Topics in Brewing: Malting

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ABSTRACT

Malted barley is, without dispute, the single most important ingredient for the brewing of beer. By way of definition, barley is the cereal grain, and malting is the modification process that prepares barley for brewing. "Modification" is a comprehensive term that maltsters use to describe all of the physical and chemical changes that occur when barley is converted to malt. These changes include enzyme creation, plant protein and plant carbohydrate simplification with the enzymes, and the physical weakening of the kernel endosperm cell wall structure, also by enzyme action. Beer is not made from barley; it is made from malted barley, a very important distinction. Although other grains are malted, most notably wheat and rye, when the word "malt" is used in brewing, it refers to barley malt. The malting process is as old as the history of beer, and in fact we all understand that some form of malting must have preceded brewing. This article reviews some of the underlying fundamentals of the science of malting, the history and evolution of malting equipment and process, and the current basic process steps required. Pale malt and specialty malts are discussed.

Keywords: germination, kilning, modification, roasting, steeping

SÍNTESIS

La cebada malteada es, sin lugar a duda, el más importante ingrediente para a elaboración de la cerveza. Se define la cebada como un grano de cereal mientras que el malteo es el proceso por lo que se prepara la cebada para el proceso cervecero. "Modificación" es un término de gran alcance que los malteros usan para describir todos los cambios físicos y químicos que ocurren cuando se convierte cebada en malta. Estos incluyen la creación de enzimas, y simplificación de las proteínas y carbohidratos de la planta mediante estas enzimas, además del debilitamiento físico de la estructura de la pared celular de la endosperma del grano, también por la acción de enzimas. La cerveza no se elabora de cebada, sino de cebada malteada, una distinción muy importante. A pesar que otros granos son malteados, notablemente trigo y centeno, cuando se usa la palabra en el mundo cervecero se refiere específicamente a cebada malteada. El proceso de malteo es tan antiguo como la historia de la cerveza, y se entiende que alguna forma de malteo seguramente existió antes que el proceso cervecero. Este artículo repasa algunos de los fundamentos básicos de la ciencia del malteado, la historia y evolución del proceso y el equipo de malteo, y los pasos básicos del proceso actual requeridos. Se discute sobre la malta clara y especialidades de malta.

Palabras claves: germinación, modificación, remojo, torrefacción, tostado

Underlying Fundamentals of Malting

The malting of barley for brewing utilizes and directs nature's germination process. In nature, when a seed, any seed, is planted in the ground, it takes up moisture, and with the right balance of moisture and warmth it germinates or sprouts. Life materials in the seed develop enzymes. The germination process then uses the enzymes to act on the protein content and the starch body of the seed that exists as a nutrient material reserve in the kernel. This process converts the reserves into new rootlets and an acrospire, a seedling that will reach the surface of the soil. Germination is a process of aerobic respiration, requiring oxygen and moisture to function, and with the byproducts of heat and CO_2. Above the surface of the soil and in the presence of sunlight, the plant will then continue to grow by photosynthesis. The seed reserves are totally exhausted as the new plant reaches the surface of the soil and the seedling green plant begins its life in the sunlight. During the photosynthesis growth phase, using moisture and nutrients from the soil, and sunlight and carbon dioxide from the atmosphere, the new green plant lives its life cycle, the mechanisms and the sacrifices of the original seed long forgotten. The plant will grow to maturity, create a new storage reserve of carbohydrates and protein in its mature seeds (kernels), and finally the seeds will be harvested, some to be consumed by humans and animals, and others to be stored for another planting and growing season.

Prior to kilning, the malting production process follows these exact natural steps through steeping (the moisture uptake) and germination (the enzyme creation, protein reduction, starch simplification, and cell wall weakening). After these enzyme actions take place, modification for the purposes of the brewer is complete. Unchecked, the germination process in the malt plant would consume the entire barley kernel and create a barley plant. Maltsters and brewers are interested in the created enzymes and the partially digested (modified) barley kernel that represent the state of the kernel at the end of germination, not the complete barley plant.

The maltster interrupts the germination process with kilning. In the kiln, the germinated barley is first dried to deprive the growing barley kernel of moisture to stop the germination pro-

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cess, and then cured at higher temperatures for color and flavor development.

Adaptation of Nature to a Malting Process

Combining the fundamentals of germination with a kilning step results in a very simple batch malting process that involves barley, lots of water and air, and applied heat to dry and cure the malt. The key differences between a barley kernel germinating in nature and in a production malting process are the requirement to run a scheduled and repeatable production process, and the effect of massed seeds in close proximity to each other performing germination simultaneously.

Seeds germinating in nature proceed at various rates based on the available warmth and moisture, depending on the weather in the spring planting period and day/night temperature cycles. They are single kernels in what appears to be a huge environment to them. In nature there is ample oxygen and moisture for a single kernel, and the CO_2 and heat that is generated are easily dissipated. In malting, it is necessary to eliminate nature's weather effects to control the production rate and to manage the effects of many barley kernels germinating in close proximity. A bushel of barley contains approximately 650,000 kernels, so a batch in the malt plant has billions of kernels. This batch has a very large cumulative oxygen and water demand, and is creating a large amount of concentrated heat and CO_2. Without a continuous supply of oxygen and water to support growth, and without the removal of the generated heat and CO_2, we do not have germination. These demands create a malting process need for a lot of water and air, along with the utility infrastructure to seasonally heat and cool them.

Malting is a batch process without any continuous elements. The grain in process is moved from malting vessel to malting vessel for each progressive step. Maltsters refer to a batch as a "piece." The total malting process generally takes 8–9 days, consisting of 2 days of steeping, 4–5 days of germination, and 2 days of kilning. After kilning, there is a critical cooling step before storage, followed by an aging period and the blending of batches prior to shipment. Figure 1 describes the basic malting process with the inputs and outputs of each process step.

Steep barley is a term maltsters use to describe the barley condition at the end of steeping. Green malt is a term maltsters use to describe the barley condition between the start of germination through the start of kilning.

The process schematic emphasis is on lots of water and air moving in and out of the process. The water is needed to wash and hydrate the barley at steep, with changes of water and air rests alternating to activate the barley. Tempered air flows are needed at steep and germination to control temperature, to provide O_2 to the respirating barley, and to carry away heat and CO_2. The goal is simply to create a consistent growth chamber where the barley should not know whether it is winter or summer. Successful malting is about having adequate infrastructure to control temperature and moisture, and to separate the malting process from seasonal ambient changes.

