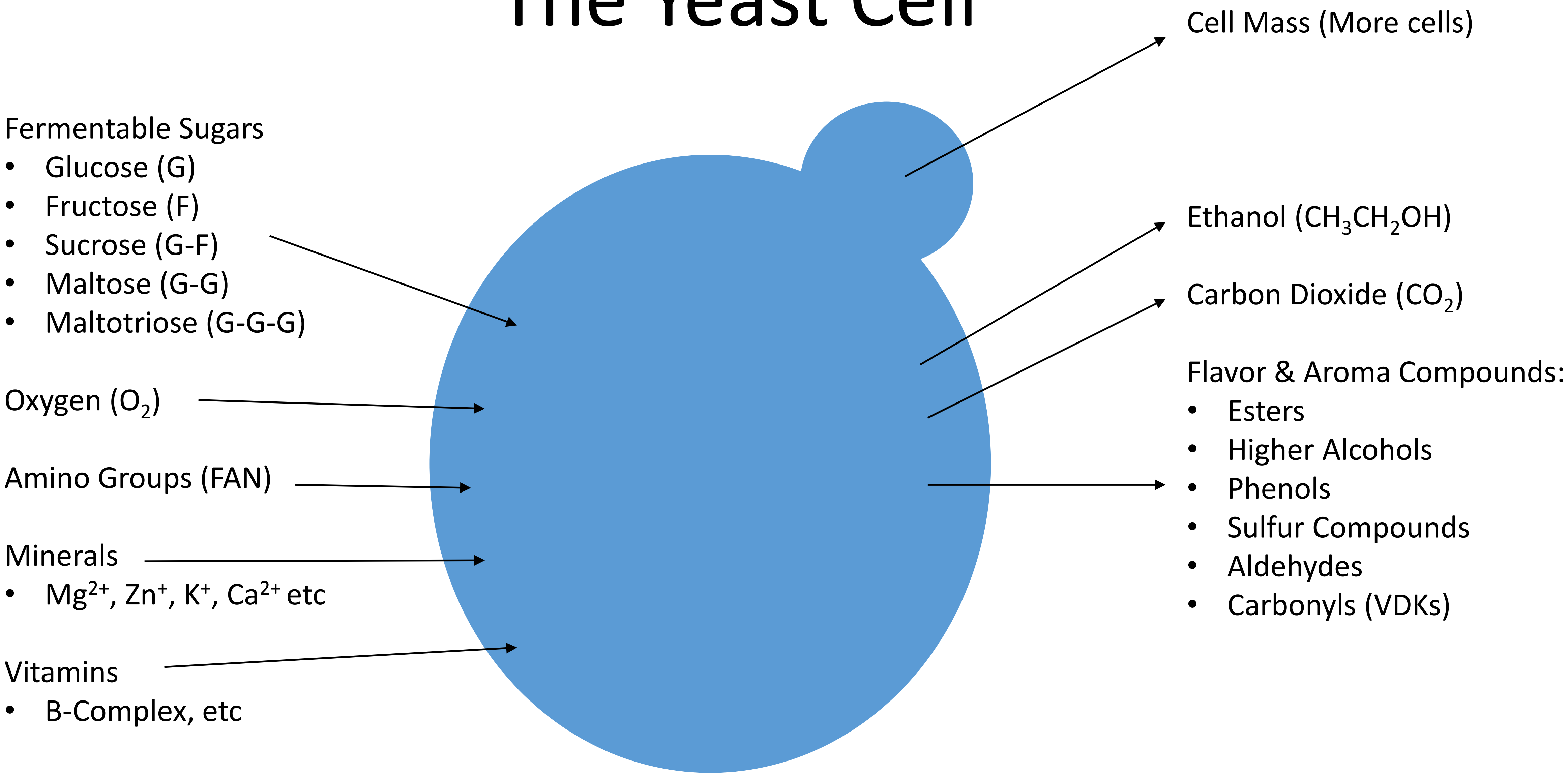
Diacetyl:
Production and Reduction

The Yeast Cell

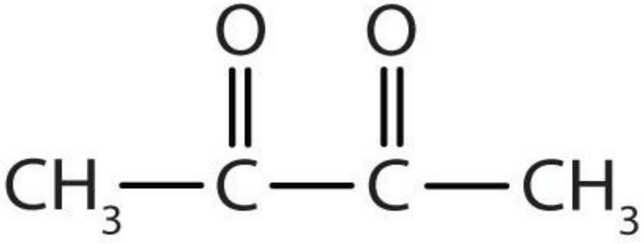


Vicinal Diketones (VDKs)

