What to Expect When You're Extracting

Does the thought of calculating a grain bill for all-grain brewing make your head spin? How much grain should you use? Don't different grains have different yields? How do you decide?

The answer is a malt analysis sheet that you should be able to obtain from your homebrewing supply shop. These information sheets from the maltster describe the amount of extract that each lot of malt can yield. Unfortunately, calculating your OG from several malt analysis sheets is not as straightforward as for malt extract. When you target an OG with malt extract, it's as simple as multiplying the weight of the extract in pounds by its yield (36 gravity points per pound per gallon for liquid malt extract or 42/lb/gal for dry), and dividing by the recipe volume. For example, 6 pounds of liquid malt extract (36/lb/gal) for a 5-gallon batch equals an OG of 6 x 36 / 5 = 43.2 or 1.043. To calculate an OG from the yield information on a malt sheet, we will need to convert that information to potential gravity points and learn how to calculate an efficiency factor that tailors that yield to our own brewery. Once we understand malt yield and efficiency, we will be able to calculate a grain bill to hit any gravity.

Extract: Fine, Coarse, As-Is and Dry

While the concept of points per pound per gallon is easy to work with, a malt analysis sheet does not give the malt's yield in these units. Instead, what you will most likely see for North American and European malts is a number called "extract."

When a malting house analyzes a malt sample to determine its extract yield, it conducts a laboratory mash, sometimes known as a "Congress mash" (named for the European Brewing Congress, or EBC, of 1975 which first standardized the procedure). These days, both the U.S. and European brewing chemists use the same infusion procedure for this laboratory mash. The procedure mixes precise amounts of ground malt and distilled water to achieve a 45° C (113° F) rest. After 30 minutes, the mash temperature is raised 1° C (1.8° F) per minute until it reaches 70° C (158° F) where it is held for one hour. The resulting wort is weighed to determine the amount of soluble material extracted. The soluble extract is expressed as a percentage of the grain original weight.

So, "extract" tells the percent of grain weight that can be transferred to your wort as soluble extract. Simple enough—except that a given malt analysis may give extract in any one of four standards based on two possible grinds (fine or coarse) and two different moisture states (dry or as is). (See Figure 1) Before we can start to calculate a grain bill, we need to understand how these values are determined and the differences between them.

Fine Grind, Dry Basis (FGDB). This extract is considered the maximum possible soluble extract that the malt can yield when mashed. This is because the malt is ground more finely than it would be in normal brewing and the water weight is subtracted from the malt value in the calculations. Since moisture can vary between malts and between samples, this is the number you will most consistently see on an analysis as it corresponds to a malt that has been oven-dried to zero moisture.

Fine Grind, As-Is (FGAI). This measure is called "As-Is" because even properly kilned malt contains about 4 percent moisture by weight, although it can range from 2 to 10 percent. To compare different lots of malt with different moisture levels, the moisture content needs to be accounted for in the extract calculation. I will explain how to use these numbers in your OG calculations in a minute, but first let's look at the other extract parameters you may see.

Coarse Grind. Coarse grind represents a mill setting that is closer to what most breweries would use. The same mash method

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EXTRACT
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is used to determine a coarse grind, as-is (CGAI) extract and the moisture is measured separately to calculate the dry basis value. Most brewers consider the CGAI a more realistic number for gauging the extract potential of a malt, but it's still a laboratory value that very few professional breweries could attain in practice.

Coarse grind extract is not measured for most specialty malts due to the extra time and difficulty of filtering them (about two hours per sample). Since specialty malts usually represent only a small percentage of the grain bill, professional brewers are not as concerned about the yield of these malts. As a result, the standard parameter of FGDB is the value that is determined for specialty malts like caramel, chocolate and roast.

Fine/Coarse Difference. The F/C Difference value is simply the percent difference between the fine and coarse grind extract numbers. This value allows the brewer to quickly convert between the two parameters. For example, looking at the numbers for Munich malt in Table 1, the percent extract for coarse grind, dry basis, is 1.1 percent less than the percent extract fine grind, dry basis, as indicated. The F/C Difference also serves as an indicator of malt modification, although the soluble/total protein ratio is most often used. (See sidebar)

Hot Water Extract (HWE). This parameter may be seen on malt analysis from the UK, where they utilize a single temperature infusion mash method that differs from the ASBC and EBC Congress mash methods. HWE (As-Is) is measured as liter-degrees/kilogram, and as a unit, it is equivalent to points/lb/gal (gallon-degrees/pound) when the metric conversion factors for volume and weight are applied. (Combined Factor: HWE = 8.345 x points/lb/gal). However, the grind/mash procedures for HWE and percent extract differ enough that the measurements are not actually equivalent, even though they are close. The best analogy I can think of is trying to compare the power ratings of a race car to a farm tractor—power is power, but the way it is expressed and utilized is different. That being said, if you get a malt sheet for Pale Ale malt with an HWE (As-Is) of 308 liter°/kg, the conversion of that number by 8.345 to 37 points/lb/gal is close enough for homebrewing purposes.