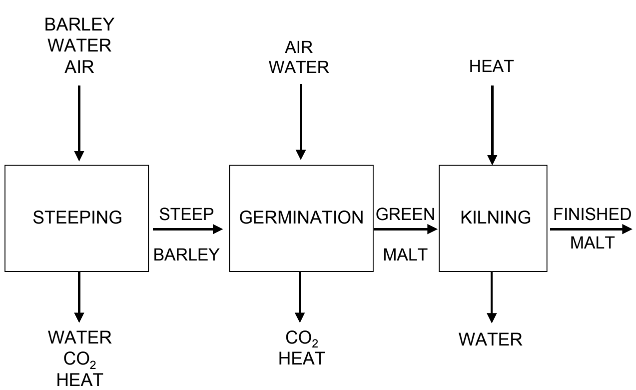

Figure 1. The malting process.

Bushels, Tonnes, and Malting Losses

Although grain is referenced in terms of bushels in the United States, it is referenced and traded on the basis of weight throughout the rest of the world, specifically on metric tonnes. Any use of the word "tonnes" in malting refers to the metric tonne (2,204.6 lb).

Bushels are a dry volume measurement of grain created in the United Kingdom during the 15th century to enable a fair grain trade. A bushel volume was and is based on an 18½ inch tall cylinder, 8 inches in diameter. This calculates to a volume standard of 2,150.4 in^3 or 1.24 ft^3. To facilitate the fair trading of grain in the United States, the USDA created pounds per bushel standards for grain so that grain could be weighed to determine the number of bushels rather than to try to make actual volume measurements. Do not be concerned that the current actual bushel weights of barley and malt do not represent the trading standards. Every transaction in barley and malt trading is first weighed, and then the weight is transitioned to bushels with the USDA established standards. Even though bushels are a volume measure, no attempts are made at actual volume measurements. This is not unique to barley and malt; the USDA has established trading standards for most grains and oilseeds, and for 66 agricultural commodities from apples to walnuts. Current USDA trading standards for the principal brewing grains are shown in Table 1.

This explanation is very simple when discussing barley; however, it becomes more complicated when discussing malt because of the dry matter mass loss during malting and the bulk density difference between barley and malt. On a weight basis, the barley to malt to transition typically has a mass loss of 18%; 100 tonnes of barley to steep will yield 82 tonnes of cleaned malt. The losses are through the respiration production of CO_2 and heat, new tissue production of rootlets that are removed during finished malt cleaning, and the moisture change from 12% moisture barley to 4% moisture malt. The bulk density of malt is lighter than barley because of the tissue simplification throughout the kernel by the malting enzymes. This simplification is confirmed by a measurable change in kernel diameter. Malt will "grow" approximately 0.5/64th in (0.2 mm) from the original barley. Malting barley that is 6/64th in diameter will result in malt that is 6.5/64th in diameter. This bulk density change creates a misleading impression that barley creates more malt than the original barley when

Table 1. USDA bushel weight standards

	Pounds per bushel
Barley	48
Barley malt	34
Wheat	60
Rye	56
Corn	56
Rice	45

considering volume measurements. When looking at the volume (bushel basis) transition, 100 bushels of two-row barley will yield 116 bushels of two-row malt based on the bulk density change (six-row converts at a lower value, closer to 112 bushels malt per 100 bushels barley). Closing the circle by converting bushels to weight, 100 bushels of barley is 4,800 pounds barley (100 × 48 lb/bu barley) and 116 bushels of malt is 3,944 pounds malt (116 × 34 lb/bu malt). Four thousand eight hundred pounds barley yielding 3,944 pounds malt takes us back to 82% yield (3,944 lb / 4,800 lb = 82.2%).

A final cautionary word on bushels and tonnes: the trading standard for malt is NOT the actual bulk density weight of malt that must be used for brewery equipment design calculations. The actual bulk density of malt ranges from 38 to 40 lb/bu or 30.5 to 32 lb/ft^3. The key measurement and conversion standards are shown on Table 2.

The History and Evolution of Malting Technology

Prior to the United States Civil War and the second half of the 19th century, brewing was conducted at a very small scale, was local, and was seasonal. All process steps were performed manually and process decisions were mostly empirical and largely made without the benefit of the use of instruments or very much scientific understanding. The second half of the 19th century represented an unprecedented period of introduction of mechanization and science into malting and brewing across the world. We take them all for granted today, but these advancements were significant and created today's modern brewing process and breweries, whether they are small or large, all-malt or adjunct, lager or ale.

In the United States, this period was dominated by the introduction of lager beer. This beer type required improved malt, a parallel evolution of malt quality, and of the scale of malting production to support brewing. Malting enjoyed the same benefits of the introduction of mechanization and scientific knowledge as brewing. Most significant among the advances was the introduction of pneumatic malting with turning machines. This significant innovation occurred during the period of 1873 to 1885.

Malting Prior to 1873

All malting prior to 1873 was "non-pneumatic," meaning that forced air was not passed through the grain at any stage of the process. As with brewing, malting was seasonal and was not conducted in the warmer months. Steeping did not have air rests with ventilation, germination and kilning were on solid floors with the process dependent on the atmosphere in the room. Scientific workers were just beginning to explore and explain the physiological and chemical processes that were taking place.

Steeping descriptions of the time ranged from troughs along the edge of the germinating floor (for a process called ditch steeping) to wooden tanks and stone cisterns. There did not appear to be an understanding of alternating air rests and water immersions to activate barley. Emphasis was placed on cleaning barley in the steep by skimming chaff, light barley, and foreign seeds from the surface of the first fill of the steep tanks. Steeping took place over several days. Steeping was complete when the grain was slightly compressible and when a "bitten through grain should make a chalk-like mark upon wood."

After steeping, the wet barley was cast onto the germination floor. The malting floor was constructed of a non-porous material in a well-ventilated room. There was no positive air flow through the grain bed and reliance was placed on diffusion of heat and carbon dioxide from the grain into the surrounding room by timely turning and tossing of the grain. The steep casting was initially into heaps or into a couch frame for a few days. Couching in heaps was a step to build up heat and to advance toward active germination. Couching is a term maltsters use to describe the process of air resting steep barley to allow it to warm up to accelerate the start of germination. Today, couching is completed in the steep tank. The couch piles were reduced and spread thinner over time with shovels and forks. Couch piles could start at a depth of 20 in (51 cm), and over time would be worked out to a depth of as little as 2 in (5 cm). Turning and depth of the germinating grain was very much determined by the grain temperature as it grew and how it was being influenced by the germination room temperature. The germination period on the floor was typically 8–10 days, and could be as long as 21 days. The duration of germination was not a fixed time; it was determined by meeting a set of completion conditions. From Thausing, Schwarz, and Bauer in 1882: "(1) acrospires must be at least two thirds the length of the grain and should not be allowed to grow beyond the length of the grain, (2) the floury body of the green malt should be white, soft, and mealy, and should crumble between the fingers, and (3) the green malt should have the odor of peeled cucumbers, and should not smell musty." The accounts of the period make no mention of malt analysis or malt chemistry. Knowledge of malting dynamics appeared limited to warmth and moisture were needed at steeping to start germination, and that excess steeping could drown barley and destroy germination. At germination, heat was generated that needed to be dispersed and it was understood that high temperatures accelerated germination but produced low quality malt. Finally, knowledge of the time understood that without oxygen there was no respiration, and without respiration there was no growth as well as no "organic life." Pure air was needed along with additional moisture to sustain germination. The pure air reference was likely directed at "fresh" air and the emerging knowledge that CO_2 was produced by the germinating grain and if allowed to accumulate it would inhibit growth.

