# Balancing Acts in the Production and Selection Decisions of Malt to Promote Beer Flavor Stability

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# Contents

# Common malt-derived staling mechanisms – manifestation dependent on beer style

Thermal load

- From sugars
- To aldehyde, e.g. **furfural**

Strecker Degradation

- From amino acids
- To **Strecker aldehydes**


Enzymatic (LOX, POD)

- From fatty acids
- To aldehyde, e.g. **T2N**

# Common malt-related beer staling phenomena and the underline mechanisms in malting

| Manifestation of beer staling | Susceptible beer types | Mechanism | Malt factor and cause |
| --- | --- | --- | --- |
| **Caramel-like, sweet, malty, butterscotch** | **Darker** beers | **Thermal load** promotes formation of furfural and hydroxymethylfurfural (HMF) | **Heating** of sugar-containing ingredients in malt kilning or roasting |
| **Sherry, soy sauce, meaty, cooked potato or almond-like** | **All-malt** or malt-rich beers | **Strecker Degradation** of amino acids | Excessive **FAN** to yeast assimilation |
| **Papery, fatty, cardboard-like** | **Adjunct** lagers, light beers | Precursors of trans-2-nonenal (T2N) formation catalyzed by **LOX** | **LOX** level and peroxidases (POD) from malt |
| | | **Free radical** catalyzed oxidation of unsaturated fatty acids like linoleic acid | **Oxygen radicals** or active metal ions trigger non-enzymatic oxidations |

# EPR for measuring free radical reactions

**Beer component (RH) + Oxidant**

⇩

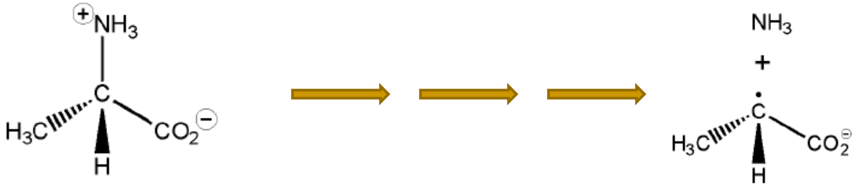
**Beer free radicals (R. + RO. + ROO.)**

⇩

**Oxidized beer components**
(aldehydes, ketones etc.)

- **Electron paramagnetic resonance (EPR)**, spectroscopically tracks the free radicals
- Free Radical Production in presence of O2 with UV, Fe, Cu .OH, ROO.
- Predicts the likelihood of oxidation

