TRACE METALS IN BREWING

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Sluggish Fermentation??

Outline

- Trace Metals in Beer and Brewing
  - Wort
  - Beer
- Impact of Trace Metals
  - Beneficial Impacts
  - Negative Impacts

Outline

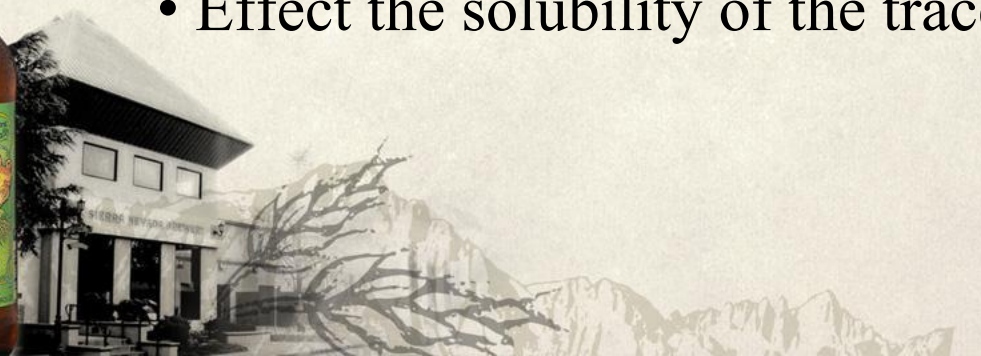
- Sources of Trace Metals
  - Raw Materials
  - Process Aids
  - Brewing Process
- Additional Steps to Address Trace Metals
- Conclusions

Introduction

- Trace metals are chromium, nickel, cobalt, copper, iron, manganese, aluminum, selenium, lead, and zinc.
- Occur at very low levels in the environment
- Essential for many physiological and biochemical processes
- Living things need very small amounts of some trace metals
- High levels can be toxic

Trace metals in wort

- More Common Trace Metals:
  - Zn, Cu, Fe, and Mn
- Other Potential Trace Metals:
  - Al, Pb, Cr, Ni, Co, Sn
- Counter ions:
  - Effect the solubility of the trace metals



Impact of Trace Metals

- **Beneficial Impacts: <u>Zinc</u>**
  - Enzyme Activity - cofactor in over 100 enzyme reactions
  - Cofactor for alcohol dehydrogenase
  - Governs protein synthesis and the phospholipid composition of membranes in yeasts
  - Important for yeast growth and metabolism
  - Stimulates uptake of maltose and maltotriose
  - Increases fermentation rate
  - Stimulates ester production
  - Stabilizes enzymes, protein, and membrane systems
  - Optimum content should be 0.15 ppm

Impact of Trace Metals

- **Beneficial Impacts: <u>Copper</u>**
  - Copper is found in many enzymes that are essential to normal cellular function
  - Yeast nutrient
  - Dissolved copper reacts with sulfides to reduce sulfur flavors and aromas in beer
  - Level recommended <0.25ppm in wort

Impact of Trace Metals

- **Beneficial Impacts: <u>Iron</u>**
  - Essential micronutrient in the metabolism of nearly all organisms
  - Important for yeast budding
  - Important in enzyme activity in yeast plasma membrane
  - Level recommended <0.1ppm in wort

Impact of Trace Metals

Beneficial Impacts: <u>Manganese</u>

- Activates and inhibits different enzymes
- Enhancing the mash enzymes
- Increases protein solubilization
- Nutrient cofactor up to 0.2ppm
- Ideal Mn levels are 0.05-0.2ppm in wort

Impact of Trace Metals

- **Beneficial Impacts**
  - Prized for their nutritional value in beer
  - Potential relationship and contribution to daily nutrition requirements
  - Unfiltered beers

Trace metals in wort

- Typical levels of trace minerals in wort

Values in PPM	Chromium	Copper	Iron	Mn	Zinc
Wheat Beer	0.007	0.08	0.04	0.22	0.47
Belgian Quad	0.019	0.17	0.65	0.25	0.50
Lager	0.004	0.09	0.11	0.16	0.32
Hefeweizen	0.009	0.06	0.14	0.18	0.57
Pale Ale	0.017	0.10	0.10	0.15	0.23
IPA	0.007	0.13	0.09	0.17	0.28
Porter	0.011	0.11	0.26	0.14	0.18
Stout	0.011	0.11	0.22	0.23	0.22

