All About Efficiency in the Brewery

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Why Care About Efficiency?

- Reliably predicting efficiency => reliably hitting your target gravities
- Is there an optimum efficiency?
  - Sort of
  - Under-efficient
    - Wasted ingredients
    - Higher costs
    - Negligible at home brew scale
  - Over-efficient
    - Potential for over sparging
    - Can lead to excess tannins, poor quality
  - It is like seeing the Grand Canyon – get as close to edge as you care to, but don’t go over.

Where to measure?

Mash Tun

How well did you change starch into sugar?

Boil Kettle

How well did you rinse the sugar from the grain?

System Efficiency

How well does your overall brewing process work?

This is of interest if you are worried about cost. We will not cover it in this presentation.

What is Efficiency? It is Simple:

$$\frac{\text{How much sugar you got}}{\text{How much sugar is available to get}}$$

How Much Sugar Is Available?

- Grain potential – often given as “Points per pound per gallon”
- Personally not a fan of PPPPG, but worth knowing how it works
- Typical numbers…
  - Base malt – 36
  - Crystal malt – 34
  - Chocolate malt – 28
  - Etc…
- Where do they get these numbers? It is more complicated than you might think

It All Starts With, Well, Sugar!

- Efficiency is measured relative to sugar, because…
- Sugar is essentially 100% soluble, nothing can be more efficient
  - Note: there are lots of kinds of sugar (i.e. sucrose, dextrose, maltose, etc.)
  - For our purposes, it is all just sugar (also called ‘extract’)
- What happens when you add a pound of sugar to one gallon of water?
- We have to do some math…

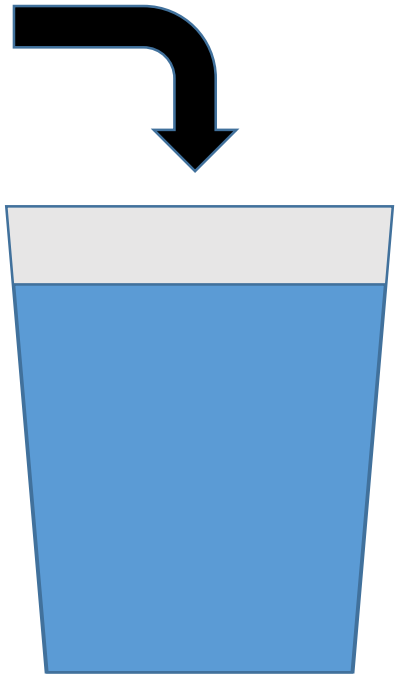
Avert Your Eyes: Some Math

- First the easy bit:
  - One gallon of water weights 8.34 lb.
  - One pound of sugar weighs 1.0 lb.
  - 1 lb. sugar + 8.34 lb. water = 9.34 lb.
- By definition, degrees Plato is the amount of sugar in wort, by weight
  - (1 lb. of sugar) ÷ (9.34 lb. of wort) x 100 = 10.7 °P
    - i.e., 10.7% of the weight of the wort is sugar
  - Convert 10.7° P into 1.043 s.g., or 43 gravity points
    - This is a standard conversion, charts and formulas readily available
  - So it looks like one pound of sugar gives 43 ppppg, right???
  - Not exactly…