- 2,3 Butanedione (Diacetyl)

Flavor: Butterscotch/Buttered Popcorn

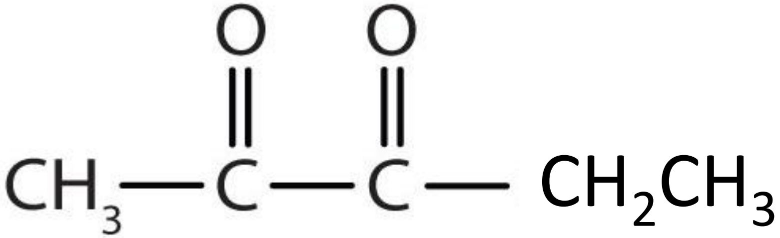
Flavor Threshold: ~ 0.1 mg/L



- 2,3 Pentanedione

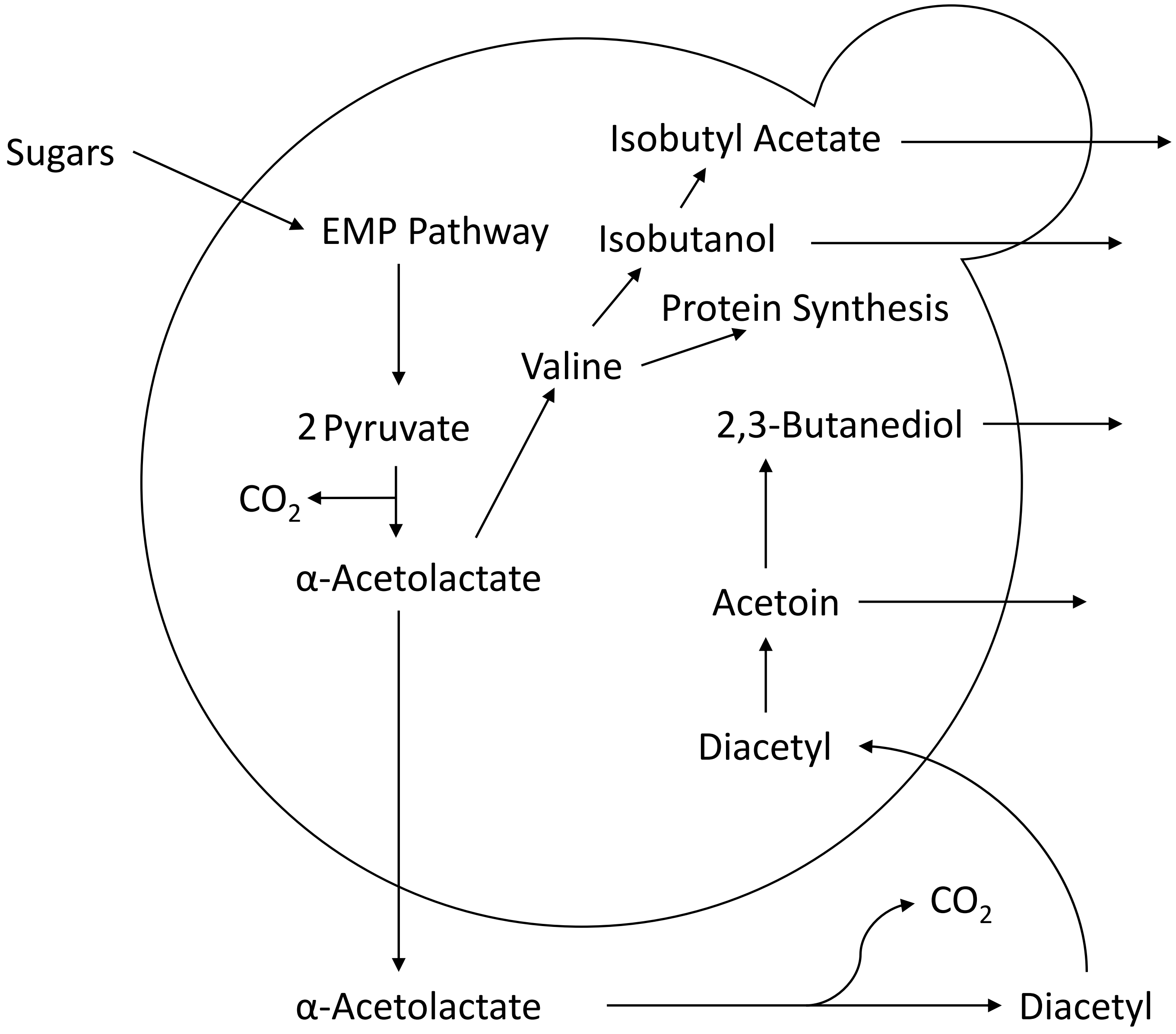
Flavor: Honey-like

Flavor Threshold: ~ 1.0 mg/L



In addition to the above flavors, both compounds will also provide a slickness or slipperiness to the mouthfeel of the beer

