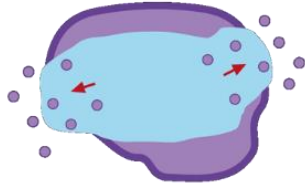
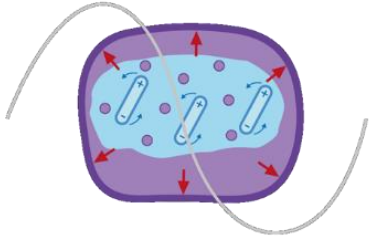
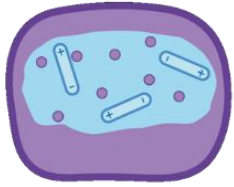
- Robust construction
 - Industrial design
- Semi automated operation
 - Load hops pellet in the reactor
 - Add water approximately 8-12 times its weight
 - Push start button
 - Collect pure hops oil
- Full extraction control for limited oxidation

TRUE HOPPING - BENEFITS

True hopping enables to brewing highly hop-forward beers with high efficiency and profitability trough



TRUE HOPPING - BENEFITS



True hopping enables to brewing highly hop-forward beers with high efficiency and profitability trough

1. Maximize extraction efficiency of flavor from hops

HOP VARIETY	TOTAL OIL [mL]		EXTRACTION [mL/100g]	CONTENT *** [mL/100g]	EFFICIENCY [%v/v]	OIL LOSS [%v/v]
	ETHOS X 2.0*	ETHOS XL**				
CITRA	16	64	1.6	1.7	94	6
CASCADE	9	35	0.89	0.9	99	0
MOSAIC	11	41	1.06	1.1	96	4
SIMCOE	16	64	1.6	1.7	94	6
CENTENNIAL	14	55	1.39	1.4	99	0

* 1 kg hop

** 4 kg hop

*** According to certificate of analysis

SFME - EFFICIENCY

Hop variety	Myrcene (%)		Caryophyllene (%)		Farnesene (%)		Humulene (%)	
	SFME	Certificate*	SFME	Certificate*	SFME	Certificate*	SFME	Certificate*
CITRA	60.2	61.4	5.6	6.5	0.1	0.1	10.1	11.1
CASCADE	29.7	30.8	10.9	10.2	9.1	9.3	17.3	24.6
MOSAIC	59.1	60.2	3.7	4.3	0.1	0.1	9.1	10.8
CENTENNIAL	66	67.1	7.4	8.4	0.1	0.1	8.5	8.8

**According to certificate of analysis, Yakima Chief Hops*

TRUE HOPPING - BENEFITS



True hopping enables to brewing highly hop-forward beers with high efficiency and profitability trough

1. Maximize extraction efficiency of flavor from hops
2. Reduce hop pellet usage by working with personal flavor extract

- Dry Hopping, extraction efficiency: 30%
- True Hopping, extraction efficiency: 95%
- Negligible oils amount retained in spent hops treated with True Hopping, less than 5%

TRUE HOPPING VS DRY HOPPING – EXTRACTION EFFICIENCY

HOPS OIL - TRUE HOPPING

Hop Variety	EXTRACTION EFFICIENCY [%v/v]	OIL STILL RETAINED IN HOPS [%v/v]
CITRA	94	6
CASCADE	99	0
MOSAIC	96	4
SIMCOE	94	6
CENTENNIAL	99	0

HOPS OIL - DRY HOPPING

Hop Variety	OIL STILL RETAINED [%v/v]	
	Range	Mean
Amarillo	35-68	57
Cascade	30-60	41
Centennial	39-65	51

TRUE HOPPING - BENEFITS

SAMPLE TYPE	MOISTURE [%w/w]
Hop pellets	9.03
Spent hop pellets	75.8 ± 2.7

- Hop pellets absorb approximately 8-10 times its weight
- Less hop pellets usage ends up in less beer adsorbed by the hopping process

True hopping enables to brewing highly hop-forward beers with high efficiency and profitability trough