Trace metals in beer

- Typical levels of trace metals in various beers

Values in PPM	Chromium	Copper	Iron	Mn	Zinc
Dark Wheat	0.054	0.30	0.51	0.59	0.04
Belgian Tripel	0.011	0.10	0.16	0.53	0.16
Gose	0.035	0.17	0.42	0.56	0.36
Wheat Beer	0.009	0.04	0.01	0.21	0.00
Lager	0.013	0.06	0.01	0.15	0.00
Pale Ale	0.013	0.07	0.01	0.12	0.00
IPA	0.017	0.08	0.01	0.17	0.01
Porter	0.015	0.04	0.03	0.09	0.00
Stout	0.015	0.04	0.06	0.31	0.00
Black IPA	0.015	0.06	0.06	0.36	0.01

Impact of Trace Metals

- **Negative Impacts: <u>Zinc</u>**
  - Commonly deficient in wort
  - Completely assimilated by yeast
  - Can be inhibitory and affect colloidal stability
  - Toxic to yeast if Zn >1ppm
  - Metallic taste
  - At 0.1-0.2ppm can increase secretion of MCFA's and soapy flavors

Impact of Trace Metals

- **Negative Impacts: <u>Copper</u>**
  - Changes yeast plasma membrane
  - Disturbs the uptake of nutrients
  - Oxidizer
  - Copper present in wort at more than 10ppm is toxic to yeast
  - Copper levels at 0.05 ppm are reported to cause damage in the final product

PPM	Chromium	Copper	Iron	Manganese	Zinc
1st runnings	0.01	1.85	0.07	0.26	0.37
last runnings	0.02	0.18	0.02	0.07	0.07
End of boil	0.00	0.22	0.05	0.19	0.29
Rinse water post CIP HCX nano	**2.60**	**449.75**	**15.95**	**0.33**	**3.64**
Wort line pre-fermenter	0.01	**3.03**	0.06	0.18	0.29
Fermenter	0.00	0.29	0.08	0.18	0.31

Impact of Trace Metals

- **Negative Impacts: <u>Iron</u>**
  - Slows saccharification; resulting in hazy wort and reduced yeast activity
  - Flavor impact- Metallic
  - Oxidation- decreased shelf life
  - Physical stability impacted
  - >0.3ppm can cause a grayish foam and an increase in color

Impact of Trace Metals

- **Negative Impacts: <u>Manganese</u>**
  - Similar oxidizing effect to iron and copper
  - To
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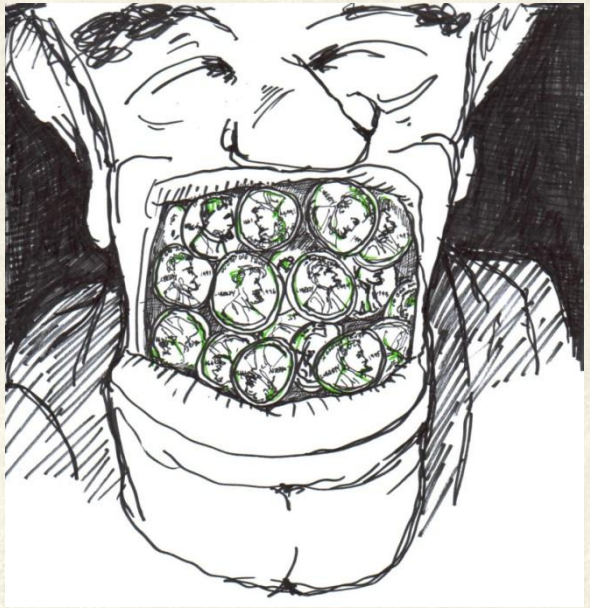
Impact of Trace Metals



- **Negative Impacts**

  In beer

  Taste and Flavor Stability-

  Iron (Fenton reaction) promote oxidative reactions

  Copper (Haber-Weiss reaction) formation of aged flavor compounds in beer

  Manganese-Similar oxidizing effect to iron and copper

Impact of Trace Metal

- **Negative Impacts**
  - Physical stability- oxidizes beer, creates haze
  - Color- oxidation from trace metals causes a browning color effect
  - Gushing
    - Iron over 0.6ppm

Impact of Trace Metals

- **Negative Impacts**
  - In Water
    - Taste
    - Scale (hard mineral coatings)
    - Corrosion deposits
    - Chlorination of water