Converting Extract to Points Per Pound Per Gallon

In a Congress mash, each grain will yield a maximum amount of fermentable and non-fermentable sugars that is referred to as its percent extract or maximum yield. This number typically ranges from 60 to 80 percent by weight, with some wheat malts hitting as high as 85 percent. For example, 80 percent extract means that 80 percent of the malt's weight is soluble in the laboratory mash. (The other 20 percent represents the husk and insoluble material.) In the real world, homebrewers will never hit this target, but it is useful for comparison.

The reference for comparison is pure sugar (sucrose) because it yields 100 percent of its weight as soluble extract when dissolved in water. One pound of sugar will yield a specific gravity of 1.046 when dissolved in 1 gallon of water. To calculate the maximum yield for the malts and other adjuncts, the extract for each is multiplied by the reference number for sucrose: 46 points/pound/gallon (points/lb/gal).

For example, let's look at the 2 Row Lager Malt in Table 1. This base malt has an FGDB of 81.7 percent. So, if we know that sugar will yield 100 percent of its weight as soluble sugar and that it raises the gravity of the wort by 46 points/lb/gal, then the maximum increase in gravity we can expect from this malt, at 81.7 percent soluble extract, is 81.7 percent of 46 or 37 points/lb/gal.

The extract data for several malts are listed in Table 1. You may be wondering how useful the maximum yield number of a malt can be if you can never expect to hit it. The answer is to apply an efficiency factor to the maximum yield and derive a number we will usually achieve—a typical yield.

Extract Efficiency and Typical Yield

The maximum yield is just that, a value you might get if all the mash variables (e.g. pH, temperature, time, viscosity, grind, phase of the moon, etc.) lined up and 100 percent of the starches were converted to sugars. But even commercial brewers don't get that value from their mashes. Most brewers will approach 80 to 90 percent of the maximum yield (i.e., 90 percent of a malt's extract of 81.7 percent). This percentage is referred to as a brewer's extract efficiency and is the ratio of his yield to the malt's maximum yield (FGAI). Every brewery is unique and your extract efficien-

Figure 1: Four Methods for Extract Representation

	Dry Basis	As-Is
Fine Grind	Fine-grind, dry	Fine-grind, as is
Coarse Grind	Coarse-grind, dry	Coarse-grind, as is

Table 1: Extract Analysis for Several Malts

The percentage of soluble extract by weight is given for several common malts with the equivalent value in points/pound/gallon (i.e., gallon•degrees/pound) given in parentheses.

Parameter	2 Row Lager Malt	2 Row Pale Ale	Munich Malt	Caramel 15	Caramel 75	Chocolate Malt	Roast Barley
% Moisture	4.4	3.9	4.0	7.9	4.8	3.5	3.3
% Extract, Fine Grind, As-Is (pts/lb/gal As-Is)	78.1 (36)	79.3 (37)	78.7 (36)	73.3 (34)	75.7 (35)	74.3 (34)	64.5 (30)
% Extract, Fine Grind, Dry Basis (points/lb/gal Dry)	81.7 (38)	82.5 (38)	82 (38)	79.6 (37)	79.5 (37)	77 (36)	66.7 (31)
% Extract, Coarse Grind, As-Is	77.1	78.5	77.6	—	—	—	—
% Extract, Coarse Grind, Dry Basis	80.6	81.7	80.9	—	—	—	—
F/C Difference	1.1	0.8	1.1	—	—	—	—
As-Is points/lb/gal at 80% Efficiency	29	29	29	27	28	27	24
Dry Basis points/lb/gal at 80% Efficiency	30	30	30	29	29	28	25

cy is dependent on your methods and equipment. I will show you how to calculate your efficiency in the next section.

In Table 1, we will assume an extract efficiency of 80 percent, which is considered good for homebrewers. A few points less yield (i.e. 75 percent efficiency) is still considered to be good extraction. A large commercial brewery would see the 5 percent reduction as significant because they are using thousands of pounds of grain a day. For a homebrewer, adding 5 percent more grain per batch to make up for the difference in extraction is a pittance. The last two lines of the table list the As-Is and Dry Basis points/lb/gal at 80 percent efficiency. The as-is value, which accounts for moisture, is preferred for estimating your yield, but it may not always be listed on an analysis. You can estimate the as-is value from the dry basis and percent moisture numbers on the malt analysis. If your extract efficiency is high, (near 90 percent), then you can figure on losing 1 point/lb/gal for every 3 percent moisture; if your efficiency is lower (about 75 percent), then you will lose 1 point/lb/gal about every 4 percent.