1. Maximize extraction efficiency of flavor from hops
2. Reduce hop pellet usage by working with personal flavor extract
3. Increase brewing yield

CASE STUDY

- Beer Style: IPA
- Batch volume: 20 hL

	Conventional Dry Hopping	Milestone True Hopping	Milestone True Hop advantages
Hop usage	18 kg	10 kg	44 % less hop usage
Beer loss	13%	5%	8% Increase brewing yield



TRUE HOPPING - BENEFITS

Hop variety	Certified α -acids content [%w/w]*	Iso- α -acid content on MW spent hop [%w/w]	α -acid content on MW spent hop [%w/w]
SIMCOE	12.6	8.3	3.1

- The spent microwaved hop contain iso- α acids
- It can be added into kettle at the end of the boiling for bittering

True hopping enables to brewing highly hop-forward beers with high efficiency and profitability trough

1. Maximize extraction efficiency of flavor from hops
2. Reduce hop pellet usage by working with personal flavor extract
3. Increase brewing yield
4. Dual purpose – hops is used 100% both for flavor and alpha acids

ALPHA ACIDS

Component	Residual solid*	Residual water*
α -Cohumulone	0.49 %	0.011 %
α -N-Adhumulone	2.60 %	0.042 %
Total α -acids	3.14 %	0.028 %
β -Colupulone	1.52 %	0.045 %
β -N-Adlupulone	2.19 %	0.032 %
Total β -acids	3.72 %	0.073 %
α -ISO-Cohumulone	1.70 %	0.056 %
α -ISO-Humulone	3.76 %	0.095 %
α -ISO-Adhumulone	2.78 %	0.100 %
Total ISO- α -acids	8.24 %	0.224 %

*reported considering the weight of dry sample and the amount of water used for the extraction

After hydrodistillation with ETHOS X 2.0, α -acids, iso- α -acids and β -acids content of residual solid and residual water were analyzed:

- Isomerization of 70/75% of the α acids is observed
- Iso- α acids mainly remain in the solid waste, which can be re-used during the boiling step



α acids and iso- α acids were analyzed by CERB (Perugia) via HPLC-DAD

TRUE HOPPING - BENEFITS



- Iso- α acids available in microwave spent hop
 - No need of boiling for isomerization process
- Reducing maturation time
 - No need to wait for dry hopping extraction
 - No need to wait for hop sedimentation
- Higher throughput, faster production

True hopping enables to brewing highly hop-forward beers with high efficiency and profitability trough

1. Maximize extraction efficiency of flavor from hops
2. Reduce hop pellet usage by working with personal flavor extract
3. Increase brewing yield
4. Dual purpose – hops is used 100% both for flavor and alpha acids
5. Increase brewing capacity

TRUE HOPPING - BENEFITS



- Essential oils from different hop varieties and botanicals
- Efficient flavor enrichment and standardization
- Very fast way to experiment rather than making boil additions

True hopping enables to brewing highly hop-forward beers with high efficiency and profitability trough

1. Maximize extraction efficiency of flavor from hops
2. Reduce hop pellet usage by working with personal flavor extract
3. Increase brewing yield
4. Dual purpose – hops is used 100% both for flavor and alpha acids
5. Increase brewing capacity
6. Easier blending and flavor enrichment

CASE STUDY



- Beer Style: German Pils
- Batch volume: 2000 L
- Hop strain: Spalter Select
- Additional botanical: Pompia



Hop usage	Conventional Dry Hopping	Milestone True Hopping	Advantages
Flavouring	1.5 g/L	0.5 g/L (only extract)	66% less hop used Explosive aromatic bouquet otherwise difficult to obtain