Very early kilning was likewise non-pneumatic. It was recognized early that green malt could not be air dried and artificial heat sources were required to produce malt that could be stored and that could produce a good beer. Air-dried malt simply would not reach moisture levels below 15% and would spoil. Kiln floors were solid and workers needed to turn malt as it was drying to achieve even drying and to avoid scorching.

The classic method of floor malting is still practiced in a limited way today, with the focus on the floor germinating process. The germinating floor is surrounded by modern steeping and modern kilns, and with the current scientific knowledge of malting. Modern steeping precisely manages air rests with CO_2 removal and immersions to hydrate and activate

Table 2. Barley and malt measurements and conversions

Metric tonne	2,204.6 lb
Barley trading bushel	48 lb
Malt trading bushel	34 lb
Barley trading bushels in a metric tonne	45.9 bu
Malt trading bushels in a metric tonne	64.8 bu
Weight yield of malt from steep barley	82%
Volume (bushel) yield of malt from steep barley	116%
Actual malt bulk density (equipment design)	31.4 lb/ft^3 (39 lb/bu)

the barley. With modern steeping techniques, couch piles and progressive thinning are not necessary on the germination floor. Properly activated barley can be spread directly at a single depth for malting, typically 6 in (15 cm) and for a much shorter germination period. Turning and tossing of the green malt on the floor remains necessary and is now done mostly with machines.

Galland and Saladin

Pneumatic germination began in 1873 and is credited to two French innovators, Nicholas Galland and Alphonse Saladin. Galland built the first pneumatic germination box using forced air cooled by water and ice in 1873. The steeped barley was arranged on a perforated floor at a depth of 25–40 in (64–102 cm). The principal advantage immediately recognized was the complete saturation of the germinating grain with oxygen (elimination of CO_2 was not prominently mentioned). The germination of the barley was more complete and was accomplished more quickly when growth took place with improved access of oxygen. The basics of pneumatic malting were established, joining the influence of flowing moist air and its oxygen with temperature control, and this is properly credited to Galland. However, Galland's first effort did not allow for any turning of the grain and the growing barley "felted" or grew rootlets and acrospires into a mat that occluded air flow through the grain. Working the grain by hand in a deep bed inside the box was very difficult and impractical. Galland did not consider a turning machine, gave up the box concept, and moved on to malting drums, the development that he is more widely recognized for today.

The weakness of the unturned Galland pneumatic box was overcome by his onetime assistant Alphonse Saladin. In 1883 Saladin invented a system of vertical helical screw turners that lifted the germinating grain from the bottom of the box to the top of the grain bed. The screws were turning alternately in opposite directions and mounted on a moving carriage that advanced along the box. We often call modern malting Saladin box malting, but to put a fine point on it, Galland developed the forced air perforated floor malting vessel, and Saladin developed the critically important turning machine.

Today, we malt in very large germination vessels with perforated floors and forced air flows that we call germination "boxes." They are loaded with grain batches of up 600 tonnes (27,560 bu) and grain beds that are up to 60 in (1.52 m) deep. They are all turned with turning machines based on Saladin's invention.

Alternates to Boxes with Turning Machines

Germination in boxes with Saladin-based turning machines dominate malting today, principally due to their ability to be scaled up to very large piece sizes. However, several other systems emerged through history. All of them had in common an effort to seek an alternative to Saladin turning machines. Galland was frustrated without a turning machine and moved on develop the malting drum. He built the first practical drums in 1883. Operation involved a slow rotation of the drum (3 revolutions per hour) to gently tumble the germinating grain in lieu of a turning machine. The Seeger Wanderhaufen system, literally translated as "walking pile," is composed of a very large box or "street" that holds as many as eight discreet pieces at a time. A transfer machine moves through the grain daily, moving the pieces progressively down the "street" from entry to exit. Several of these systems remain in operation today. The Lausmann Transpose system consists of multiple germinating compartments with floor panels that lift vertically into a machine that skims the germinating grain into the next compartment progressively from the entry compartment to the exit compartment on a daily basis. These systems are now limited to very small scale and research malting.

Steeping Improvement and Kilning Improvement

While Galland and Saladin were developing the concepts that preceded modern germination equipment and process, evolving scientific and engineering knowledge led to improvements in steeping and kilning.

Early steeping technique evolved from simple changes of water to clean barley to modern steeping with the understanding the how air rests impact hydration and barley activation. Steeping vessels quickly evolved to conical bottom tanks with a screen area in the cone bottom for water fill and drain, and to establish air flow with a suction fan when the barley is on air rest. Steep tanks were also fitted with air nozzles on the cone to bubble air through the barley when it was immersed. The standard for steeping became alternating immersions with air bubbling through the grain and water, with air rests with a suction fan to draw fresh air through the grain bed to provide oxygen and to remove CO_2 and heat.

Early kilns were direct fired, single deck, and airflow was by natural draft. Multiple deck kilns were tried but did not immediately come into use. Although single deck kilns were thermally inefficient, two and three floor kilns were difficult to construct and operate effectively with only natural draft for air movement. When the use of kiln fans for forced air draft was developed, multiple deck kilns become the standard. The standard malt kiln at the turn of the century was a double deck kiln, with one deck above the other. The kiln was open between the decks with a direct fired heat source and a single forced air flow with fans through both decks sequentially before a direct discharge of exhaust air from the upper deck to the outside. The kiln floors were constructed of perforated metal tipping trays. The tipping trays allowed the grain drops to be accomplished in minutes without manual handling of the malt inside the kiln environment. This kilning approach is energy efficient and various configurations continue to dominate kiln construction today.

Circular Vessels and Malting Towers

As malting batch sizes steadily increased, an alternative to multiple and larger conical steep tanks was sought. Conical tanks are simple and self-emptying, but pressure on the grain at the bottom of a very large conical steep tank is a concern due to grain compression damage and resistance to air flow when the tank is on CO_2 ventilation. In the 1960s, development began on large flat bottom steep tanks. They offered several advantages when compared to multiple conical tanks for a large batch, particularly shallow grain beds. Generally flat bottom steeps are used only on very large batch sizes.