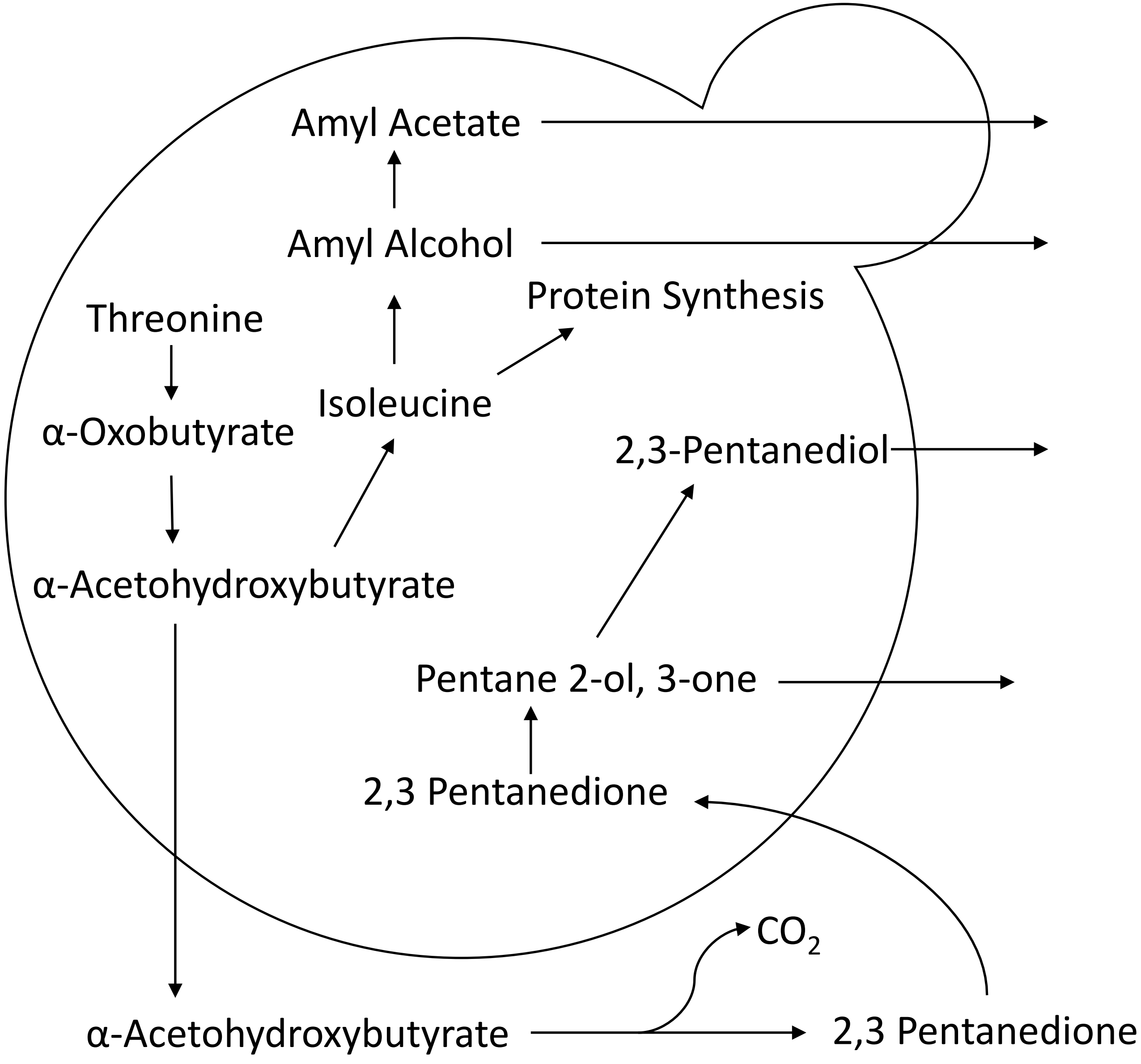
Biochemical Pathway of Diacetyl Production & Reduction



