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Malting in the Lab and at Home: The Forgotten Step on the Path to Beer

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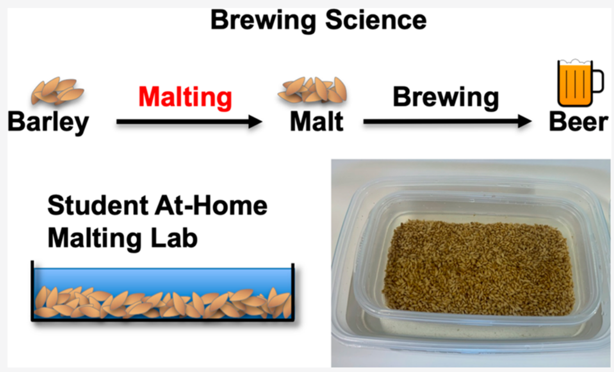
ABSTRACT: Brewing science is an interdisciplinary course taught at many universities in both lecture- and lab-based modalities. The laboratory component of this class typically focuses on the brewing process from malted barley to beer. However, this ignores the malting process—an essential step in making beer, although one typically performed by maltsters outside of the brewhouse. In this report we discuss the development of a malting lab that is suitable to incorporate into introductory brewing science courses in order to help students demonstrate and explain the key process of converting raw barley into malt. During this week-long experiment, students start with raw barley (commercially available in scales that work for all course sizes) and, using small scale and inexpensive custom-made equipment, malt the barley at home for later use in the course. This experiment is suitable for hybrid course laboratories in student homes and apartments with minimal course expenses or requirements and can be implemented in any brewing science course—even those that are predominantly lecture-based.



KEYWORDS: *Upper-Division Undergraduate, Hands-On Learning/Manipulatives, Distance Learning/Self Instruction, Laboratory Instruction, Biochemistry, Interdisciplinary/Multidisciplinary, Agricultural Chemistry, Industrial Chemistry, Laboratory Equipment/Apparatus*

■ INTRODUCTION

Brewing science is a cross-disciplinary course taught at a wide range of colleges and universities. Resulting from this nature, it is taught in many different departments including chemistry, engineering, biology, biochemistry, food sciences, and business.[1−10] As a course it helps to bring together these disciplines and students from a cross-section of majors to provide an application driven course discussing many of the fundamentals from each discipline. This course can be taught as a lecture-based course, a laboratory course, or a series of courses building toward a certificate, minor, or degree. At Colorado School of Mines, we teach it as a single lab/lecture combination course, with students representing ∼75% of the majors on campus having taken it. While the work we present below on a malting laboratory experiment is likely of highest value to laboratory-based courses, depending on available resources this may also be suitable for supporting learning in lecture-based courses as well.

The brewing process, in industry, in academic settings, or at home, typically starts with malted barley as a raw ingredient. From here it proceeds through the brewing process detailed in other places.[11−14] Briefly, and overly simplified by focusing on the barley and sugars, the brewing process converts the starches in malted barley to sugars, followed by fermentation to convert those sugars to alcohol. However, malted barley is not the true raw material! Raw barley is the material grown and harvested, and before use in the brewing process it must undergo the process of malting. The malting process and resulting biochemical changes are essential in the path from barley to beer, but while covered in the lecture portion of courses, it is often overlooked in the laboratory portion of brewing courses as malting happens outside of the brewhouse—in the malthouse.

The goal of the malting process is to prepare the barley for the brewing process. This requires many biochemical changes in the grain. Perhaps the most important change is the production of the enzymes necessary for mashing later in the process. However, malting also provides a number of other changes to the grain including the breakdown of the endosperm cell walls (releasing the starch), and flavor modification of the grain. There are three key steps in the malting process (Figure 1): steeping, germination, and kilning. Steeping is the process of soaking the raw barley in water to bring its moisture content up

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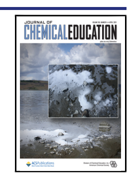