Barr *et al* 2005



Alanine

Long-lived paramagnetic species

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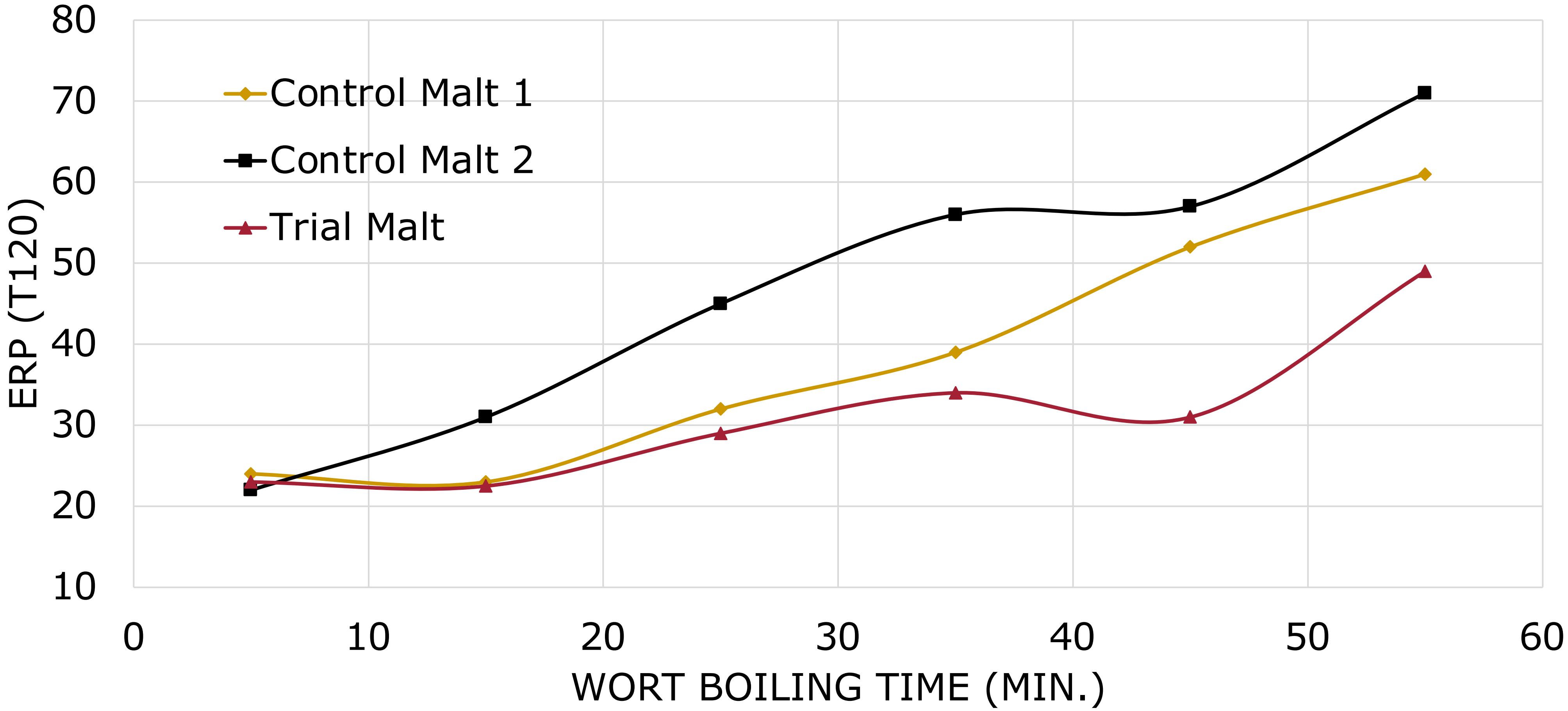
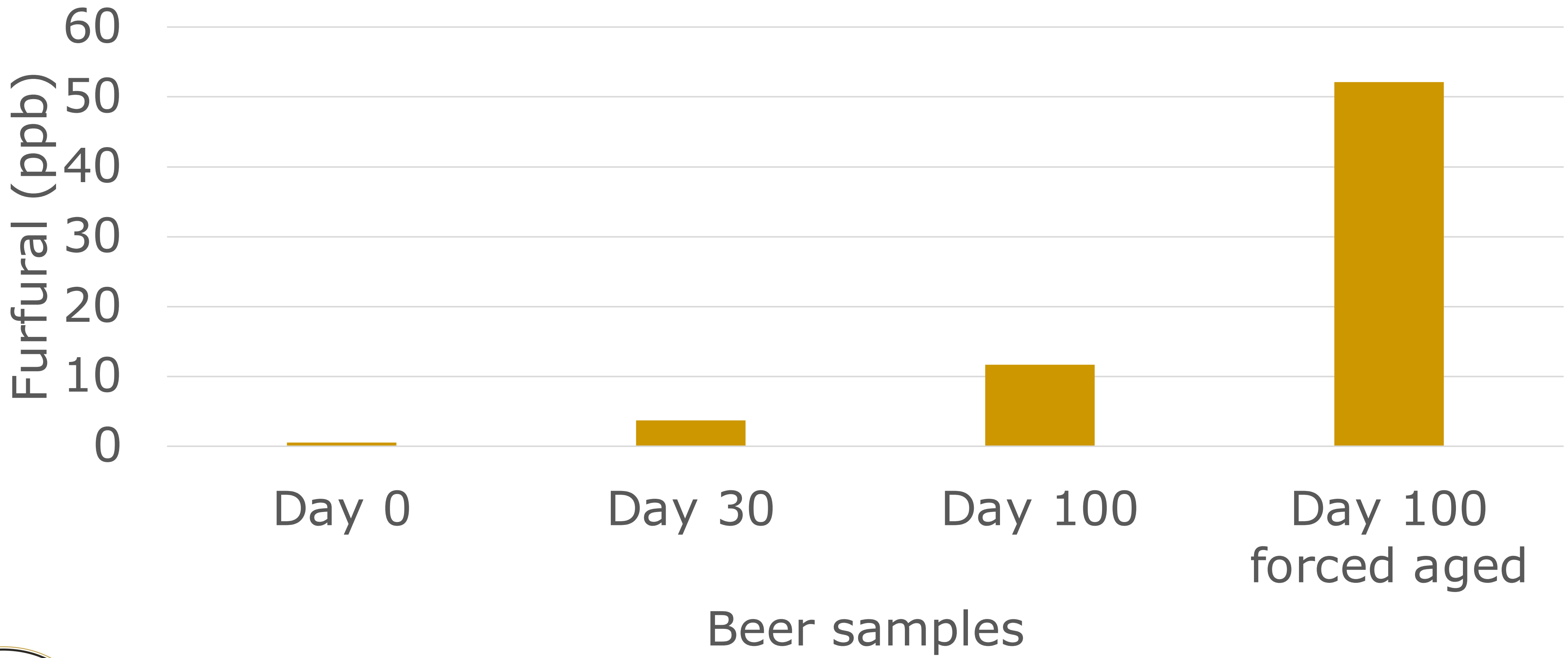
- Introduction to malt-derived staling mechanisms
- **Impact of thermal load**
- Lipoxygenase (LOX) in malt and impact on beer T2N
- Amino acids and Strecker Degradation
- Summary - Balancing acts in malting

# Free radical development (EPR values) during wort boiling

## - Trial malt was more resistant to radical formation than the control malts (Yin, 2012)



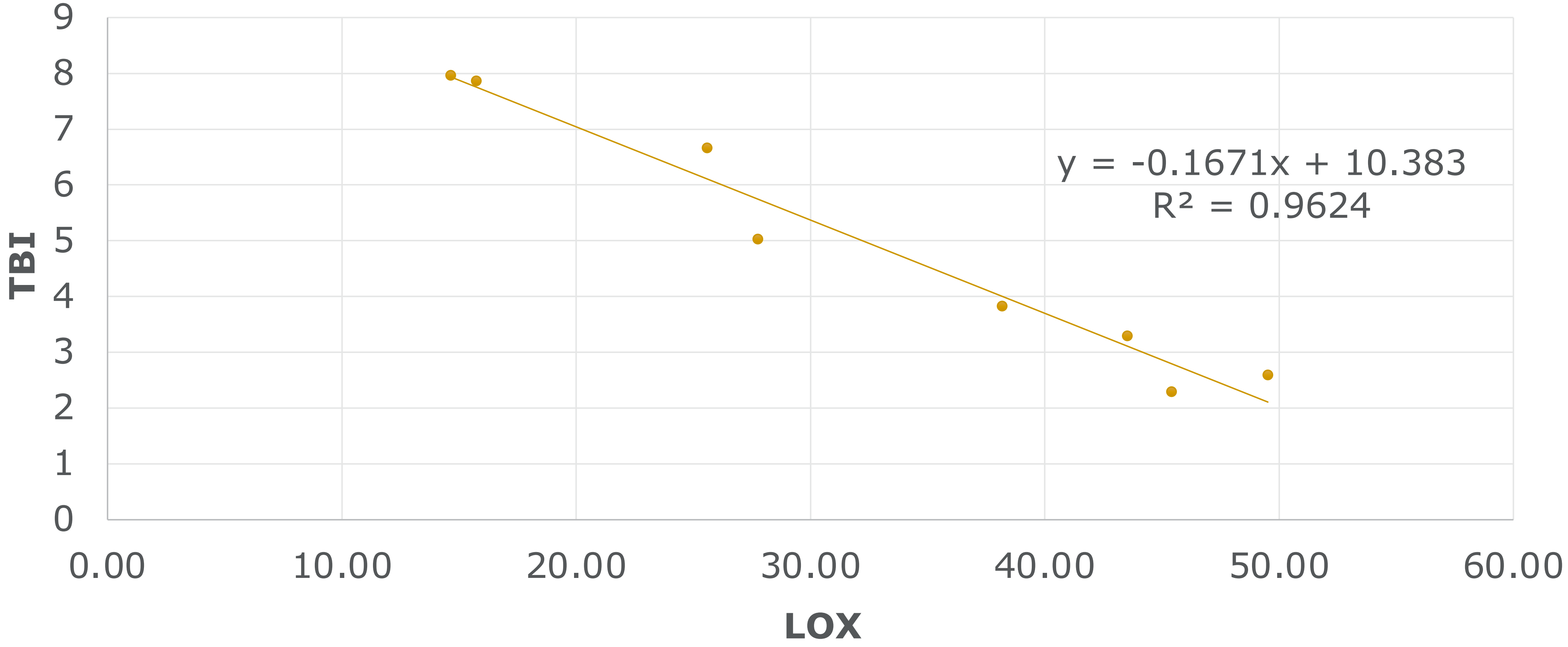
# Changes in furfural* levels in a pale ale beer with different degrees of aging