- Sugars enter cytoplasm. EMP Pathway begins
- Pyruvate creation w/ 2 ATP
- α-Acetolactate created from 2 Pyruvates for Valine Synthesis by Acetolactate Synthase (loss of CO_2)
- Valine utilized for protein synthesis or proceed via Ehrlich Pathway to the Higher Alcohol Isobutyl Alcohol and released. This process can continue with Ester synthesis to create Isobutyl Acetate
- Excess α-Acetolactate excreted from cell into green beer
- Spontaneous (non-enzymatic) Decarboxylation into 2,3-Butanedione (Diacetyl)
- Diacetyl reabsorbed by cell
- Diacetyl reduced to Acetoin by Diacetyl Reductase for NAD^+ regeneration and excreted
- Acetoin reduced to 2,3-Butanediol by Acetoin Reductase and excreted

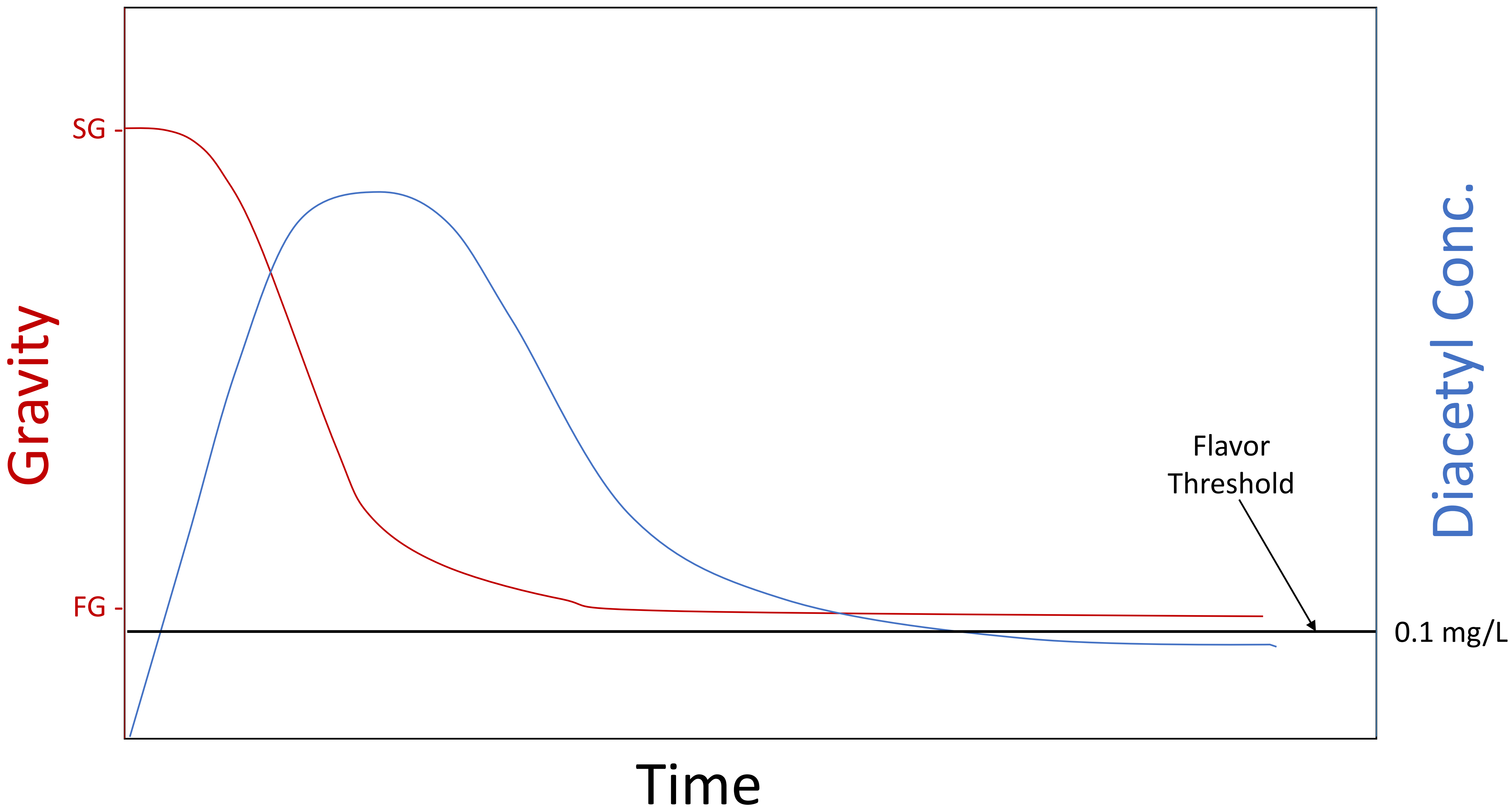
NAD^+/NADH: Redox coenzymes containing Niacin (B3) that participate in glycolytic pathways, aerobic pathways, and with dehydrogenase enzymes