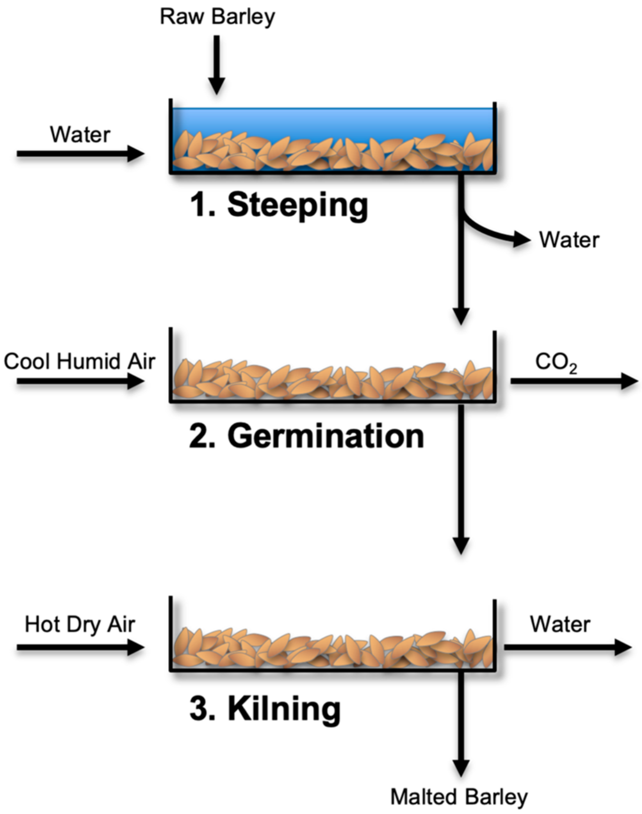

Figure 1. Malting process comprising three steps. In steeping raw barley is held with water to rehydrate the kernels to enable germination. After rehydration, the barley is drained and moved to the germination step where the grain is kept cool and moist to allow the kernels to begin the growth process. After the germination step, the grains are dried to arrest the growth and enable long-term storage of the malted barley.

from >5% used for storage to ∼42−46% necessary for germination[15] (with the appropriate moisture content depending on the final desired malt[16]). After the grain is hydrated, it moves on to a germination step where many of the desired biochemical changes occur. Amylase enzymes are produced (necessary in mashing later in the brewing process), the grain is softened, and cell walls are broken down allowing better access to the starches in the grain. After several days, the grain is moved to a kilning step. Here the grain is heated to remove excess moisture while retaining enzymatic activity. When the grain has reached the desired moisture content (<5%[15]) and flavor characteristics (determined by the kilning temperature profile), it is stored for use later in the brewing process. Optionally, the grain can also be drum roasted at this point in the production of specialty malt, resulting in increased flavors, but typically a loss of enzymatic power.[16] The U.S. has an industry group, the American Malting Barley Association, devoted to improving the barley available for malting. Additionally, there are commercial programs (e.g., Coors, AB-InBev) and international organizations (e.g., Brewing and Malting Barley Research Institute) directed toward the same goals. For an excellent introduction to malting the reader is referred to Chapter Five of Scientific Principles of Malting and Brewing,[15] and for a detailed reference please see *Malts and Malting*.[17]

At Colorado School of Mines, we have been running an elective course in Brewing Science for 6 years, and as part of that course we have developed a laboratory experiment for students to malt their own raw barley (and use it later in the course to make their own beers). There are also numerous malting courses or workshops which do include malting experiments, in academic,[18−21] industrial,[22,23] and blended[24] programs, but typically as part of an intensive short course, a larger degree program, or a certificate program. This laboratory experiment is targeted as a drop-in option in interdisciplinary introductory brewing science courses, suitable for both in-person laboratory classes and hybrid learning. Inclusion of this experiment enables courses to cover the necessary process steps before the brewhouse to manufacture beer.

■ CLASSROOM ALIGNMENT AND PREPARATION

To prepare students before the laboratory experiment there are several key concept areas that are discussed in lectures. For malting in particular, we focus on the three key required process steps detailed above and in Figure 1: steeping, germination, and kilning, with limited focus on supporting steps (storage, grain transport) and optional steps (roasting, malting specialty grains). We discuss the key biochemistry of the malting process, and students see videos of different process scales for malting (industrial, small scale, and floor malting) and a preview of their laboratory experiment. The course has also included a tour of a commercial malting facility (Golden Malting—the in-house malting division at the Molson Coors Beverage Co., Golden, CO Brewing Facility). While that resource is geographically constrained, there are many craft malt houses throughout the world that may be available to tour (see, e.g., Appendix C of the Craft Maltsters' Handbook[16] or the Craft Maltsters Guild[25]). The above material provides enough basic understanding for students to apply their knowledge in the laboratory portion of the course through preparing their own malt.

