

Yeast Metabolism and Flavor Impacts

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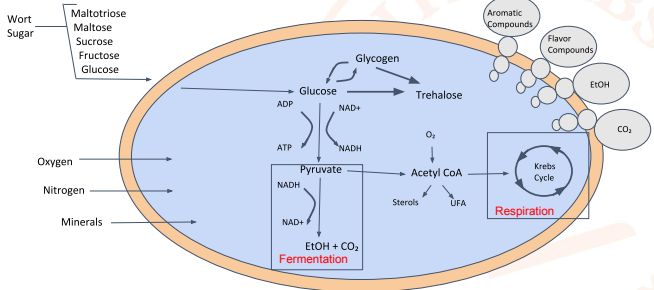
Introduction to White Labs?

- Started in 1995 in San Diego
- Liquid yeast provider for home and professional users
- Yeast, bacteria, enzymes, nutrients, beer, education

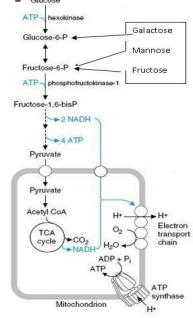


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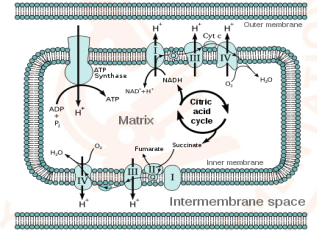
Overview of Yeast Metabolism



Respiration



The goal of a yeast cell is not to produce alcohol but to survive and reproduce



Requirements for Fermentation:

Yeast Nutrition

- Carbohydrates (carbon source: malt sugars)
- Amino acids (nitrogen from malt)
- Minerals (from malt and brewing water)
- Vitamins (from malt)
- Oxygen (from aeration or agitation)

Yeast Nutrition

Nitrogen

- Used in production of proteins → protein complexes for cell wall components, enzymes
- In the form of FAN (free amino nitrogen) or amino acids
- Ideally, 100-150ppm FAN
- All-malt wort IS usually sufficient in amino acid content, unless high gravity
- High adjunct brewing will require additional

Yeast Nutrition

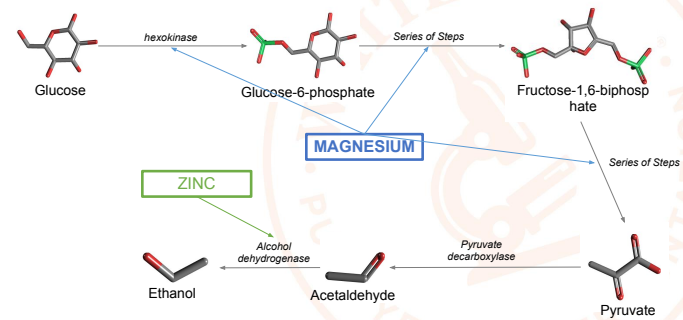
Minerals

- Magnesium → cofactor for yeast metabolic enzymes
- Zinc → specific cofactor for alcohol dehydrogenase
- Calcium → essential in yeast flocculation pathway
- Manganese and Potassium (trace)

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Yeast Nutrition

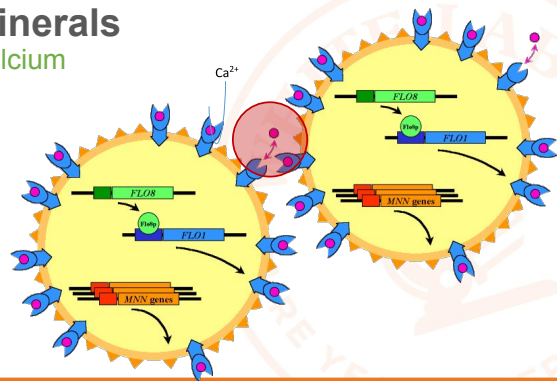
Minerals



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Minerals

Calcium



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Yeast Nutrition

Oxygen

- Oxygen needed to synthesize sterols and fatty acids
- Essential components of yeast cell membrane
- Yeast is only capable of growth under anaerobic conditions if a surplus of sterols is available
- Yeast growth is sterol-limited

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Yeast Nutrition

Oxygen

- Requirements are strain-dependent
- Generally 8-10ppm for moderate gravity wort (higher with increasing gravity)
- Without adequate supply → low vitality → poor fermentation performance
- Especially important in later generations when yeast are in an anaerobic physiological state

Quality of Yeast

- Yeast can be new, first generation, or reused from a previous fermentation
- Yeast can be reused 5-10 times
- Add a specific amount of yeast to freshly oxygenated wort, at the correct fermentation temperature
- Pitch more yeast for high gravity beers

Low Pitching Rates	High cell growth	Increased flavor compounds
High Pitching Rates	Low cell growth	Decreased flavor compounds