Circular germination vessels and circular kilns were also developed in the 1960s. They have the advantages of simplified grain loading and unloading, and offer improved distribution of air. There is no practical limitation on size for these vessels. Generally they are constructed with a fixed floor and a turning machine that pivots on a center column while traveling on an outside rail.

With the development flat bottom steeps and circular germination and kilning vessels, malting moved to all circular processing vessels and then to a stacked arrangement in a tower. The center column loading and unloading made towers a very practical configuration. Where conditions allow the construction of a tall tower, they are a preferred configuration. A tall tower utilizes gravity for most of the grain transfers and is an efficient building technique that minimizes foundation area and roof area, both very expensive aspects of construction. Even in situations where a tall tower is not possible, circular malting vessels are the current standard and are arranged in mini towers or on a single elevation.

Combination Malting Vessels

Multifunction vessels that complete multiple malting processes in the same vessel have been developed and put into production use. The most common is the GKV or germination kilning vessel. In the United States, these are called Fleximalt plants or "Flexies." After steeping, the steep barley is placed in the GKV where it will complete both the germination process and the kilning process, typically a 5 day process in the United States, 4 days germination and 1 day kilning. Several Fleximalt plants were built in the United States in the 1960s and 1970s. They fell out of favor quickly during the later 1970s because of their major disadvantage: energy consumption. The high energy consumption derives from every fourth day the germination environment of cool and moist has to be converted to the kiln environment of hot and dry, and then back again. This means expending a lot of energy to heat and cool buildings and machines multiple times per month. A second disadvantage is that combination vessels represent a process compromise and do not optimize either process. When optimizing individual process vessels, grain depths and air flow requirements are very different for germination and kilning. Neither can be fully optimized in a combination vessel. Although no new Fleximalt plants have been built in the United States in some time, as of 2013, two still operate in North America.

Malting Cycles

Germination capacity is the overall capacity determinant for a malt plant. Steeping equipment and kilning equipment are selected and arranged to support the germination equipment. A standard malting unit layout will have germination boxes to provide the production of one batch or piece per day. Four boxes for 4 day germination plants and five boxes for 5 day germination plants.

Malting units operate continuously and are typically rated at 98% utilization, 358 operating days out of 365 days in a year. Malting is only suspended for maintenance or for lack of malt sales. Malt plant batch sizes are dimensioned in the starting barley load to steep and germination, and the overall malt plant capacity is dimensioned in finished malt produced. Assuming a 400 tonne (18,375 bu) barley batch size, a single malting unit will produce approximately 120,000 tonnes (7.79 million bu) of malt annually. Malt plants built with smaller batch sizes can have as many as eight malting units on a single site. Today in North America, the smallest non-specialty malt plant produces 83,000 tonnes (5.4 million bu) of malt annually, and the largest malt plant produces 420,000 tonnes (27.2 million bu) of malt annually. The most recent circular vessels built in North America have been for a 400–450 tonne (18,400–20,700 bu) batch size. Although circular germination boxes are not limited in size of construction, grain transfer rates are the sizing limitation in very large malt plants today.

With the evolution of malt equipment and technique, accompanied by the development of scientific knowledge of malting mechanisms, malting cycles are now shorter than they were prior to 1873. Table 3 indicates the estimated malting cycle changes from 1870 to today.

There are always exceptions. The classic Czech malting plants still prefer very cool 6 day germination and there are climates where the low ambient air humidity allows 24 hour and 36 hour kilning cycles. Although 2 day steep and 4 day germination are the standard today in North America, the predominant varieties, especially Metcalfe, steep easily in 1½ days and will fully germinate in 3½ days.

Table 3. Estimated evolution of malting cycles

	Steeping	Germination	Kilning	Total
1870s floor malting	3 days	10 days	3 days	16 days
1900s pneumatic malting	3 days	5 days	2 days	10 days
United States today	2 days	4 days	2 days	8 days
Europe today	2 days	5 days	2 days	9 days

The Current Malting Process

Selection of Barley for Malting

It can be argued that the first step in the malting process is to select the barley to be malted. Just as brewers attempt to define the malt that they will use for brewing with a malt specification, maltsters attempt to define the barley that they will malt with a barley specification. Variety is always specified and only pure lots are accepted. Moisture is critical for the sound storage of barley and only moisture levels below 13.5% are accepted. Protein is specified as a maximum. In North America, 13.5% maximum is typical and in Europe, 11.5% maximum is the norm. Sizing or plumpness is specified as the percentage retained on a 6/64th in screen in the United States or on a 2.5 mm screen in Europe.

Beyond variety, moisture, protein, and sizing, the balance of the barley specifications focus on soundness for germination and cleanliness of the barley. It can be a long list of items, not unlike a brewer's malt specification, but barley specifications can be condensed into just four categories:

- Germination capacity
- Threats to germination
- Cleanliness – free of evidence of disease
- Cleanliness – free of foreign materials

Germination potential is clearly the single most important malting barley specification. Without the ability to germinate, none of the goals of malting can be met. Many other quality issues that can vary from crop year to crop year can be managed and overcome if sound germinative capacity is present. The lack of sound germinative capacity cannot be overcome. Maltsters must enforce a strict standard of no less than 96% germination when evaluating barley for purchase. Maltsters likewise enforce a strict standard for any threats to germination such as sprouted kernels, immature kernels, frost damage, heat damage, and/or excessive skinned kernels.

Key learning on barley specifications. Barley must have sound germination value and be free of any threats to germination. It must be clean and free of any threats to malt and beer aroma and flavor. It must be free of any significant levels of extraneous material that will cause immediate and direct economic loss on cleaning and grading.

Cleaning and Grading

Upon arrival at the malt plant the barley is cleaned and graded. Cleaning and grading equipment is mechanical and based on the separation of anything that is not the precise size, shape, or density of a barley kernel. There are also magnetic separators to remove any metal that was picked up during the handling prior to this point in the process. After cleaning is complete, the barley is size graded to eliminate the smallest barley kernels. For two row, all barley sized above a 5.5/64th in screen is malted together (in Canada all barley above a 6/64th in screen), and for six row, all barley above a 5/64th in screen is malted together. Malting the single grade is possible because today's varieties are quite uniform on size distribution, and all kernels respond evenly to water in steeping.

Key learning on barley cleaning and grading. Barley must be cleaned of all extraneous materials prior to malting. They can interfere with malt flavor and appearance quality, and cannot be allowed into the process. Barley must be graded to assure that only a uniform and repeatable size distribution enters the malting process. Size uniformity assures repeatable water uptake at steeping and consistent germination.

Steeping

Malting typically commences with 2 days of steeping. The process consists of alternate periods of underwater immersion of the barley with aeration bubbling through the water and grain, and dry couching periods with ventilation passing through the grain to provide oxygen, to remove CO_2, and to dissipate heat. The process temperature ranges from as low as 52°F (11.1°C) during the early underwater phases to as high as 65°F (18.3°C) during final dry couches. Typical steeping practice is three immersions and three dry couches.