■ EXPERIMENT OVERVIEW

The overall goal of the laboratory experiment is to take raw barley and use the malting process they learned in class to convert it to malt on a small scale, similar to industrial micromalting experiments.[26−28] This process can be performed at home or a combination of at home and in the laboratory. Unfortunately, the timeline for malting (multiple days with steps every day) is not well suited to laboratory only experimentation, although it can be possible with more frequent room access for students (e.g., an open access lab setting). In our course, the students perform the first two malting steps (steeping and germination) at home, with the third step (kilning) typically done in the laboratory. This setup is suitable for a single student to run, and the equipment and supplies are affordable enough to enable all students to malt individually. Overall the experiment takes approximately 1 week to complete: 1−2 days for steeping, 2−3 days for germination, and 2 days for kilning. We have students start steeping the grain Friday evening for a lab session on Tuesday (where they start the kilning process) and on Sunday evening for a lab session on Thursday. More details on the timing are in the provided laboratory handout in the Supporting Information.

■ GENERAL PROCEDURE AND KEY EQUIPMENT

This experiment can be done with minimal equipment, building on what students already have at home (i.e., a mixing bowl, a plate, and a spoon). To simplify the experiment and improve malt quality, we introduce several low-cost pieces of equipment (Figure 2). We use store brand plastic storage containers (smaller, 2.25 L, 26 cm × 15 cm × 7 cm; larger, 3.785 L, 32 cm ×

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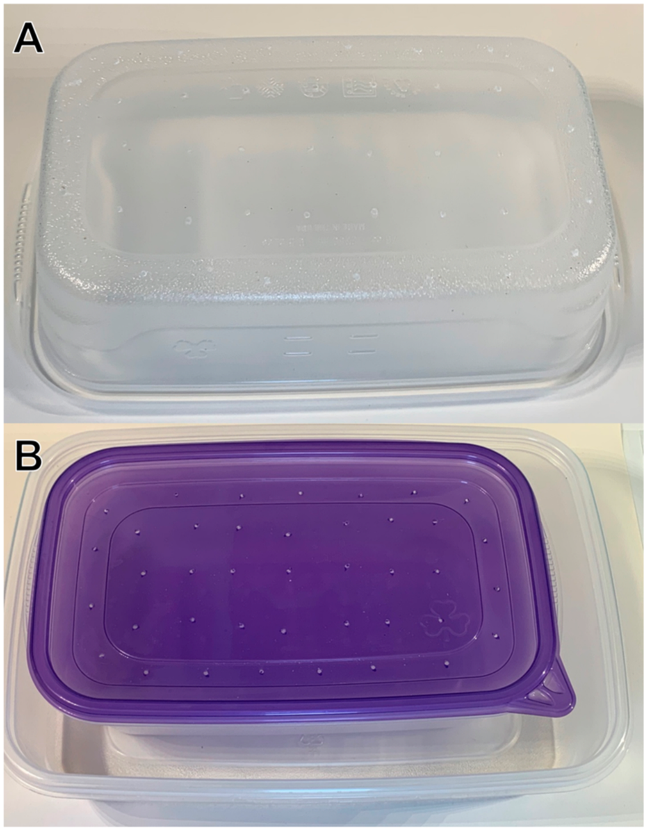

Figure 2. Examples of the malting equipment used in this laboratory experiment. The inner container has holes drilled in the bottom (A) and top (B) to enable draining of water during and after the steeping step, similar to a colander, with the outer container (B) holding the water. The containers are sized to allow for significant expansion of the grain during the process (~2−3×).