* Exhibits caramel/almond/butterscotch notes

(Yin, 2012)

# Reduce thermal load (in TBI: thiobarbituric acid index) may lead to LOX survival in malt




Aron and Yin, 2019

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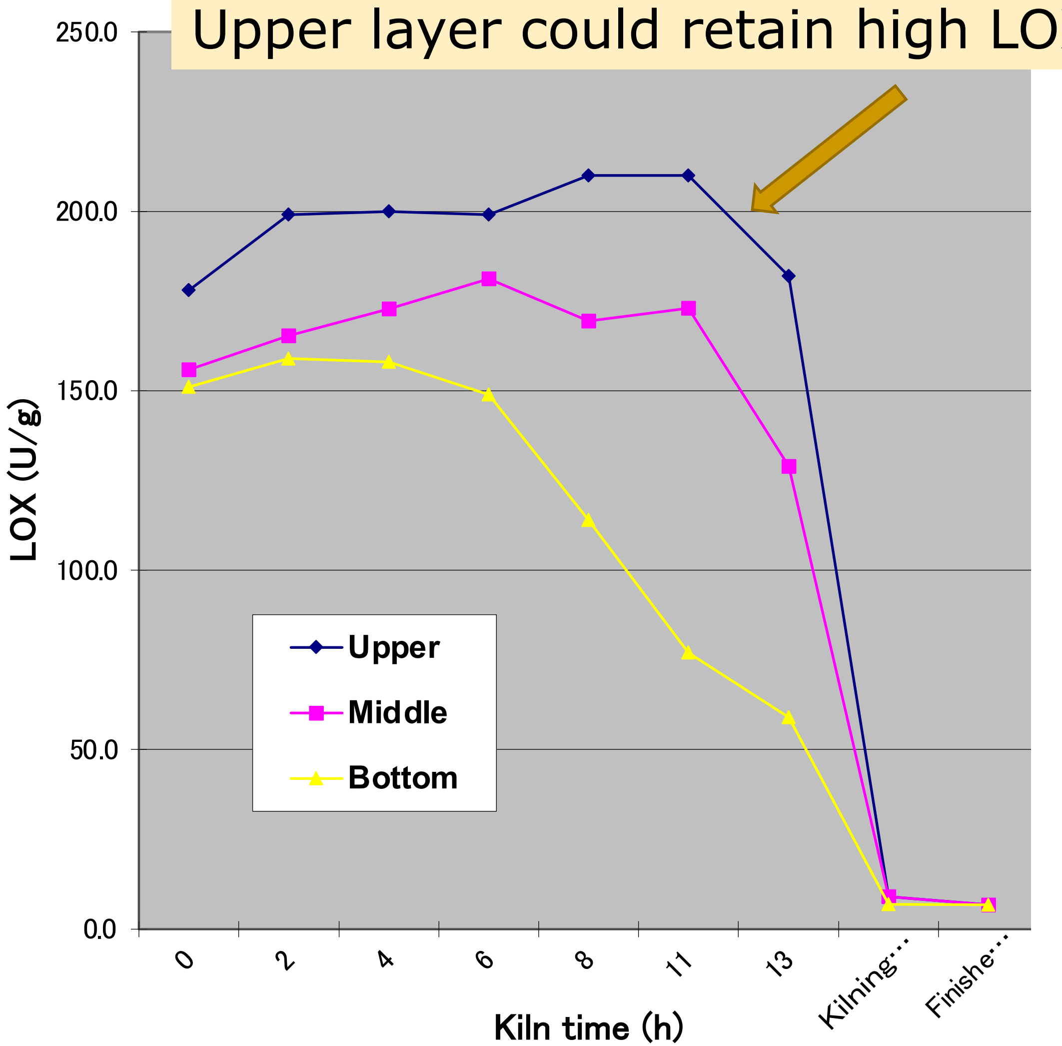