Steeping equipment. Steeping equipment is found in two shapes, conical bottom tanks and flat bottom tanks. Conical tanks have the advantages of using less water per batch, they are self-emptying, and they are easy to wash, but they have the disadvantages of not having the optimal geometry for ventilation of CO_2, have deep grain beds when constructed in larger sizes, and it is difficult to evenly load individual tanks in sets of multiple conical steep tanks. Maltsters now generally limit conical tanks to loads of 50 tonnes (2,300 bu) each to avoid deep grain beds that compress the grain and occlude ventilation airflow. Since typical production batches in new malt plants are now exceed 350 tonnes (16,100 bu), multiple conical tanks are required. The alternative shape for larger batch sizes is a single flat bottom steep tank. Flat bottom steeps are not limited in size, have the advantages of single tank batch processing, shallow grain beds, and have very good geometry for ventilation of CO_2. But they have the disadvantages that they consume more water per batch, have more complex machinery to level and empty, require more air handling equipment, and are much more difficult to wash. Since their introduction, steady improvements have been made in flat bottom steep tanks to address the water usage and cleaning issues.

All steep tanks have two key features in common regardless of shape or size. They all have a perforated bottom area to allow filling and emptying of water while retaining grain, and to allow airflow through the grain for CO_2 removal during air rests. They also have air nozzles under the perforated bottom and on the solid walls of the conical bottom to allow the bubbling of air through the water and barley mixture to provide oxygen during immersion periods.

Steeping process. The key process goal of steeping is to activate the embryo and to uniformly hydrate barley to 44–48% moisture so that the hydrolytic enzymes produced can degrade the structural components of the barley kernel.

Although activation points of different barley varieties vary, no barley is known to germinate below 30% moisture and a minimum of 42% is required for most barleys. When barley is immersed in temperate water it will begin aerobic respiration. This respiration process requires oxygen and evolves CO_2 and heat. As the moisture level increases in the barley, the respiration rate increases along with the oxygen demand and the amount of CO_2 and heat evolved. The need to manage these factors has created a steeping regime that alternates periods of full immersion and air rests to assure the respiration process stays aerobic. Respirating barley rapidly depletes dissolved oxygen in steep water and cannot stay underwater indefinitely. The underwater periods include air being bubbled through the water and grain mixture to maintain dissolved oxygen in the water. Without oxygen, the barley will convert to anaerobic respiration, produce alcohol, and eventually become nonviable. Air rest periods are ventilated with a suction fan to remove CO_2 and to provide oxygen.

Factors such as kernel size, protein content, variety, and harvest conditions are important to barley hydration. The process control tools for maltsters focus on the initial water and grain mix temperature, and the balancing of immersion time and air rest time in the steep schedule. After the initial water and grain mix temperature is achieved, air rest periods and immersion periods are balanced to achieve the final steep out moisture. Maltsters consider air rests as the accelerator of the steep process and immersions as the brakes. It is more about changing the respiration rate and the need for the barley to "drink" from the next immersion than about the length of the next immersion.

Temperature steadily increases through the steep process from the initial starting immersion mix point. Temperatures ramp up during air rests and are quenched back in the following immersion. It is desirable to manage the last air rest to arrive at the starting temperature for germination, approximately 64°F (17.8°C). At the completion of the last air rest, the grain is transferred to germination. At this point, the barley should be chitted. The chit is the small white nub that appears at the base of the kernel that will split and become the rootlet as germination proceeds.

Key learning on steeping. A moisture level of 44–48% is needed to fully activate the barley. Consistent hydration requires alternate immersions and air rests, not simple immersion. Air rest temperatures should not be allowed to exceed germination temperatures. Steep out barley should go to germination visibly chitted and near the desired germination temperature to prevent a lag period at in the start of germination.

Germination

After steeping, the activated and chitted barley at 44–48% moisture is transferred into the germination vessel and leveled. The germination process consists of 4–6 days of actively managing the aerobic respiration process that was activated at steep. Oxygen and moisture must be provided to the barley, and the CO_2 and heat generated must be dissipated. The generally accepted germination process temperatures range from as low as the ending temperature from steep, 64°F (17.7°C), up to 72°F (22.2°C).

Germination equipment. All germination vessels have key features in common regardless of shape or size. They all have a perforated floor to allow airflow through the grain for malting temperature control, for a supply of oxygen to the growing barley, and for CO_2 removal. All germination vessels have a helix turning machine based on Saladin's original design. During germination, the chit at the base of the kernel at steep transfer grows into a tuft of rootlets. These rootlets will mat together and form a solid barrier that will interfere with airflow through the grain. The turning machine breaks up the mat and separates the rootlets. The turning machine has nonmetallic wipers on the bottom of each helix to assure that the rootlet mat is not allowed to grow into the floor perforations. The turning machine also has a spray bar mounted on it to enable the maltster to water the grain as necessary during the turning runs. This malting floor and turning machine equipment is obvious and visible in the malt plant. More important to sound malting practice is the equipment that you don't see, the infrastructure to provide adequate humidified and tempered air flow through the grain. This air must be humidified to above 95% and kept as close to 100% as possible. The airflow needed to control malting temperatures will dry out the green malt if the air is not adequately humidified. Since moisture is critical to continued growth during germination, this humidification plus additional watering from the turning machine is necessary to maintain moisture levels.

Germination process. The key process goal of germination is to comprehensively modify the barley kernel to make it functional for brewing without over consumption of the barley kernel.

Since the time of Galland and Saladin, germination vessels have been typically loaded to a depth of 55–59 in (1.4–1.5 m). Leveling side to side and end to end during the loading in the germination vessel is critical. Airflow in large germination vessels is distributed by the resistance of the bed and by keeping the airflow high enough to slightly pressurize the inlet fresh air side of the grain bed. If the germination vessel loading is not level, the thinner areas that offer less resistance will favor higher airflow at the expense of low airflow in the thicker spots.

The magnitude of the challenge of actively managing aerobic respiration in a germination vessel cannot be minimized. There are approximately 30 million barley kernels in a tonne of malt, or approximately 12 billion kernels in a 400 tonne batch, all respirating together in close proximity to each other. Their combined demand for moisture and oxygen is significant, as is the need to dissipate heat and CO_2. Temperature controlled and humidified airflow must be continuous, along with timely watering. The growing barley is swelling in volume and after the first day of germination the rootlet growth rate requires turning of the bed every 8 hours for the balance of germination.