TRUE HOPPING - BENEFITS



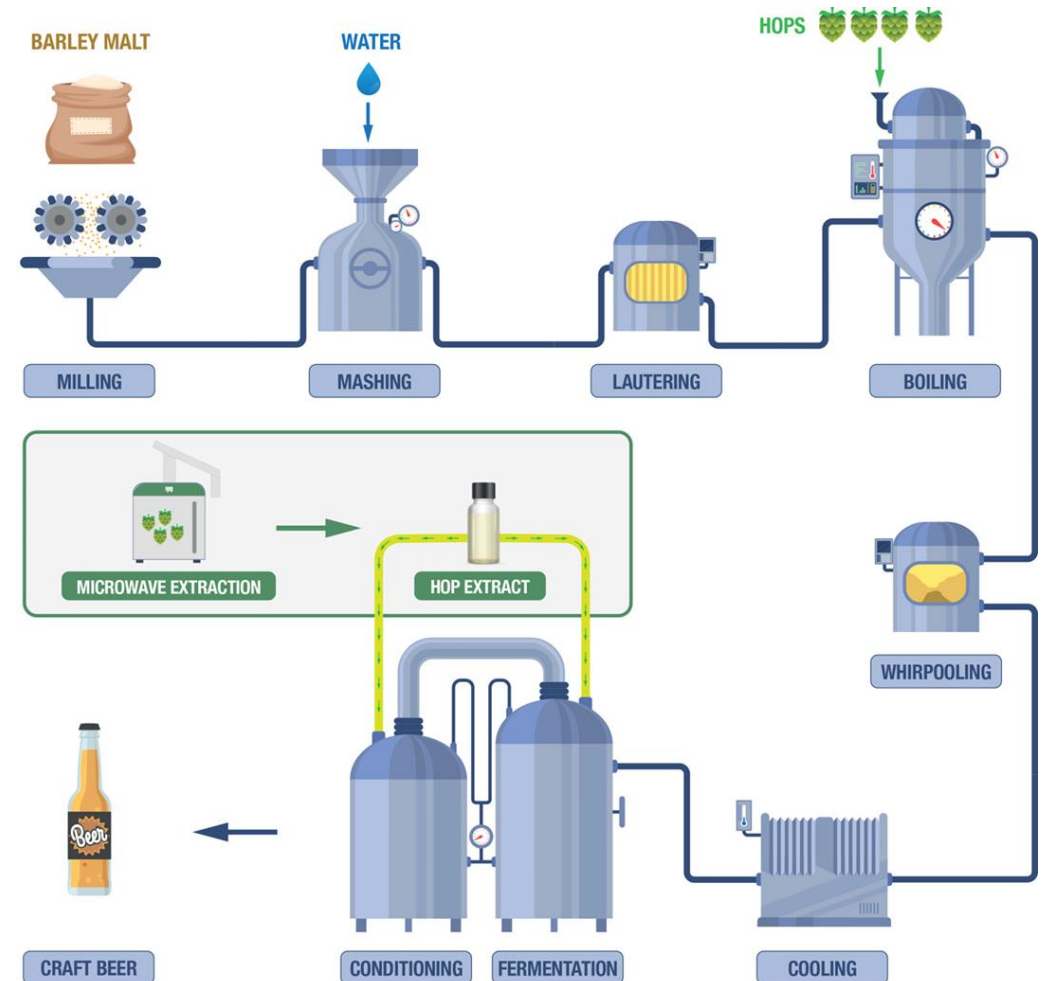
- Increased stability by adding less vegetable material and oxygen
- Product stability is a must when working with Ho.Re.Ca. industry

True hopping enables to brewing highly hop-forward beers with high efficiency and profitability trough

1. Maximize extraction efficiency of flavor from hops
2. Reduce hop pellet usage by working with personal flavor extract
3. Increase brewing yield
4. Dual purpose – hops is used 100% both for flavor and alpha acids
5. Increase brewing capacity
6. Easier blending and flavor enrichment
7. Longer shelf-life

CONCLUSIONS

- Dry hopping is a widely employed technique across a diverse range of beer styles, both traditional and modern
- Despite its widespread and continuous use over time, in some cases it appears to have limitations and difficulties in standardized use
- True-hopping enables to brewing highly hop-forward beers with high efficiency and profitability





WOULD YOU LIKE TO LEARN MORE?

Contact me: lorenzo.rossi@milestonesrl.com



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