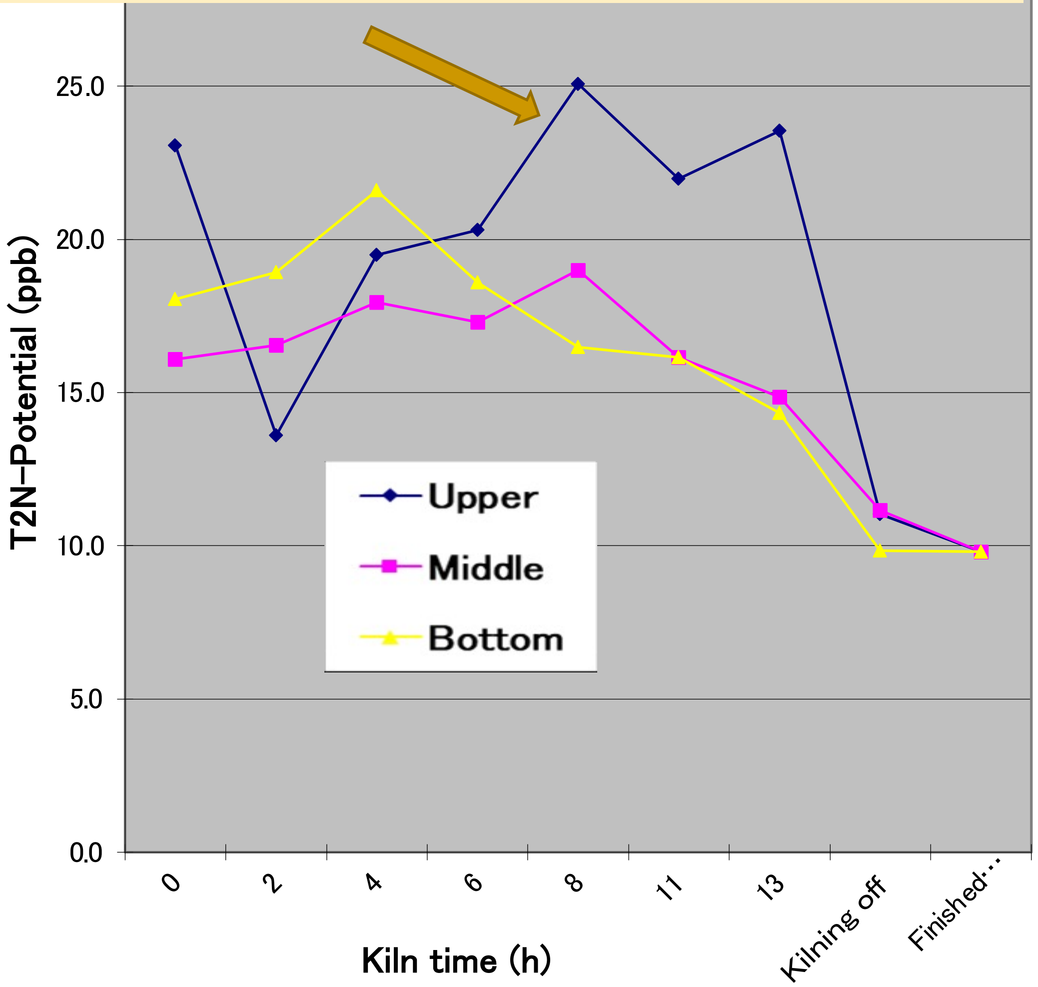
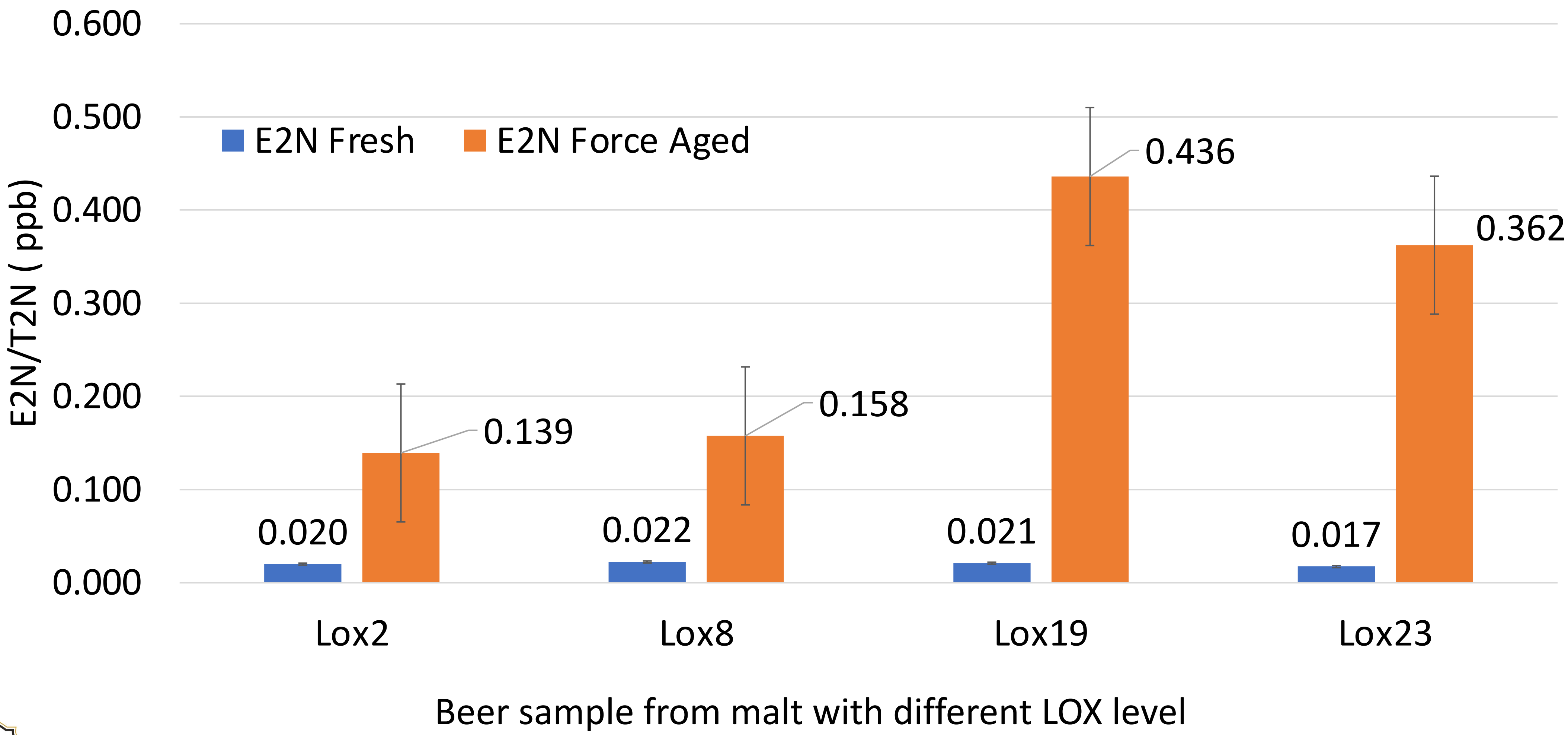
# LOX and T2N-potential trending in the top, middle and bottom layers in kiln in a commercial batch of malt (Yin et al 2022)