As germination and modification progresses, the maltster has two process control tools to manage growth, moisture and temperature. Modification accelerates with higher grain moistures and slows when the maltster withholds moisture, and modification accelerates with warmer temperatures and slows as malting temperature is lowered. Moisture level has a larger impact on growth rate than temperature. All the enzymes being produced in malting are hydrolytic, meaning that the bond-breaking catalytic action of the enzymes requires a water ion to be present. Once the enzymes are created, they need the 44–48% moisture level achieved at the end of steep to be maintained for the modification actions.

The maltster must use measures that "infer growth" to monitor the germination process. He has two: acrospire growth and kernel rubout. The first inferred growth tool is the maltster's observation of the acrospire growth. Green malt is modified when the acrospire growth reaches between ¾ and the full length of the kernel. Maltsters will add moisture and/or warmth if they feel the green malt acrospires are "short" or will withdraw moisture and/or warmth if the green malt acrospires appear "long." It is not possible to avoid some overgrown kernels (<10% is preferred and 15% is considered excessive), but a more important process observation is that no kernels can be shorter than a ¾ length acrospire.

The second inferred growth tool the maltster has is the kernel rubout. The endosperm of unmalted barley is tough and hard to crush. As the green malt modifies, the endosperm becomes soft and doughy. The maltster can split a modified kernel with his thumbnails and rub it out between his index finger and thumb. When rubbed out, well-modified green malt will smear and not have any hard parts (steely ends). This crushability is the basis for a friability test on malt after it is kilned. After the growth requirements are met, the green malt is transferred to the kiln.

The final step in germination control is to look at the kiln analysis of every piece of malt daily and to associate the finished malt analysis with the watering and temperature recipe used, and with the growth counts observed. Necessary adjustments for future batches are then made to watering schedules and germination temperature profiles to stimulate or to hold back the germination rate.

Key learning on germination. Germination requires the 44–48% moisture level created in steep for hydrolytic enzyme activity. Uniform airflow distribution is determined by the grain bed and the grain bed must be level. Germination airflow must continuously bring in new oxygen and carry away CO_2; it can never be turned off or run at low levels for extended periods.

Kilning

Following the completion of germination, the green malt is transferred to the kiln for finishing. Kilns are found in two configurations, single deck kilns and double deck kilns. Single deck kilning is self-explanatory and is more clearly defined as a kiln isolated from all other kilns and one that independently processes one production batch from beginning to end. Flexi-malt kilning is a form of single deck kilning. Double deck kilns process two production batches simultaneously with a single air flow being used twice as described in the kilning description section below. Every 24 hours, a classic double deck kiln must first unload the finish deck, then transfer the wither deck to the finish deck for curing, and finally load the wither deck with a new batch from germination. A single deck kiln simply unloads finished malt and reloads green malt from germination.

Kiln equipment. Regardless of configuration, all kilns have common features. The first notable feature of malt kilns is their size in reference to the germination vessels in a malt plant. Malt kilns are loaded with a thinner grain bed 34–39 in (.9–1.0 m) than germination vessels 55–59 in (1.4–1.5 m). This requires a much larger surface area for the same batch size. All kilns have a heat source, a heat exchanger that heats air without direct contact with the products of combustion. All kilns have fans to draw air from the heating source through the grain. These kiln fans are sized based on the average ambient air humidity levels at the malt plant site. All kilns have heat recovery exchangers for the air being discharged from the kiln. Fully saturated air cannot carry any more moisture but it does have valuable heat that can be recovered. All kilns have cold air bypasses around the heating elements for the cooldown cycle of the finished deck after curing. Double deck kilns have cold air bypasses and hot air bypasses to adjust the air temperature between decks. There are times when the air leaving the cure deck, particularly at the high temperature finish, is too hot for the wither deck. In this case, the cold air bypasses are opened to cool the air between decks to the desired withering temperature before it enters the withering deck.

This double deck kilning principle approach is energy efficient and continues to dominate kiln construction regardless of the exact layout. Single deck kilns require less capital investment but require higher operating costs in heat and electricity as they cannot be made as energy efficient as a double deck kiln.

Kilning process. The key process goal of kilning is to reduce malt moisture to 4% with the minimum amount of expended energy that completes the process within the time available, and creates the desired color, enzyme profile, and malt aroma and flavor that meets the brewer's specifications.

An understanding of the basics of the green malt drying process is necessary to begin the comments on the kilning process. Green malt drying occurs in two distinct phases. In the first phase, green malt is reduced from the end of germination moisture level, 44–48%, to 12%. Drying is rapid and the phase is referred to as "withering" or free drying. Germination continues in this phase until the moisture falls below 40% and/or the temperature exceeds 120°F (48.8°C). The air leaving this phase is at low temperature, is fully saturated, and has no additional drying value. In the second phase, moisture is reduced from 12% down to 4%. This is a much slower drying process; the temperatures exiting the malt go up dramatically and the humidity of the exit air declines sharply. This discharge air is not fully saturated and does have additional drying value. This phase is referred to "heating and curing" or bound drying. The transition between the withering phase and the curing phase is called the "breakpoint" or "breakthrough." It is defined as the point when all malt finishes the withering phase, and it is marked by a sharp increase in temperature leaving the bed along with a sharp reduction in humidity.

With the above understanding, an approach to optimizing kiln energy is apparent. Saturated air at 100% humidity leaving the withering phase cannot hold any additional moisture and has no drying value. It should be discharged from the kiln into the atmosphere. But the warmer, unsaturated air leaving the curing phase has significant value. It is not saturated to 100% humidity and should not be discharged from the kiln; it should be reused to optimize energy consumption. This is done by passing the unsaturated airstream from the curing deck through the malt that is in the withering phase. The reuse of curing phase air is the basis of double deck kilning.

All malt kilning starts at low temperatures for withering, with air applied to the malt at 125–140°F (51.7–60.0°C) and the malt bed not exceeding 80–90°F (27.7–32.2°C) as only saturated air leaves the bed prior to breakthrough and the moisture level reaching 12–15%. After breakthrough is achieved, the malt is first heated with air at 150–170°F (65.6–76.7°C) until the moisture reaches 5–8% and finally cured with applied air temperatures of 175–190°F (79.4–87.8°C). Standard pale malt kilns typically only have the capability to apply up to 190°F (87.8°C) air during curing. The final steps in all kilning cycles are a cooldown period followed by finished malt cleaning. With the heating elements off, the kiln fans pull ambient air through the grain until the temperature reaches 100°F (37.7°C). Malt that is placed into storage without cooldown will continue to increase in color and decrease in enzyme activity, particularly the enzymes with lower temperature stability. Cleaning removes the rootlets, overgrown acrospires, and any loose husk material.