Biochemical Pathway of 2,3 Pentanedione Production & Reduction



- The amino acid Threonine is converted via transamination to α-Oxobutyrate (also called 2-Ketobutyric Acid)
- α-Acetohydoxybutyrate created from α-Oxobutyrate for Isoleucine synthesis
- Isoleucine utilized for protein synthesis or proceed via Ehrlich Pathway to the Higher Alcohol Amyl Alcohol and released. This process can continue with Ester synthesis to create Amyl Acetate
- Excess α-Acetohydroxybutyrate excreted from cell into green beer
- Spontaneous (non-enzymatic) Decarboxylation into 2,3-Pentanedione
- 2,3 Pentanedione reabsorbed by cell
- 2,3 Pentanedione is broken down into Pentane 2-ol, 3-one and excreted from cell
  - Pentane 2-ol, 3-one broken down into 2,3 Pentanediol and excreted from the cell

Fermentation Profile With Total Diacetyl Overlay



Methods to test VDK levels in beer

- Gas Chromatography
- The simple (cheap and easy!) test:

1. Take 2 samples of beer and cover.
2. Leave one at room temp and heat the other to ~150 °F for 10 minutes.
3. Cool back down to room temperature. Swirl and smell both.
4. If both are negative: Ready for packaging.
5. If only the heated sample is positive, a short period of aging is needed (1-2 days likely, more for lower temp lager).
6. If both are positive, much more time is needed (several days+)

Get to know your yeast!

How are levels of Diacetyl increased/decreased in beer?

- Yeast Variety – The British Ringwood Yeast Cult
- Yeast Viability – Dead yeast tell no tales. Nor do they do anything else of worth! Strive for 95+% Viability.
- Yeast Vitality – Think of your Division I basketball team vs your local Nursing Home. Sure they're both alive, but can they both run up and down the court? Higher generations of yeast usually have longer fermentation profiles
- Pitching Rate – Lower total quantity of yeast will tend to slow Diacetyl breakdown. Kräusening?
- Yeast Flocculation – Highly flocculant yeast strains drastically reduce surface area for the yeast to interact with the green beer. Think of the surface area interaction of a Hefeweizen vs. traditional English yeast strain. Rousing?
- Fermentation Temperature – The higher the fermentation temperature, the higher Diacetyl production. Luckily, this also quickens reduction into 2,3-Butanediol due to the Arrhenius Principle. Raise temp at end of primary?
- Wort Aeration – Providing sufficient Oxygen to wort is important on many levels as a brewer must insist on building strong fatty acids and sterols for the cell/organelle membranes, especially with multiple generations. Low aeration can cause a higher quantity of Diacetyl in the beer.
- Nutrient Deficiency – Low FAN (low malt mod./high adjunct), low vitamins, etc can increase Diacetyl quantities in beer.
- Micro Contamination – Gram positive bacteria Pediococcus and Lactobacillus in kegs, draftlines, etc. Also Hafnia protea and Enterobacter
- ALDC Enzyme – α-Acetolactate Decarboxylase converts α-Acetolactate directly to Acetoin.
- Time! – Allow your yeast the proper time to fully complete fermentation and Diacetyl breakdown (The Diacetyl Rest).

Additional Reading

- Diacetyl in Fermented Foods and Beverages
  by Takashi Inoue
- Technology Brewing & Malting, 5th Ed.
  by Kunze. Pages 397-400
- Brewer's Yeast (The Blue Book)
  by The Institute of Brewing. Pages 51-54
- Yeast
  by White. Pages 37-38, 111-113
- Brewing
  by Lewis. Pages 334, 336-337
- MBAA Practical Handbook for the Specialty Brewer, Volume 2
  By MBAA. Pages 26-32
- Malting and Brewing Science, Volume 2
  by Hough, Briggs, Stevens, & Young. Pages 595-596

Questions?