Upper layer could retain high LOX and hence high T2N potential



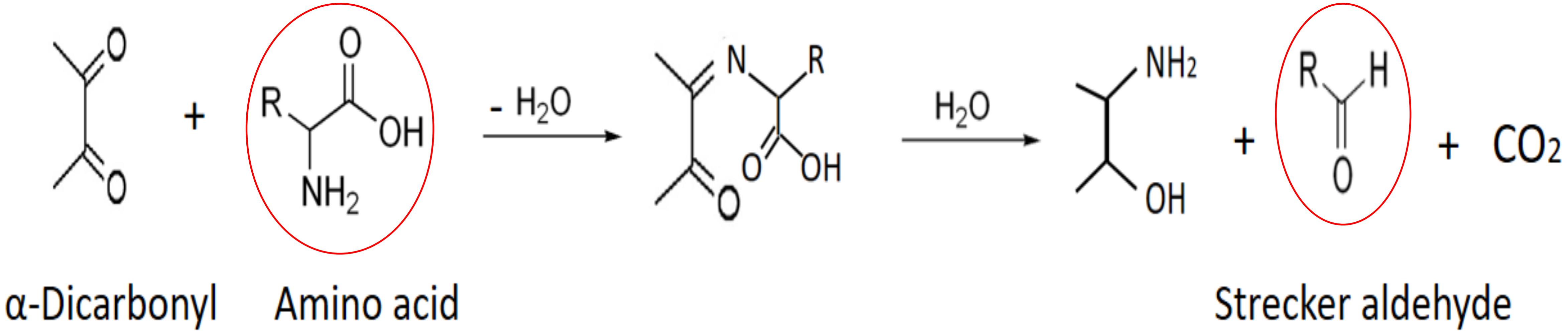
# High LOX malt leads to high T2N beer over time



# Contents

# Simplified mechanism of Strecker Degradation of amino acids

Schonberg et al., 1952; Barišić et al., 2019. Courtesy X. S. Yin -©ASBC




S-Containing AA, e.g. cysteine and cystine, form $H_2S$, $NH_3$ etc.

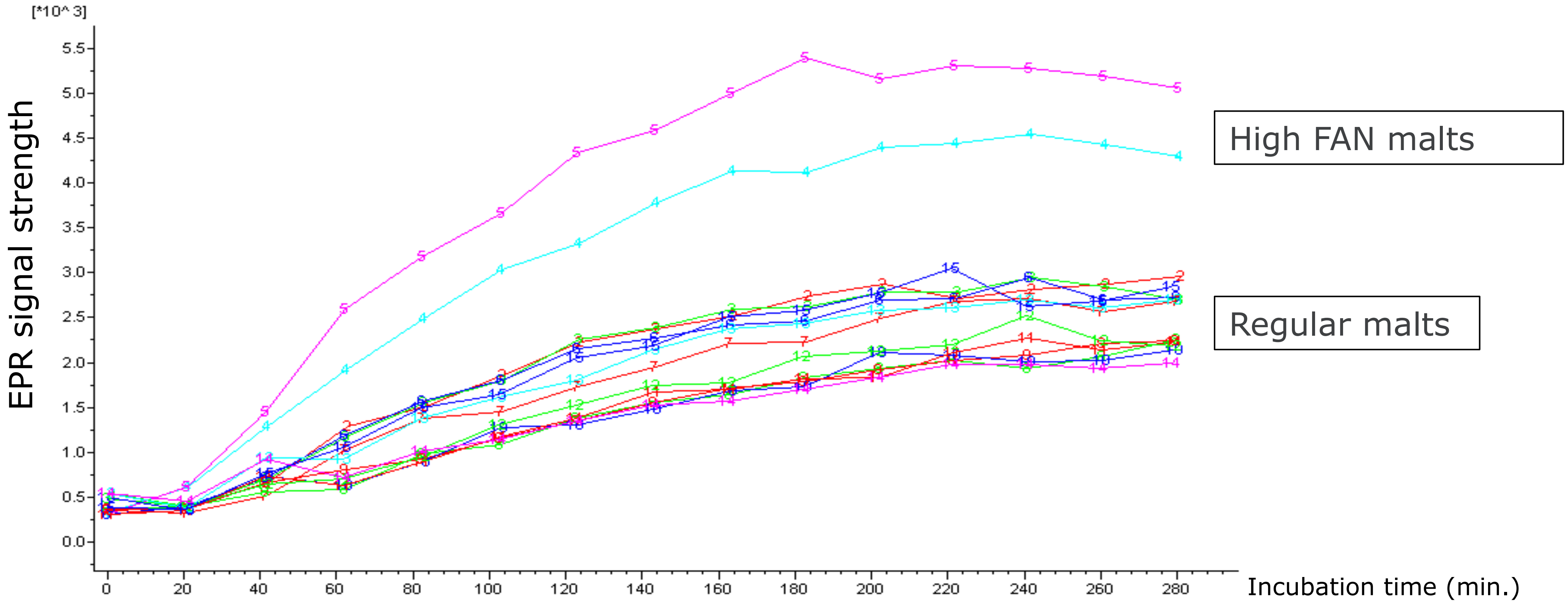
# Examples of Strecker Degradation of amino-acids and resultant flavor compounds

| Amino acid | Strecker aldehyde | Threshold (ppb) | Odor characteristics |
|---|---|---|---|
| **Alanine** | Acetaldehyde | 10,000 (1,114)[c] | Pungent, sweet, green apple |
| **Leucine** | 3-Methylbutanal | 600 (56)[c] | Acrid-pungent, fruity/ pleasant at very low concentration. Toasted bread. Malty, chocolate, almond, cherry |
| **Phenylalanine** | (indirectly) Benzaldehyde | 2,000 (515)[c] | Almond, cherry, stone fruit |
| **Methionine (S-containing)** | Methional | 250 (4.2)[c] | Onion-meat-like, cooked potato, worty |
| **Proline** | Pyrrolidine, 1-pyrroline, (Non Strecker aldehyde) | 20,000 | Bread-like, seaweed-like, cooked rice or popcorn |

Catalyzed by diketones with indirect need for O2, favored by high temperatures and high pH (4.3 - 4.6) of the beer and may happen in the bottle even at room temperature.

