Scientific Principles of Beer and Brewing

Instructor:
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Description:
This seminar is designed to introduce students to scientific principles through an examination of beer and the brewing process. The brewing process is complex and relies on multiple aspects of biology and chemistry. Through examination of the ingredients and methods of brewing the student will be exposed to fundamental themes in these basic sciences.

Readings:
Relevant readings have been selected from the following texts:


Essays in Brewing Science. Lewis. Online through Yale library.

Most of the required readings are available online and those that are not will be distributed as .pdf files. Along with the assigned readings, these texts have a great deal of other material and extensive reference lists for each chapter. This material can be consulted for clarification and further understanding of topics discussed in class.

Assignments:

Problem Sets:
Each week there is a homework question or questions based on the topic covered in class. These problem sets are designed to stimulate thinking outside of class about course material and are likely to require independent research. Answers to the problem sets will be in essay form and should require around one page to be answered completely. These problem sets will address the scientific topics discussed in class and make up a significant portion the final grade.

Papers:
In addition to the problem sets, students will write two papers on different topics. Both papers will require independent research and sources outside of the assigned reading. For each paper a rough draft will be collected and edited prior to the final papers being turned in on the due date.

Paper #1 5 pages.
Students will write an outside research project dealing with some aspect of beer and brewing within their own area of expertise (i.e. major) or some other topic not discussed in class. The topic of your paper should be discussed with the instructor. This paper should demonstrate an understanding of the relationship between beer or the brewing process outside of the technical scientific aspects discussed in class. Students with papers of exceptional quality will be encouraged to submit their papers to brewing related magazines for publication.

Paper #2 5 pages.
The second paper is about inefficiencies and environmental waste within commercial breweries. Students should also suggest alternative and innovative methods to make the brewing process more ecologically sound. This paper should demonstrate understanding of the technical aspects of brewing and the environmental impact of commercial brewing.
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Lab Report:
Week 8 is a lab section and a report of the experiments will be written and should contain sections on the background and significance, procedure, results, and conclusions of the experiments being performed. This report should demonstrate knowledge of the question being asked and experimental techniques and methods being utilized.

Presentation:
The final week of class, each student will give a short (~5 minute) presentation that highlights the topic of paper #1, or another topic determined by collaboration between the student and instructor. The presentation is expected to provide the rest of the class a brief overview of pertinent findings made by the student. Although not required, it is strongly recommended to review your presentation with the instructor before the presentation date. This will help ensure that your presentation is clear and of sufficient content that your fellow students enjoy and benefit from your presentation.

Quizzes:
There are two different quizzes scheduled for week #4 and week #10. Together these quizzes make up 20% of the final grade and will test the students understanding and application of the scientific topics discussed.

Grading:
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Goals and Learning Objectives:
During this course students will:

- Recognize the expansive variety of beer styles and how differences in ingredients and process lead to this diversity.

- Become familiar with the raw ingredients of beer and understand the molecular transformations that take place during brewing.

- Gain comprehension of scientific principles and methodologies as they relate to the brewing process.

- Have firsthand exposure to techniques used by brewing scientists.

- Develop a greater appreciation for beer and brewing in relation to the larger world.

- Examine current industrial brewing practices and identify alternative methodologies.

- Describe their findings of independent research, orally and in writing.
Proposed Weekly Topics:

Week 1: Introduction, beer styles, and overview of brewing.
Week 1 will include time for administrative issues and outline the expectations for successful completion of the seminar. An examination of different beer styles and their classification will be used to introduce qualitative and quantitative characteristics of beer. Awareness of these characteristics will be essential in further discussions of how changes in ingredients and methods affect the final product. A brief overview of brewing from "grain to glass" will be presented to lay the foundation for more in-depth discussions on specific topics.

Reading:
Priest and Stewart. Chapter 2: Beer Styles: Their Origins and Classification. pg. 39-56
Briggs et al. Chapter 1: An outline of brewing. pg. 1-10
Bamforth. Chapter 3: Eyes, Nose and Throat: The Quality of Beer. pg. 65-86

Week 2: Ingredients I. Malted barley.
This week will introduce structure function relationship through an examination of barley anatomy and the events that occur during germination. This will lead to a discussion of how the malting process exploits the biology of germination to produce the main sugar and enzyme source of beer. Finally, fundamental concepts in macromolecular structure will be introduced through an examination of starches and sugars. This will be re-examined in later classes on mashing and enzymatic reactions.

Reading
Priest and Stewart. Chapter 5: Barley and Malt. pg. 139-161
Bamforth. Chapter 4: The Soul of Beer: Malt. pg. 87-109

Week 3: Ingredients II. Water.
The class dealing with water provides an opportunity to discuss inorganic chemistry, ionic bonds, and acid-base chemistry. In addition, the mineral composition of different water sources and how the composition of brewing water affects the final product will be explored. Later classes will come back to acid-base chemistry in discussions on the influence of pH on yeast growth and enzyme activity.