Sources of Trace Metals

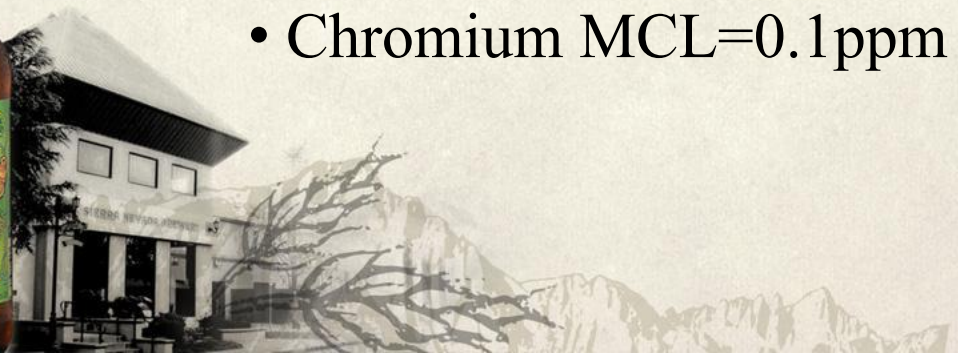
- **Raw Materials**
  - **Barley and Malted Barley**
    - Agronomic sources: soil, water, fertilizers, and pesticides
    - Kilning and roasting process (caramel and crystal malts, dark malts)
  - **Other sources of carbohydrates or flavors**
    - Wheat, rye, oats, rice
    - Flavorings and spices
    - Cocoa nibs
    - Wood chips
    - Fruits and nuts
    - Candy syrups, sugars for re-fermentation

Sources of Trace Metals

- **Brewing and Process Water**
  - Source water
    - Maximum permissible levels (EPA)
    - Water conditioning or treatment
    - Ion Exchange
    - Membrane filtration (pores 0.1-0.45um)
    - Ultrafiltration (pores <0.1um)
    - Reverse Osmosis
    - Dechlorination (carbon filter)
    - Ultraviolet radiation

Sources of Trace Metals

- **Brewing and Process Water**
  - Source water
    - Maximum Contaminant Levels (MCL)of trace minerals enforceable
    - (SMCL) is secondary and recommended or unenforceable
    - Zinc SMCL=5ppm **GOAL is 0.1-0.5ppm**
    - Copper SMCL=1.0ppm **GOAL is <1ppm**
    - Iron SMCL=0.3ppm **GOAL IS ZERO**
    - Manganese SMCL=0.05ppm **GOAL is <0.1ppm**
    - Chromium MCL=0.1ppm



Sources of Trace Metals

- **Hops-**
- **Yeast-**
- **Yeast nutrients-** Zinc, but many others also available
- **Brewing salts-**

Sources of Trace Metals

Process Aids

Kettle finings -verify with COA low levels of trace metals

Physical stabilizers -confirm low levels of beer soluble iron(BSI)

Filtration aids -Diatomaceous Earth(DE) use low iron DE

Sources of Trace Metals

- **Brewing Process**
  - **<u>Brewery Equipment</u>**
    - Tanks, Pipes, pumps, etc.
    - Copper equipment