Calculating Your Efficiency

There are two different gravities that matter to a brewer. One is the extraction or boil gravity (BG), and the other is the post-boil or original gravity (OG). Most of the time, people refer to the OG because it determines the strength of the beer. When brewers plan recipes, they think in terms of the OG, which assumes that the wort volume is the final size of the batch, e.g. 5 gallons.

But when it comes to the extract efficiency, we want to think in terms of the boil gravity because that volume and gravity of wort is our actual yield. When all-grain homebrewers get together to brag about their brewing prowess or equipment and they say something like, "I got 30 (points/lb/gal) from my mash schedule," they are referring to their yield in terms of the amount of wort they collected.

You should realize that the total amount of sugar is constant, but the concentration (i.e. gravity) changes depending on the volume. To understand this, let's look at the unit of points/pound/gallon. This is a unit of concentration, so the unit is always expressed in reference to 1 gallon ("per gallon"). Another way of writing this unit is gallon-degrees/pound. When mashing, you are collecting "x" gallons of wort that has a gravity of "1.0yy" that was produced from "z" pounds of malt. To calculate your mash extraction in terms of points/lb/gal, you need to multiply the number of gallons of wort you collected by its gravity and divide that by the amount of malt that was used. This will give you the gravity (gallon-degrees) per pound of malt used. Let's look at an example.

Grainbill for Palmer's Short Stout

(Yield = 6 gallons of 1.038 wort)

6.5 lb of 2 Row
0.5 lb of Caramel 15
0.5 lb of Caramel 75
0.5 lb of Chocolate Malt
0.5 lb of Roast Barley
(8.5 lb total grain bill)

For our example batch, we will assume that 8.5 pounds of malt was mashed to produce 6 gallons of wort that yielded a gravity of 1.038. The brewer's total sugar extraction for this batch would be 6 gallons

Figure 2: Calculation of Potential Beer Gravity from Malt Bill

Malts	Max. points/lb/gal As-Is
6.5 lb of 2 Row	36 x 6.5/6 = 39
0.5 lb of Caramel 15	34 x 0.5 / 6 = 2.8
0.5 lb of Caramel 75	35 x 0.5 / 6 = 2.9
0.5 lb of Chocolate Malt	34 x 0.5 / 6 = 2.8
0.5 lb of Roast Barley	30 x 0.5 / 6 = 2.5
Maximum Yield (As-Is)	***50 points or 1.050***

Table 2: Converting Malt Analysis Values to Practical Recipe Yields

The first column gives percent extract numbers as you might find them on a malt analysis in any of the four forms: fine grind/dry to coarse grind/as-is. The second column gives the equivalent points/lb/gal assuming 100 percent efficiency of extraction during brewing. The remaining columns tell the points/lb/gal assuming various different practical extraction efficiencies during brewing.

% Extract from malt analysis (by any of the four methods)	100% Efficiency points/lb/gal	85% Efficiency points/lb/gal	80% Efficiency points/lb/gal	75% Efficiency points/lb/gal
85	39	33	31	29
84	39	33	31	29
83	38	33	31	29
82	38	32	30	28
81	37	32	30	28
80	37	31	30	28
79	36	31	29	27
78	36	31	29	27
77	36	30	28	27
76	35	30	28	26
75	35	29	28	26
74	34	29	27	26
73	34	29	27	25
72	33	28	27	25
71	33	28	26	25
70	32	27	26	24
69	32	27	26	24
68	31	27	25	24
67	31	26	25	23
66	30	26	24	23
65	30	26	24	23
64	30	25	24	22
63	29	25	23	22
62	29	24	23	21
61	28	24	23	21
60	28	24	22	21

multiplied by 38 points/gallon = 228 points. Dividing the total points by the pounds of malt gives us our mash extraction in points/pound e.g. 228/8.5 = 27 points/lb/gal. Comparing these numbers to lager malt's maximum 36 points/lb/gal (as-is) gives us a good approximation of our mash efficiency: 27/36 = 75 percent.

If we look at the maximum points/lb/gal as-is numbers from Table 1 for each of the recipe's malts, we can calculate our actual mash efficiency (See Figure 2):

In this case, our mash extraction of 1.038 means our actual efficiency was 38/50 = 76 percent. Table 2 lists the conversions of percent extract to points/lb/gal for efficiencies of 75, 80, 85 and 100 percent.

Planning Malt Quantities for a Recipe

We use the efficiency concept in reverse when designing a recipe to achieve a targeted OG. Here the question is: "How much malt do we need to produce five gallons of 1.050 wort?" To find out, let's go back to our Short Stout example.