21 cm × 7.5 cm—these sizes are appropriate for a 500 g batch, and can be adjusted as required for different batch sizes) in which we drilled holes (3/32 in. diameter, although slightly smaller or larger would work) into the smaller container to produce a grain colander. Students would then pick up the inner container with the grain to drain away the water during rinsing and steeping steps. After the grain is initially rinsed in the colander, students soak the grain for 2 h and then remove and replace the water using the colander system. After a 10 h soak, students lay the grain out on a surface to aerate, followed by more soaking sessions and a final drain before moving onto germination.

During germination students keep the grain in the same storage containers, add a small amount of water (1/4 in.) to the larger container, space the grain colander above the water, and cover it with a wet paper towel to attempt to keep the humidity high. Students mix the grain frequently to keep the grain bed even, help exchange carbon dioxide, cool the grain, and prevent rootlet clumping.

For the kilning step we use commercial dehydrators and an oven—letting us use a precise temperature profile (140 °F (60 °C) for 24 h, 185 °F (85 °C) for 2 h) to kiln the grain. Note that more complicated kilning profiles can be used to mimic commercially used micromalting experiments,[26] but with more challenging implementation in the laboratory. Given budgetary constraints, other suitable approaches would be to build a grain drying system (e.g., from an old refrigerator[29]) or have students use a home oven (at the lowest setting). Students spread their grain onto perforated pans and dehydrate them, followed by weighing the final amount of dried malt and storing for several weeks (to ensure stabilization of moisture content in the grain and better milling). Example images showing the grain throughout the malting process are shown in Figure 3.

The malting process uses biological materials and relies on biological processes, so changes in the raw material and environment can alter how long the process takes—potentially causing difficulty in the experiments. The biggest variable outside of student control is the temperature and humidity of their apartment/dormitory/house. Temperature controls how rapidly the germination steps occur, with the optimal conditions being ~59−65 °F (15−18 °C)[29] with ~100% humidity to avoid drying the grain. At increased temperatures the grain steeps and germinates faster,[16] potentially causing timing disruptions with

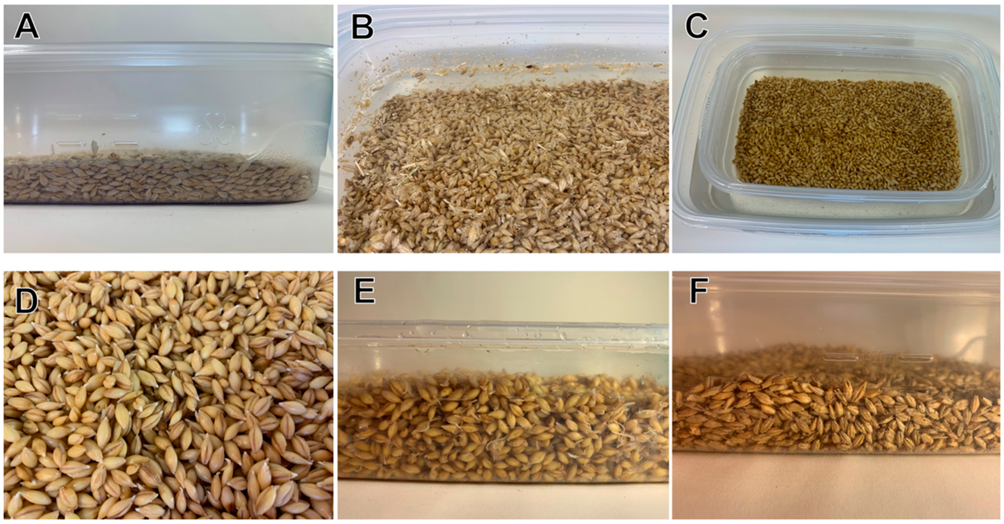

Figure 3. Example images of the barley at different stages during the malting laboratory experiment. (A) Image shows dry raw barley. (B) During the wash step, chaff floats on the water surface enabling separation. (C) The barley is then shown in the steeping step. (D) Chitting is the small white growths that signify the kernels are ready to move from steeping to germination. (E) During germination rootlets grow from each kernel. (F) After kilning the grains are dry enough for storage and have a slightly darker color than the raw barley.