Fermentation Temperature

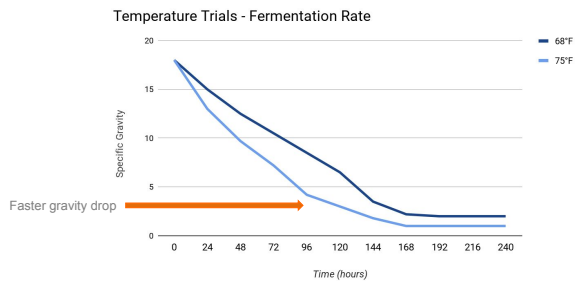
One of the Most Important Control Factors

- Temperature affects both yeast metabolism and the speed of fermentation
- Most *S. cerevisiae* strains are optimal between 65-70°F (18-21°C), but there is a wide range
- Higher or lower temperatures can lead to varying fermentation effects

Temperature Control Matters to Flavor

Compound	75°F	66°F	Threshold
Ethanol	5.04% abv	4.74% abv	1.4% abv
1-Propanol	22.76 ppm	23.78 ppm	600 ppm
Ethyl Acetate	33.45 ppm	22.51 ppm	30 ppm
Iso-amyl alcohol	114.92 ppm	108.43 ppm	70 ppm
Total Diacetyl	8.23 ppb	7.46 ppb	150 ppb
Total 2,3-pentanedione	3.17 ppb	5.09 ppb	900 ppb
Acetaldehyde	152.19 ppm	7.98 ppm	10 ppm

Fermentation Temperature Effects on Fermentation Rate



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Flavor Active Compounds

- Apart from ethanol and CO₂, yeast contribute significantly to the flavor and aroma of beer
 - Esters
 - Alcohols (fusel)
 - Vicinal diketones (diacetyl, 2,3-pentandione)
 - Aldehydes (primarily acetaldehyde)
 - Phenols
 - Organic acids
 - Sulfur compounds
 - Fatty acids

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Yeast Flavor & Aroma

- Remain at levels produced after primary fermentation
 - Esters
 - Higher alcohols
 - Sulfur dioxide
 - Phenols
- Decline during beer maturation
 - Acetaldehyde
 - Diacetyl

Esters

Flavors - fruity, banana, apples, perfume, solvent, nail polish remover

Formation:

- Reaction of alcohol group and acid group in the yeast cell
- Alcohol part comes from ethanol and fusel alcohols
- Acid part comes from various acids that are inside the yeast (acetyl-CoA compounds)
- Reaction is catalysed by an enzyme (alcohol acetyltransferase)



Higher (Fusel) Alcohols

Flavor - alcoholic, spicy, vinous, warm

Formation:

- Intermediates in amino acid metabolism
- Produced during uptake of amino acids
- Produced from glucose when yeast needs to make amino acids
- Directly related to yeast growth



Sulfur Compounds

Flavor – sulfuric, rotten eggs, burnt rubber, striking a match

Formation:

- Intermediates in amino acid metabolism
- When yeast needs to make sulfur containing amino acids

Control:

- Wort oxygen content (more is better)
- Fermentation temperature
- Yeast "health"



Phenols



Phenolic Off Flavor (POF):

- POF positive yeasts are generally unwanted in brewing (wild yeast characteristics)
 - **There are exceptions** - Bavarian Hefeweizen style where the phenol, 4-Vinyl Guaiacol, is a desired compound due to its clove character as well as in some Belgian beers

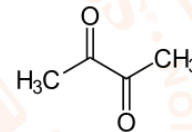
Flavor – Clove, solvent, plastic, band aid, smoke (Wild/Belgian!)

Formation:

- During primary fermentation
- POF positive yeasts decarboxylate cinnamic acid derivatives in wort to produce vinylphenols

Diacetyl

Flavor – Buttered popcorn, butterscotch, yogurt, slick mouthfeel



Formation:

- Precursor (α -AL) produced during primary fermentation
- α -AL is converted to diacetyl outside cell
- Diacetyl is again taken up and metabolized by yeast during maturation
- Reaction related to amino acid synthesis
- pH and temperature dependent



Acetaldehyde

Flavor – Grassy, green apples, avocado, squash

Formation:

- During primary fermentation, then reduced during maturation
- Intermediate of alcoholic fermentation pathway
- Metabolized to ethanol during maturation

Control:

- Healthy yeast
- Adequate conditioning time
- Temperature

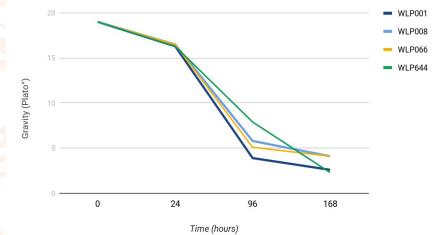


Fermentation Monitoring Do Experiments!

Brewers can make more informed decisions with this type of data!

- Alcohol
- IBU
- Attenuation
- Specific gravity
- Calories
- Diacetyl
- Wild yeast contaminants
- Bacteria contaminants

Tabberer IPA Fermentation Data



Questions?



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