1. First, we need to assume a brewing efficiency (let's say 80 percent) for our primary malt, which has a CGAI extract of 78 percent. Now we can calculate an anticipated yield.

78 percent x 80 percent x 46 (points/lb/gal/100 percent sucrose) = 28.7 points/lb/gal

2. Then we multiply the target gravity (50) by the recipe volume (5) to get the total amount of sugar the recipe will require:

5 gal x 50 points = 250 lb-pts.

3. Dividing the total points by our anticipated yield (28.7 points/lb/gal) gives the pounds of malt required:

250 / 28.7 = 8.7 pounds.
(We'll call it 9 pounds.)

4. So, 9 pounds of malt will give us our target OG in 5 gallons. Using the malt values for 80 percent efficiency in Table 1, we can figure out how much of each malt to use to make up our recipe. You can build a grainbill "top-down" or "bottom-up"—meaning that you can plan the bulk of your

Malt Modification in a Nutshell

One topic that new all-grain brewers will often hear about, and one that even experienced all-grainers may not have a clear understanding of, is malt modification. Here's a brief explanation.

The starches that a brewer wants to convert to sugars by mashing are locked within the seed in a protein-carbohydrate matrix in the *endosperm*. During malting, the grain germinates and enzymes in the seed begin unlocking this matrix to make the nutrients available for growth of the new plant. The purpose of malting is to allow germination to proceed just far enough to liberate the starch for the brewer to use without letting the plant use it all up first. The degree to which the starch is liberated is called the *modification*. The more the barley kernel is modified during malting, the easier it is for the enzymes to access and convert the starches to sugars during mashing. Thus, a small Fine/Coarse Grind Difference indicates that the starches are readily accessible in the coarse ground condition and that the malt is probably well modified. But the F/C Difference is not the whole story.

The most common indicator of malt modification is the Soluble to Total Protein Ratio (S/T ratio), also known as the Kolbach Index. To generalize, a ratio of 36 to 40 percent is a less-modified malt, 40 to 44 percent is a well-modified malt and 44 to 48 percent is a highly modified malt. Less-modified malts may require decoction mashing where boiling of portions of the mash and multiple temperature rests help to fully solubilize and convert the starches. Well-modified malts may benefit from multiple temperature rests during mashing, but can be fully converted using a single temperature rest. Highly modified malts can easily be converted using a single temperature rest.

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fermentables from the base malt first and adjust the specialty grains to make up the rest, or you can plan your specialty grain additions first and use the base malt to complete the OG. I generally use the bottom-up approach and, for this example, I am going to use a half-pound of each specialty malt, and then calculate how much base malt I need to hit my target gravity.

Specialty Malt OG Contributions based on points/lb/gal, As-Is at 80 Percent Efficiency

Caramel 15	.27 x 0.5 / 5 = 2.7
Caramel 75	.28 x 0.5 / 5 = 2.8
Chocolate Malt	.27 x 0.5 / 5 = 2.7
Roast Barley	.24 x 0.5 / 5 = 2.4
	10.6 points out of 50

To calculate how much base malt is required, subtract the specialty malt contribution from the total, multiply that amount by the recipe volume and divide that by the base malt's 80 percent points/lb/gal number (29).

(50 - 10.6) x 5 gal. ÷ 29 = 6.8 lbs of base malt, which I would round up to the nearest half pound for convenience (7 lbs.)

Thus, the grainbill for Palmer's Short Stout, based on these particular lots of malt and 80 percent extract efficiency is:

Grain Bill for Palmer's Short Stout

2 Row Lager malt	**7 lbs.**
Caramel 15	**0.5 lbs.**
Caramel 75	**0.5 lbs.**
Chocolate Malt	**0.5 lbs.**
Roast Barley	**0.5 lbs.**
For a total of	**9 lbs.**

Remember though that this is the OG—the post-boil gravity. When you are collecting your wort and are wondering if you have enough, you need to ratio the measured gravity by the amount of wort you have collected to see if you will hit your target after the boil. For instance, to have 5 gallons of 1.050 wort after boiling, you would need (at least):

6 gallons of 1.042 (250 pts/6 gal.)
or 7 gallons of 1.036 (250 pts/7 gal.)

Summary

So there you have it: the key to understanding malt yield, extract efficiency and determining your grain bill for all-grain brewing. A malt analysis sheet will list the maximum yield as percent extract and we can convert that weight percentage to specific gravity points via the 46 points/lb/gal of sucrose. By comparing the collected wort gravity with maximum calculated yield, we can determine our extract efficiency, and by knowing our efficiency, we can calculate a grain bill for any wort we want to brew. Cheers!

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