Reading:
Lewis. Chapter 7: Inorganic Ions. pg. 69-76.
Briggs et al. Chapter 3.6. The effects of ions on the brewing process. pg. 65-68
Priest and Stewart. Chapter 4: Water. pg. 91-122

Week 4: Ingredients III. Hops.
Hops contain α-acids that contribute bitterness to beer that balances the sweetness of sugars provided by malt. The discussion of hops will focus on the nature of hop oils and resins and the isomerization of α-acids that occur during boiling of hops. In addition other means of extracting α-acids using ethanol or supercritical CO₂ will be covered to introduce solubility and current research to generate very hoppy high-gravity beers. Finally the section on hop will discuss hop ecology and generation of new strains engineered for desired characteristics.

Reading:
Priest and Stewart. Chapter 7: Hops. pg. 177-209
DUE: Paper #1 rough draft

Week 5: Ingredients IV. Yeast.
The section on yeast will provide a broad overview of cell biology with an emphasis on structure function relationships by relating the overall structure of yeast cells in this section to function in later classes on fermentation. This class will examine the molecular composition and major organelles of...
eukaryotic cells. Discussion of major classes of cellular macromolecules will augment previous topics on starches and sugars. The structure and analysis of proteins will be introduced and revisited in the lab section of week 9.

**Reading:**
Lewis. Chapter 11: Yeast. pg. 114-130
Briggs. Chapter 11: Yeast biology. pg. 363-399

**Week 6: Process I. Mash and wort production.**
Wort is the sugary unfermented liquid produced by the enzymatic breakdown of starches present in malted barley. Examination of the mashing process requires understanding the relationship between starch and sugar and how different classes of enzymes break down the starch into fermentable sugars. This section will provide a general conceptual summary of enzymology and examine how variables of pH, temperature, and concentration affect specific enzymes that are active during mashing. Finally, different mashing regimes will be investigated to relate the enzymatic processes that occur during mashing to the final product.

**Reading:**
Lewis. Chapter 10: Enzymes pg. 105-113
Briggs et al. Chapter 4: The science of mashing. pg. 85-87, 122-167

**DUE: Paper #1 final draft.**

**Week 7: Process II. Fermentation.**
This week applies topics covered during week 5 on the structural analysis of yeast cells to the function and physiology of yeast cultures during fermentation. The fundamental process of aerobic and anaerobic respiration and molecular pathways by which cells convert sugars to energy, carbon dioxide and ethanol will be covered. In addition, examination of fermentation allows a discussion of practical aspects of unicellular culture characteristics and provides a foundation for the lab section.

**Reading:**
Briggs et al. Chapter 12: Metabolism of wort by yeast. pg. 401-465.

**Week 8: Lab Section. Protein analysis and fermentation.**
Science is an experimental discipline and hands-on techniques doing actual experiments can provide a deeper level of understanding to topics covered during class. The lab section consists of two different parts; analysis of yeast proteins during different phases of fermentation and examination of how different variables (yeast strain, sugar source, or temperature) affect the rate of fermentation. These experiments will reinforce ideas covered in class discussions and expose students to techniques and methodologies of the scientist-brewer.

**Reading:**
Lab Handout.

**Week 9: Process III. Packaging, carbonation, and oxidation.**
The final step of beer production is conditioning and packaging for distribution to the consumer. Examination of carbonation will cover the physical properties of gases and the relationship between temperature, pressure, and amount of gas dissolved in liquid. Analysis of foam and molecular models of foam formation and stability will be covered and highlight previous topics on proteins and enzymes. Finally, breweries go to great lengths to minimize oxidation and this section will cover the chemical nature of oxidation and organic molecules that function as antioxidants.

**Reading:**
Lewis. Chapter 4: Foam. pg. 28-42
Bamforth. Chapter 8: Refining Matters: Downstream processing. pg. 159-171.
**Week 10: Post-Production I. Microbiology and sanitation.**
Proper cleaning and sanitation are essential to the production of quality beer because infection by numerous spoilage microorganisms can occur during the brewing process. This section will cover basic topics in microbiology and examine differences prokaryotic microbes and eukaryotic yeast cells that were discussed in week 5. In addition, different methods of sanitation and their mechanism of action will be explored.

**Reading:**
Priest and Stewart. Chapter 16: Microbiology and Microbiological Control in the Brewery. pg. 607-628.

**DUE: Paper #2 rough draft**

**Week 11: Post-Production II. Commercial brewing and guest brewers.**
The topic of week 11 is designed to complement paper #2 and provide the students with actual examples of the environmental impact that brewing has.

**Reading**
Briggs et al. Chapter 18: Brewhouses: types, control and economy. pg. 650-661
Priest and Stewart: Chapter 18: Brewery By-Products and Effluents. pg. 655-693

**Week 12: Post-Production III. Current topics in brewing research**
This week will be journal club style presentation of current research from peer-reviewed journals. Discussion of primary literature has three main learning objectives. First, topics that were covered in previous weeks will be examined further, allowing a reinforcement of concepts previously covered. Second, advanced techniques and methodologies will be presented that are used in research within as well as outside of brewing. Finally, the students will be exposed to the scientific method (identification of a problem, development of a hypothesis, and experimentation to test the hypothesis) using actual examples of brewing science from universities and industrial laboratories.

**Possible Readings:**


**Week 13: Presentations**

**DUE: Paper #2 final draft**