Sources of Trace Metals

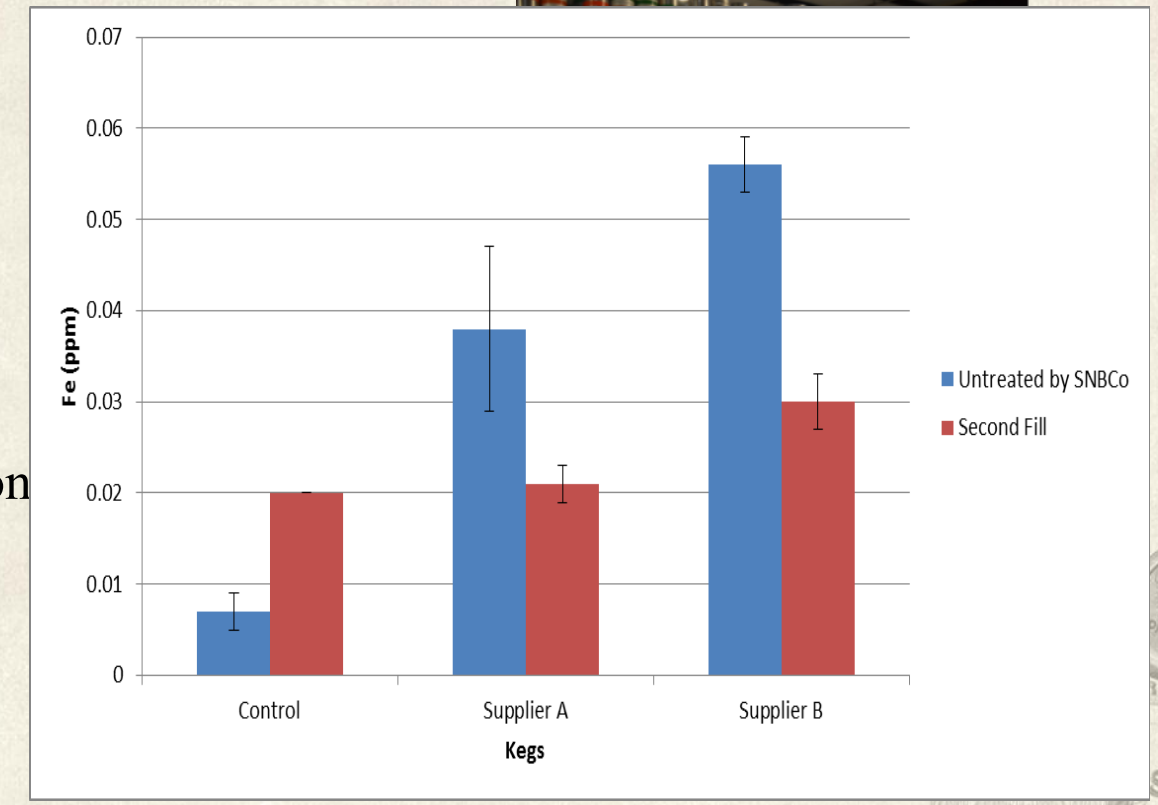
- **Brewing Process**
  - **<u>Brewery Equipment</u>**

Sources of Trace Metals

- **Brewing Process**
  - Packaging Equipment

Sources of Trace Metals

- **Package**
  - New Kegs
  - Cans
  - Tap systems
  - Brass equipment can increase the copper con
  - Growlers
  - Bottles and Crowns

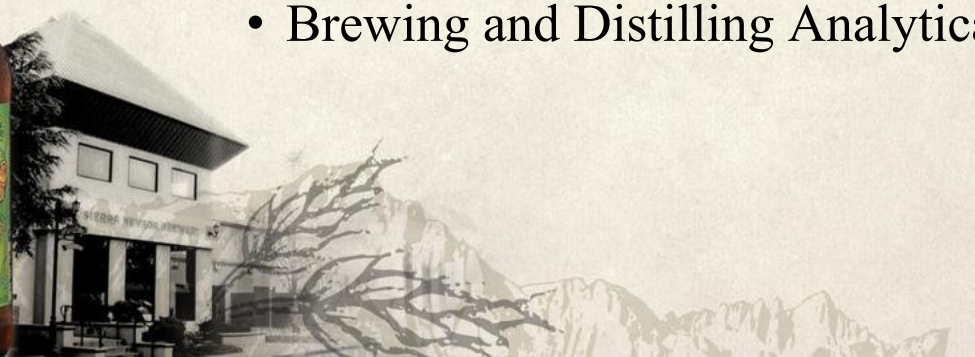


Losses in the brewing process

- Spent grain from the lauter traps Fe, Mn Cu
- Zinc is lost in **significant** amounts in mashing, kettle boil, and trub removal
- Completely assimilated by yeast
- Cold break removal
- Yeast removal
- Centrifugation
- Filtration

Additional steps to address trace metals

- Certificates of Analysis from suppliers and Continuing guarantees
- In house sampling and analysis of potential sources
  - Test kits, test strips, ion specific probes
  - Spectrophotometric analysis
  - Atomic Absorption Spectrophotometry (AAS)
  - Inductively coupled plasma (ICP)
  - Outside lab analysis
    - White Labs (Siebel)
    - Brewing and Distilling Analytical Services



Conclusions

- Very important and influential in the brewing process
- Essential cofactors for numerous fermentative enzymes
- Zinc is the most important trace element
- Copper and iron most frequently analyzed
- Copper, iron, and manganese affect shelf life -all oxidative agents

Conclusions

- Sources include water, raw materials, brewing process and equipment as well as bottling, aging and storage
- Prized for their nutritional value in beer
- Preserving the consistency and quality of the product

Acknowledgements

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Questions?

Thank you