Color, flavor, and aroma increase during kilning through a set of similar and linked reactions. The principal reaction is the Maillard or browning reaction and the compounds that are formed are melanoidins. This reaction is ubiquitous throughout food preparation; it browns meat during cooking, turns bread into toast, and in brewing it is the reaction that turns wort darker when the kettle is boiled and when wort is held at high temperatures. When considering green malt on the kiln, the Maillard reaction is based on the balance between grain moisture and the application of heat to the well-modified green malt that is rich in sugars and amino acids. How much heat is applied during kilning must always seek a balance between malt flavor, malt color, and diastatic power objectives. A traditional view of pale brewer's two row malt is that the malt color analysis should be 1.60–1.80 ASBC (3.15–3.55 EBC). A more intense "malt flavor" goal cannot be achieved without an increase in this finished malt color specification. It is not possible to kiln green malt without significant enzyme destruction. Enzyme destruction starts at temperatures above 140°F (60.0°C) and is influenced by moisture content and exposure time. Up to 40% of green malt diastatic power (DP) that is present at the end of germination is routinely destroyed during kilning. Increasing the temperatures applied during the withering phase will result in a further destruction of DP. A more intense "malt flavor" goal cannot be achieved without a decrease in diastatic power specification.

Key learning on kilning. Color, flavor, and enzyme destruction are linked and cannot be resolved independently. Knowledge of grain temperature and moisture is critical to constructing a kiln control strategy and recipe. Maltsters react to numerical specifications, but numerical specifications are inadequate to describe the aroma and flavor outcomes for brewers.

Specialty Malts – High Kilned and Roasted

A simple definition of high kilned and roasted malts would be that they all have the common trait of the application of more heat to the malt finishing process than the standard kilning for pale malt. The barley selection, barley cleaning, steeping, and germination process steps for high kilned and roasted malts are essentially the same as pale malt. A more complete definition would be that specialty malt processing requires specialized equipment that can recirculate or contain exhaust air in order to hold higher moisture levels prior to the application of higher finished heats. Specialty malt processing requires precise recipes to develop sugars and amino acids prior to the application of the higher heats. Standard malt double deck kilns will not typically have exhaust air recirculation and their applied air maximum temperature capability generally does not exceed 190°F (87.8°C). Standard malt double deck kilns are also not generally compatible with specialty malt processing because two batches are being kilned simultaneously and the process on each deck has a great influence on the other deck. By comparison, specialty kilns will be single deck and typically will have a maximum applied temperature capability of 250°F (121.1°C). Roasting plants will typically have the capability to reach 450°F (232.2°C). A discussion of specialty malts should include roasted green malt, roasted white malt (already fully kilned malt), roasted barley, and specialty kilns.

Roasters

A malt roaster is a specialized piece of batch processing equipment. Internally, a malt roaster has a solid walled rotating drum with internal vanes that assures the turning and mixing of the malt for consistent heat distribution and to prevent burn on. The drum rotates in a direct heat source and is sealed from the heat source. The products of combustion do not come into contact with the malt. In modern roasting plants, the batch size is from 195 to 355 bu (3 to 5.5 tonnes) of finished product. The drums can be sealed after green malt loading for stewing. "Stewing" is a malting term defined as holding the green malt at a higher moisture level and at a temperature range to promote enzyme activity. To a brewer, the process achieves "mashing conversion in the kernel" and creates high levels of simple sugars. Roasters also have water quenching capability for roasting black malt and barley, and for general fire protection. Roasting plants have two more pieces of critical equipment. They have an after cooler to quickly drop the temperature of the finished malt dumped from the roaster with a high ambient air flow through a thin grain layer. This is necessary to "set and hold" the attributes gained by the roaster recipe and to prevent any color creep. Typically a finished temperature below 75°F (23.9°C) is targeted before finished malt storage. The second piece of equipment is an after burner or a catalytic converter to treat the discharge air from the roaster. High temperature roasting produces unacceptable aroma compounds that cannot be discharged directly to the local neighborhood. They are treated with either catalytic oxidation or thermal oxidation prior to final discharge. Roaster cycles are relatively short. Depending on the product being produced, the entire roasting cycle prior to cooling typically does not exceed 3 hours. Roasted malt products will not have any enzyme activity after roasting.

Green Malt Roasting

The roasted green malt process is used for a range of caramel malts from C-10 through C-120 and is the most common use of roasters. For a caramel roasting cycle, green malt at 44–48% moisture is loaded into the drum and the drum is sealed. The unventilated roasting drum is then heated to stewing temperature of 145–155°F (62.8–68.3°C) and held for 30–60 minutes. Next, the sealed drum is opened to exhaust and the free moisture is removed from the grain. Finally, the grain temperature is raised to 250–320°F (121.1–160.0°C) and held for a range of times to make the C-10 to C-120 range of caramels. The caramels below C-60 are described as sweet, pronounced caramel, honey-like, and candy-like. The caramels above C-60 are described as burnt sugar and raisin-like, as well as pronounced caramel.

White Malt Roasting

Roasting malt that has been previously fully kilned to 4% moisture produces chocolate malt and black malt. For black malt roasting cycles, fully finished and traditionally kilned malt is loaded into the drum and the drum is not sealed. The roasting drum is then heated directly through the stewing range and is not held (it cannot be stewed; it does not contain adequate moisture). It is typically heated to 425–435°F (218.3–223.9°C). The discharge from applying this temperature range is very acrid and must be managed by the roaster's emissions systems. The heat is removed from the drum and the malt is usually quenched with water. Black malts will have a color as high as 700 ASBC (1,379 EBC) and are described as biscuity, dry, burnt, and astringent, but they are different than roasted barley because they possess a hint of sweetness.

Unmalted Barley Roasting

Roasted barley is a classic stout ingredient. For a barley roasting cycle, barley is loaded into the drum. The drum is then heated directly to 435–450°F (223.9–232.2°C) and held. As one technical journal describes the roasted barley process, "heat applied in the final stages is continually reduced as final temperature is reached, and the burners are turned off; however, the grain is near combustion and the temperature rises spontaneously. When the operator judges the color is correct, and before the batch catches fire, the barley is cooled with quenching water sprays." The overall cycle for roasting barley is shorter than malt and will typically be just 2 hours. Roasted barley will have a color of 700 ASBC (1,379 EBC) and is described as burnt, dry, coffee-like, and intensely bitter.