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bringing it to campus if the germination step finishes at a time when students cannot come to campus (e.g., evenings, weekends). Fortunately, both students and malt are remarkably adaptable. Over the years, students have determined that freezing the grain over a weekend or refrigerating the grain to arrest germination both work to stabilize the grain without any perceptible changes in the beers made from these base malts (i.e., still suitable diastatic power to convert the malt). We recommend refrigeration over freezing due to a lower risk of potential changes to the grain. For more experimental details and a student laboratory handout, see the Supporting Information.

LEARNING OUTCOMES AND ASSESSMENT

This laboratory experiment contributes to several course learning objectives. Briefly, these related objectives require students to (1) describe the biochemistry of the malting process, (2) describe the purpose of the malting process, and (3) describe how ingredients and process impact beer characteristics. We include assessment points on student's knowledge in the lab report from the experiment as well as on exams. The lab report details a student's process in malting the grains, with the primary goal being the description of the growth process and timeline. However, for formative assessment students are asked to identify key observation points in the process and justify the decisions they made on moving the grain through the process. We do not have any supporting data examining the specific learning gains of this experiment compared with control options such as a lecture only implementation or students watching videos of the malting process.

The primary summative assessment for these outcomes is on the exams. The exam assessment includes both low-level and high-level questions. Some example low-level questions include the following: Describe the steps in the malting process. How can you identify when grain is ready to move from germination to kilning? When should you ramp the temperature in kilning? When in the brewing process are amylase enzymes produced, and when are they used? Some example higher level questions are as follows: Describe the sensory and measurable outcomes in the final beer if grain is in the germination step for either too long or not long enough. What would happen to your grain if you ramped the temperature in kilning immediately to the final set point? While multiple questions are required to assess all objectives, the exam is a suitable point for addressing student learning on both the lecture and laboratory components on malting.

HAZARDS AND SAFETY PROCEDURES

The heat source of an oven or dehydrator used in this experiment is the primary hazard to students. While temperatures are low compared with other processes, the final kilning temperature step is 185 °F (85 °C), which is hot enough to burn skin. Oven mitts are provided for in-lab oven use, and students kilning at home were directed to use oven mitts. This lab does not involve any hazardous chemicals (students only use grain and water). Future expansions (see below) may add additional hazards, especially production of crystal malt which can produce low-pressure steam during the process depending on implementation.

POTENTIAL EXPERIMENT EXPANSIONS

While this laboratory experiment is currently suitable for inclusion into other brewing science courses, there are still several key avenues for expansion in the future. A minor addition to the experiment is to include additional measurement capabilities for the students to use at home. This would likely include a precision ruler (to measure acrospire length more accurately) and a scale (for better estimates of grain moisture content and losses throughout the process). A larger expansion of this experiment is to explore the malting efficiency of the student malting process. Currently, the malt is used in the next brewing session in the course, but this provides minimal feedback on how effective the malting process was. The brewing community has invested significant time and effort into developing standardized malt analysis (e.g., a reduced scale congress-style mash[30] or more recent 65 °C mash[31]), and incorporating that into this laboratory experiment will enable students to more directly assess their malting efficiency, potentially through the use of microscale mashing as detailed by others.[5,26,32,33] Another potential expansion of this experiment is to move students into preparing specialty malts in addition to the base malt currently produced. This includes roasted malts (where the malt is roasted after the kilning step,[16] which we can accomplish with our current oven) and crystal/caramel malts (where heat is applied to wet malt while maintaining a humid environment[16]). We are currently exploring options for small scale approaches to producing crystal/caramel malts. Adding these modules to the experiment will enable students to explore key process parameters in the lab and assess impact on the malt and their final beers.

CONCLUSION

The malting lab we describe here provides a modular and adaptable addition to a brewing science class. It can be run in an on-site or hybrid format and altered to align with a given class' economic constraints and learning objectives. Additionally, it would be possible to incorporate into a lecture only course as an at-home project. With the addition of this laboratory experiment, students in brewing science courses will have hands on experience with a key step in the process of producing beer not currently implemented in many laboratory portions of these courses.

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available at https://pubs.acs.org/doi/10.1021/acs.jchemed.0c01279.

Example laboratory handout used in 2020 (PDF, DOCX)

Instructor Notes (PDF, DOCX)

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Notes

The author declares no competing financial interest.

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