The Real Sugar PPPPG is 46

And here is why…

Pound Sugar



Gallon of Water

Volume Increases

1.07 Gallons Wort

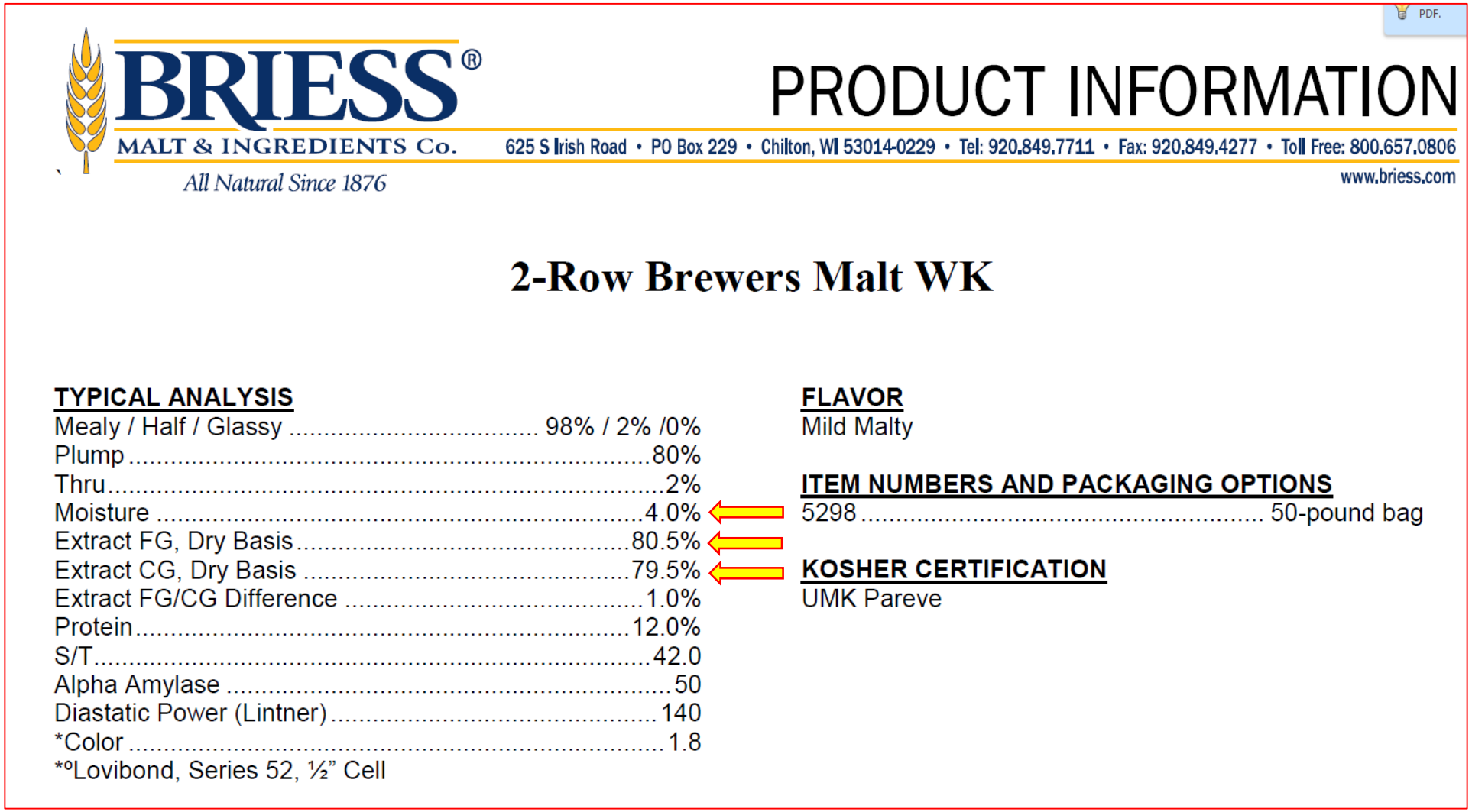
43 Points

Normalize to 1 Gallon

1 Gallon Wort

46 Points

PPPPG for Malt…



BRIESS®
MALT & INGREDIENTS Co.
All Natural Since 1876

PRODUCT INFORMATION

625 S Irish Road • PO Box 229 • Chilton, WI 53014-0229 • Tel: 920.849.7711 • Fax: 920.849.4277 • Toll Free: 800.657.0806
www.briess.com

2-Row Brewers Malt WK

TYPICAL ANALYSIS

Mealy / Half / Glassy	98% / 2% /0%
Plump	80%
Thru	2%
Moisture	4.0%
Extract FG, Dry Basis	80.5%
Extract CG, Dry Basis	79.5%
Extract FG/CG Difference	1.0%
Protein	12.0%
S/T	42.0
Alpha Amylase	50
Diastatic Power (Lintner)	140
*Color	1.8

*°Lovibond, Series 52, ½" Cell

FLAVOR
Mild Malty

ITEM NUMBERS AND PACKAGING OPTIONS
5298 ..... 50-pound bag

KOSHER CERTIFICATION
UMK Pareve

Figuring PPPPG for Malt

- ASBC (American Society of Brewing Chemists) set standards for testing
- Malts are testing in the lab by grinding them up, making wort, and determining how much sugar (extract) it yields
- Note FG = Fine Grind
  - Grain is ground to a powder and converted, not practical for brewing
- CG = Coarse Grind
  - More like the brewing environment
- Note both tests are “dry basis” i.e., all moisture dried from malt

Figuring PPPPG for Malt

- So, in theory the maximum yield for Briess 2 Row is
  - 46 x 80.5% = 37.0 ppppg (FGDB, fine grind dry basis)
- But since you don’t grind your malt to a powder,
  - 46 x 79.5% = 36.6 ppppg (CGDB, coarse grind dry basis)
- And since your malt holds some moisture
  - 46 x 79.5% x 96% = 35.1 ppppg

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PRODUCT INFORMATION

Caramel Malt 20L WK

TYPICAL ANALYSIS

Mealy / Half / Glassy	0% / 5% / 95%
Plump	70%
Thru	5%
Moisture	6.0%
Extract FG, Dry Basis	73.0%
*Color	20

*°Lovibond, Series 52, ½" Cell

FLAVOR
Candy-like Sweetness, Mild Caramel

COLOR CONTRIBUTION
Golden

ITEM NUMBERS AND PACKAGING OPTIONS
5360 ..... 50-pound bag

STORAGE AND SHELF LIFE
Best if used within 6 months from date of manufacture.
Store at temperatures of <90 °F.