*Meilgaard, 1975; Ho, 1996; Shahidi et al., 1998;* [c]*Saison et al 2009*

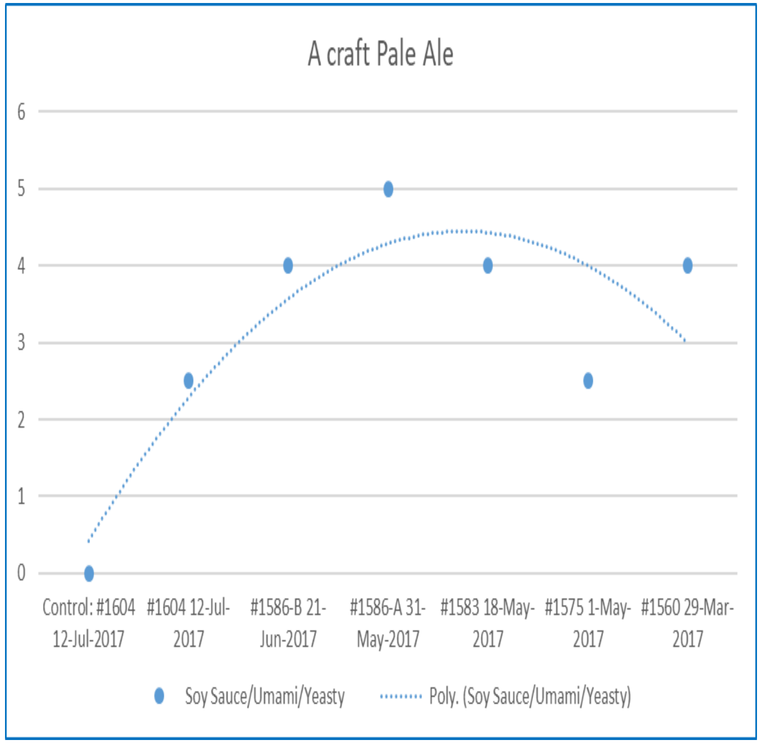
# Wort free-radical level (EPR) for different malts

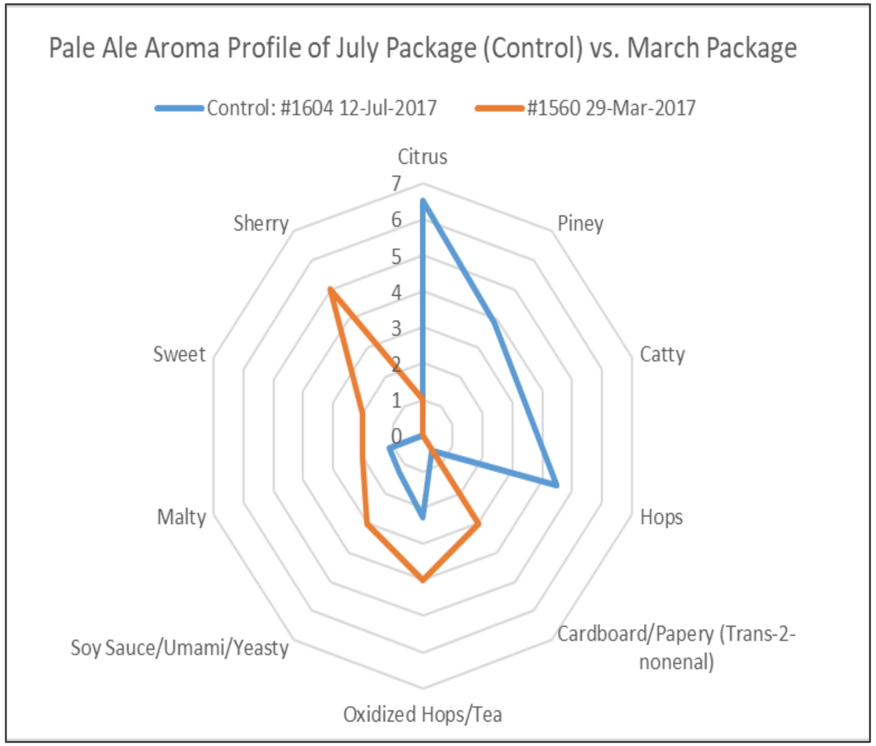


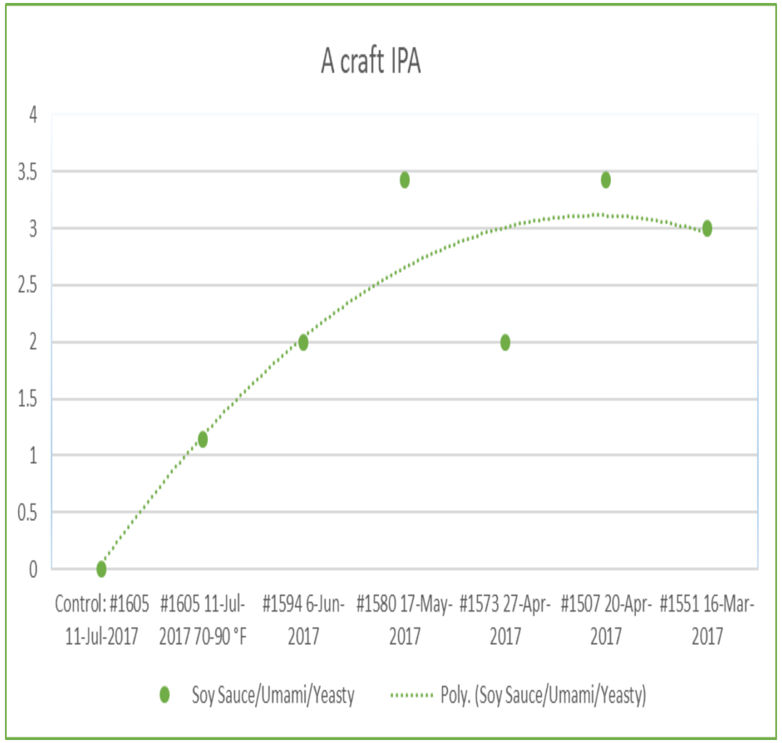

Malting process can lead to different EPR response levels. Degree of protein solubilization impacts the free radical levels.