Specialty Kilns

As an alternative to roasted caramel malts, when the demand for specialty malt in the United States increased significantly during the late 1980s, a few specialty kilns were built in the United States that can process C-20 through C-60 malts, as well as Vienna and Munich type malt. What makes these specialty kilns different from a classic pale malt kiln is that they are single deck, they can recycle exhaust air, and they can apply up to 250°F (121.1°C) instead of the standard kiln maximum of 190°F (87.7°C). Stewing is accomplished by recycling discharge air and retaining all the moisture in the kiln and grain bed prior to moving to high finish heats. The principal purpose of specialty kilns in the United States has been to meet the craft brewing demand for C-40 and C-60. For this caramel malt production, the stewing temperature range is the same (145–155°F [62.7–68.3°C]) as on a roaster. After stewing, the kiln malt is increased to final temperature, 205–215°F (96.1–101.7°C); the final hold time for C-60 on the specialty kiln will be longer than a roaster cycle because of the lower final temperature. The roaster-made and specialty kiln-made caramel malts share the 60 ASBC color, but they are different. Each brewer must decide how the flavor differences apply to his process and product. Table 4 describes the key similarities and differences between C-60 malts made with different equipment.

Prior to craft beers, specialty malts represented a very small segment of the North American malt supply. During 2013, of the 20 malt plants in North America, just three have malt roasters. The specialty malt kilns described did not exist in North

Table 4. Specialty kiln made vs. roasted caramel 60

	Specialty kiln made caramel	Roasted caramel
Malt color	60 ASBC (118 EBC)	60 ASBC (118 EBC)
Grain handling	Fixed stationary bed	Tumbled and constantly moving
Stewing temperature	145–155°F (62.7–68.3°C)	145–155°F (62.7–68.3°C)
Heating method	Heated air through the grain bed	Heated rotating drum
Stewing time	4 hours	1 hour
Finishing temperature	205–215°F (96.1–101.7°C)	250–320°F (121.1–160.0°C)
Total cycle	21 hours	3 hours

America prior to 1990. With the addition of supplemental heaters, Fleximalt plants can produce some of the highly kilned specialty malts. The malt plants with roasters are not the same malt plants that have specialty kilns. Most of the malt plants in North America cannot make specialty malt, only standard pale malts.

Specialty Malts – Other Grains

Among all of the cereals, only the grass-based cereals wheat and rye are very similar to barley in their biochemical reactions during malting. The activated embryo signals the aleurone layer with gibberellins and a set of enzymes are produced and released in sequence from the aleurone layer. This leads to similar patterns of modification and similar finished malt outcomes. Additionally, the gelatinization temperature for the starches of barley, wheat, and rye are in the same range. By comparison, the source and release of enzymes in corn and sorghum during malting are quite different and so are the malt outcomes from these grains. The similarities to barley allow wheat and rye to be malted in the same malt plants as barley without any equipment modifications.

Regardless of the similar biochemical reactions, the malting of wheat can be physically very different from barley. Wheat does not have a husk and the bulk density of the wheat grain is higher than barley. Without a husk, the naked wheat kernel lacks rigidity when it takes on water at steeping and is more compressible into a tighter grain bed as it reaches malting moisture. This compacted grain bed condition creates resistance to airflow that can result in processing difficulties. To mitigate this resistance, some malt plants will process batches of wheat that are 10–20% smaller than the barley batches.

At steeping, the lack of a husk allows the wheat to swell without structure to a greater degree than barley, and the water uptake is not regulated by the husk membrane. The net outcome is that wheat takes up water more quickly, is easier to activate for malting, and shorter steep cycles are used. The cycle can be as short as 24 hours and steep out moisture targets will be lower for wheat, 39–41%, compared to barley's 44–48%. Wheat will typically be steeped with just two immersions and no final couch. It will be steeped out as wet slurry to facilitate grain transfer.

At germination, the lack of a husk creates a new problem to add to the compressibility issue. Without a husk, the acrospire is not protected as it is in the malting of barley where it grows under the husk. The wheat acrospires grow uncontrollably in all directions and are very susceptible to damage during turning. The maltster is faced with a conflict between a wheat grain bed, which is very compressible and needs turning, and the fact that the turning machine breaks the exposed acrospires and ends the germination of the affected kernels. After the acrospires are broken, the nonviable plant tissue in the germination process can lead to undesirable mold growth. To mediate, some maltsters will germinate wheat at lower temperatures for less than 4 days to get the green wheat malt in and out of the germination environment quickly. Germination turning runs for wheat will generally be less frequent than with barley, every 12 hours instead of every 8 hours.

At kilning, wheat malt is typically exposed to lower withering and curing temperatures and will be finished at higher final moisture (6% instead of barley malt 4%) to control color and flavor development. The lower curing temperature of 165–175°F (73.9–79.4°C) is likely one of the reasons that wheat malt flavor is typically described as "cereal, floury, creamy, and spicy," but not usually as "malty" or "aromatic." Higher finish temperatures similar to barley malt curing are used when the brewer customer requests darker wheat malts.

It is important to note that wheat malt from both hard red spring wheat and soft white winter wheat are commonly offered by maltsters. Hard red spring wheat will have smaller kernels and higher protein. This malt will generally be lower in extract due to the higher protein. Soft white winter wheat will have plumper kernels and lower protein. White wheat malt will generally be higher in extract, as high as 85% extract due to lower protein. Some brewers prefer soft white wheat malt because there are less malt mill adjustments required for the larger kernels. Some brewers note that soft wheat malt has a more neutral beer taste impact.

Compared to barley malt, all wheat malt is characterized as smaller kernel sizing (especially hard red) but with higher extract (no husk). It is usually higher in protein than barley and is well-modified as indicated by S/T ratio, with higher FAN and soluble protein. Wheat malt will generally have higher finished malt color and moisture than barley malt.

Rye malting is very similar to wheat malting when compared to barley malting. A key issue is that rye kernels are even smaller than hard red wheat kernels. The malt outcomes are driven by a lower rye total protein, and even with a good S/T, the rye malt enzymes are lower. Rye malt will usually have a higher malt color than wheat malt.

Malting Summary

After selection of clean sound barley with high germinative capacity, the barley is cleaned of foreign seeds and other extraneous material. It is sized to remove any small and broken barley. The barley is then steeped in cool water in a 2 day process of alternating immersion and air rest periods to activate the embryo and to achieve 44–48% moisture. The hydrated barley is then germinated for 4–5 days in a temperature and moisture controlled environment. Both steeping and germination place the barley in the aerobic respiration state that requires management of the respiration moisture and oxygen demand, and the management of CO_2 and heat that is evolved. The germination proceeds until enzymes are created and the barley protein and carbohydrate cell structure has been simplified. After germination the green malt is kilned over 2 days to dry it to a stable state and to cure it to create color and flavor. The kilned malt is cooled and cleaned of rootlets, overgrown acrospires, and any loose light materials, and placed into storage.

In conclusion, the fundamentals of malting can be summed up to a malting mission statement. The malting mission is to comprehensively modify the barley kernel to create the malting and brewing enzyme package, to partially digest the barley kernel into simplified starch, and to digest the insoluble barley protein into the needed soluble protein for the brewing process. The germinated barley then must be kilned into finished malt for color and flavor optimization.

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