KOSHER CERTIFICATION
UMK Pareve

- Caramel 20 = 46 x 73% = 33.6 ppppg
- Notice 6% moisture = so 33.6 x 94% = 31.6 ppppg
- Note extract is FG, so real yield probably slightly lower

Real World Mash Efficiency

- These yields are the maximum you can expect
- In practice the yields are lower
- Typical conversion values in my brewery is 85% to 90% of expected CG moist yield, or 30 to 31 ppppg
- How can you measure your mash conversion efficiency?

Real World Example, Batch 304

Grain Bill	Weight lb	Maximum Extract Percent	Maximum Extract lb
English Pale Malt	5.07	81.5%	4.13
Crystal 120	0.26	75.0%	0.20
Total	5.33	81.2%	4.33
		37.3 ppppg	

- Water added for mash = 3.6 gallons or 30.2 lb
- Maximum expected °P = 4.33 ÷ (4.33 + 30.2) = 12.5 °P or 1.051 sg
- Observed sg = 1.044 or 11.0 °P
- Starch Conversion Efficiency = “44 points” ÷ 51 “points” = 86%

Note: I batch sparge and measure the gravity in the kettle after first runoff. If you fly sparge you will need to measure gravity in mash. Beware of stratification.

Lautering Efficiency

- The second part of efficiency is lautering efficiency
- Lots of ways to lauter:
  - Fly (continuous sparge)
  - Batch sparge (mash, drain, refill, drain)
  - No sparge
  - Brew in a bag
- None of these methods are inherently better or worse, key is to avoid over-sparging which can extract tannins (fly sparging is probably the most likely way to do this)

Lautering Efficiency, Batch 304 Continued

- Since the starch conversion efficiency is 86%, the maximum amount of sugar I can get out of the grain is:
  - 4.33 lb x 86% = 3.72 lb

    <Assuming I rinse 100% of that sugar from the grain>
- Actual yield was 5.4 gallons of wort at 7.4 °P / 1.029 sg
- Total weight: 5.4 gallons x 8.34 lb/gal x 1.029 = 46.3 lb.
- Sugar weight = 46.3 lb x 0.074 = 3.43 lb
- Lautering efficiency = 3.43 lb ÷ 3.72 lb = **92%**
- Overall Batch 304 Yield = 29 x 5.4 ÷ 5.33 = **29.4 PPPPG**

What was the Percent Efficiency for the Batch?

- How much sugar was in the wort, pre boil, versus what was the maximum possible?
  - So in this case
    - 3.43 lb in wort (29.4 ppppg)
    - 4.33 lb possible (37.3 ppppg)
    - **Efficiency = 79%**
  - Reliably predicting your starting gravities requires you know your ‘Starch Conversion Efficiency’, which should be relatively consistent batch to batch
  - However you also need to understand how lautering efficiency varies with batch size…

Lautering Efficiency vs. Batch Size

- Your efficiency changes with the size of the batch (assuming the same wort volume)
- Example: assume we are making two different single malt worts
  - Use 10 lb of grain in Batch 1, 20 lb in Batch 2
  - Assume FGDB extract = 80%
  - Assume our starch conversion is 85%
  - Target 6 gallons of wort, preboil
  - Assume “Brew in a Bag” or “No Sparge” method (but it applies to all)
- Assume grain holds about 0.15 gallons of water per pound of grain, which is what I typically get

A Tale of Two Batches…

	Batch 1	Batch 2
Target Volume (gallons)	6.0	6.0
Grain Weight (lb)	10.0	20.0
Water Absorbtion (gal/lb)	0.15	0.15
(gal)	1.5	3
Total Water Needed (gal)	7.5	9.0
FGDB Yield	80%	80%
Maximum PPPPG	36.8	36.8
Conversion Efficiency	85%	85%
Sugar Yield (lb)	6.8	13.6
Total Weight Wort (lb)	69.4	88.7
°P	9.8	15.3
sg	1.039	1.063
PPPPG	23.4	18.9
Overall Efficiency	**64%**	**51%**

The only way to compensate for this is to use **more water** and then **boil longer…**

Conclusions

- Efficiency, by itself, does not normally have much impact on beer quality
- Knowing how to manipulate the parameters related to efficiency can help you consistently hit target gravities
- If you are interested to learn more, give me holler. I have some pretty complex spreadsheets for predicting efficiency using the models presented here…