Malt with high soluble nitrogen (FAN >230ppm) exhibited high intensity in free radical generations during incubation in EPR measurement. Malt samples: high-soluble nitrogen Harrington (#4-5), regular malts (FAN <190ppm) from AAC Metcalfe (#2-3), CDC Copeland (#8-9), and Harrington (all others). (Yin 2012)

# Flavor stability sensory and beer analysis




| Sample | SG | ° Plato | % ABV | pH | FAN (ppm) |
|---|---|---|---|---|---|
| **Pale Ale** | 1.010080 | 2.59 | 6.11 | 4.68 | **171** |
| **IPA** | 1.010773 | 2.76 | 7.06 | 4.7 | **182** |

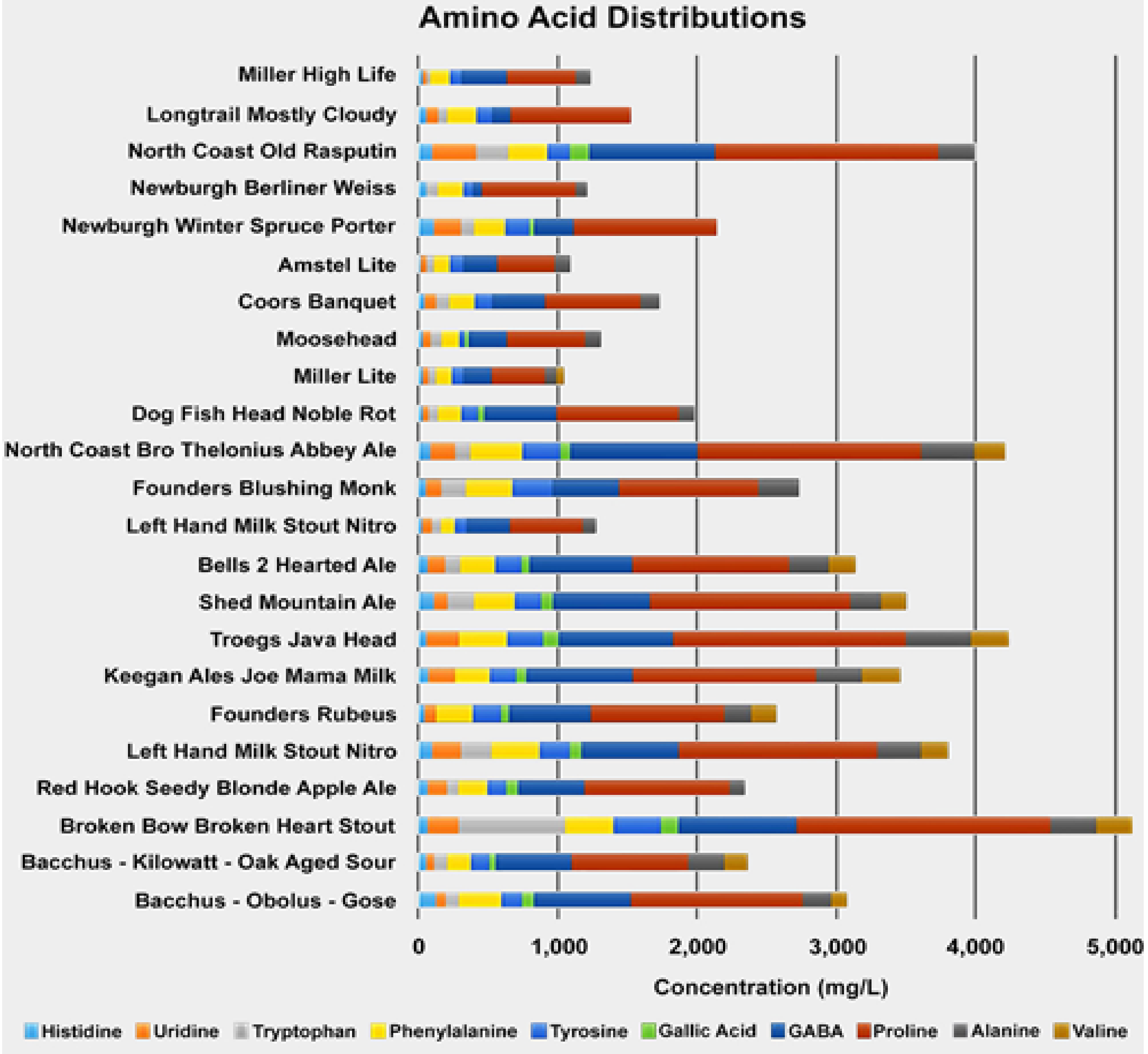
RTC, 2019

# Amino acids in commercial beers

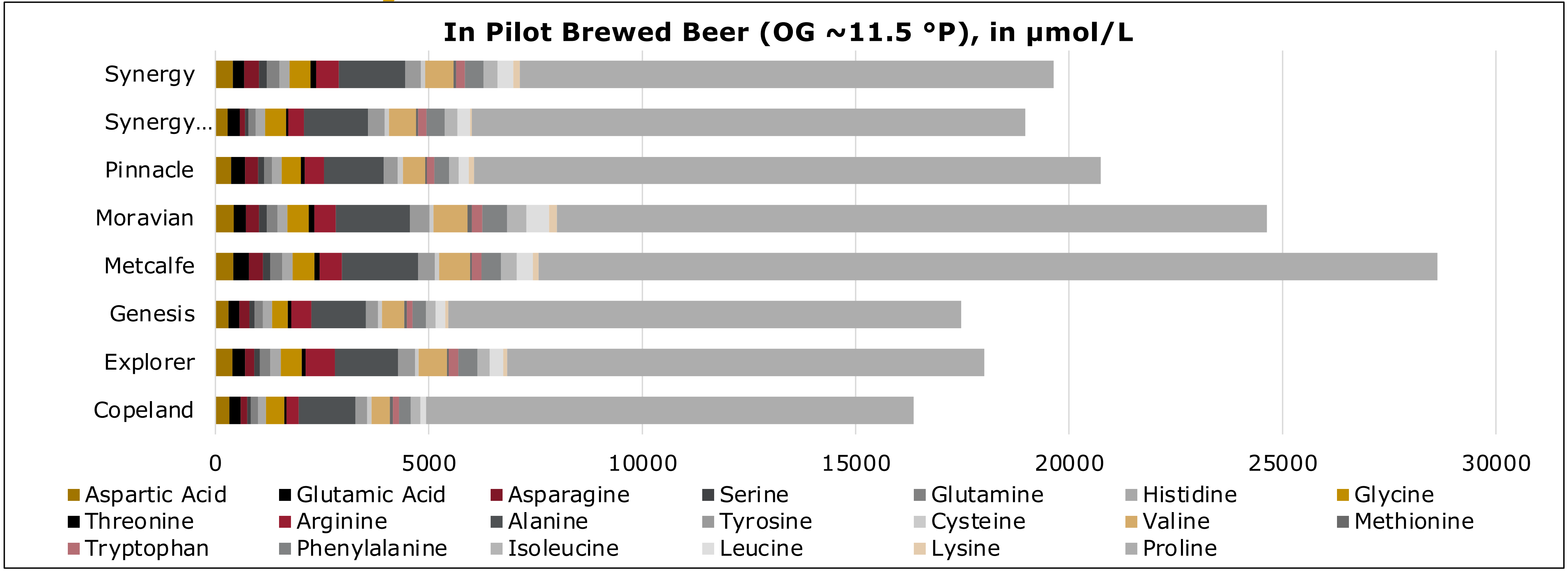
Edwards WBC 2016

-Amino acid levels vary from 1000mg/L in commercial light beers to 5000 mg/L in specialty/craft beers

-Strecker amino acids (Alanine and phenylalanine ) present in significant levels!

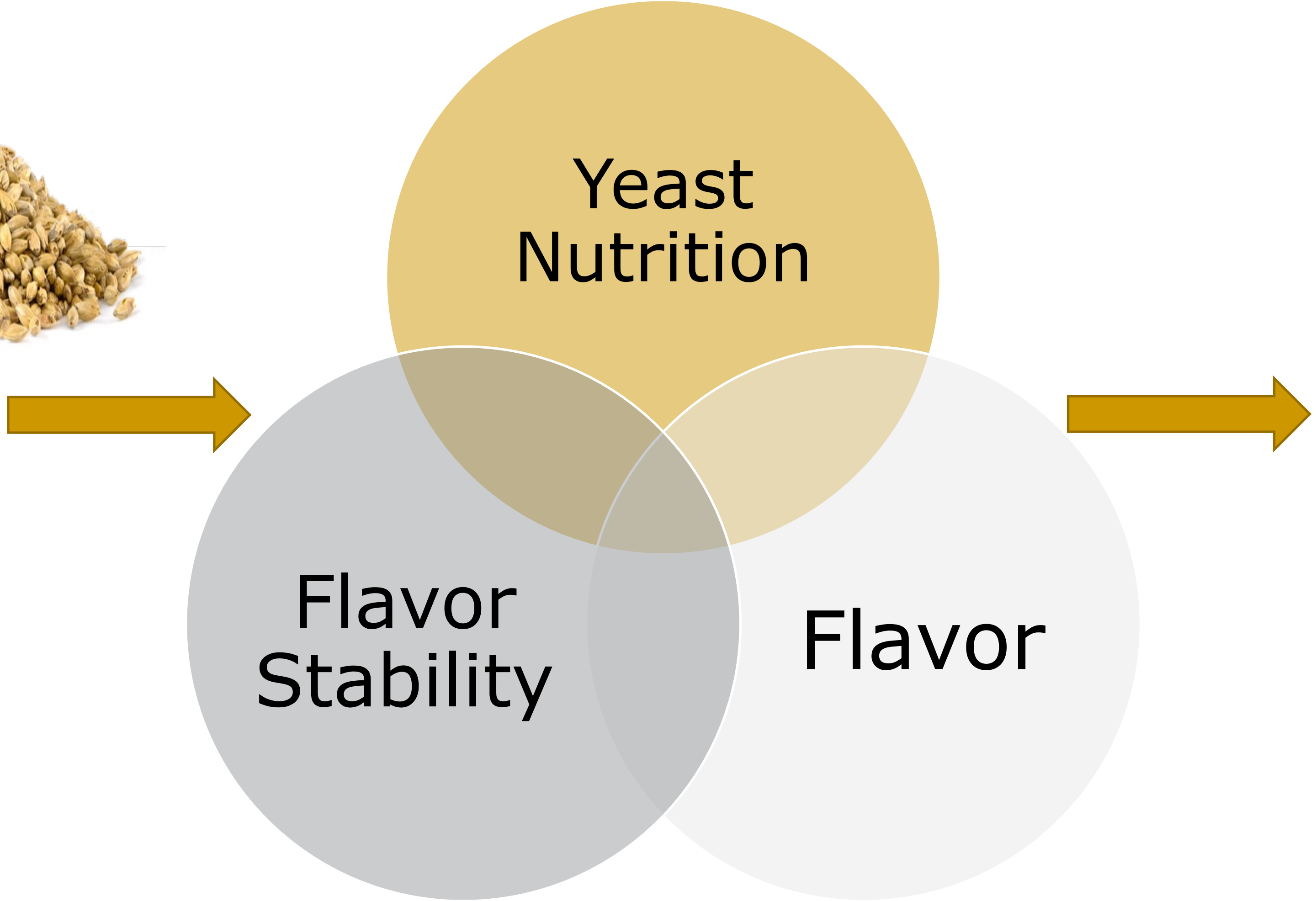


# Amino acids in pilot brewed beers (3 hl brewhouse) (Updated from Tynan et al. 2018)




- Most residual amino acid is proline which could further react to form flavor active compound (bread-like) in beer. Alanine is left in considerable level which could form acetaldehyde through Strecker Degradation.
  Varieties like Genesis, Explorer, Copeland resulted low total residual amino acids

# Functions of Free Amino Nitrogen

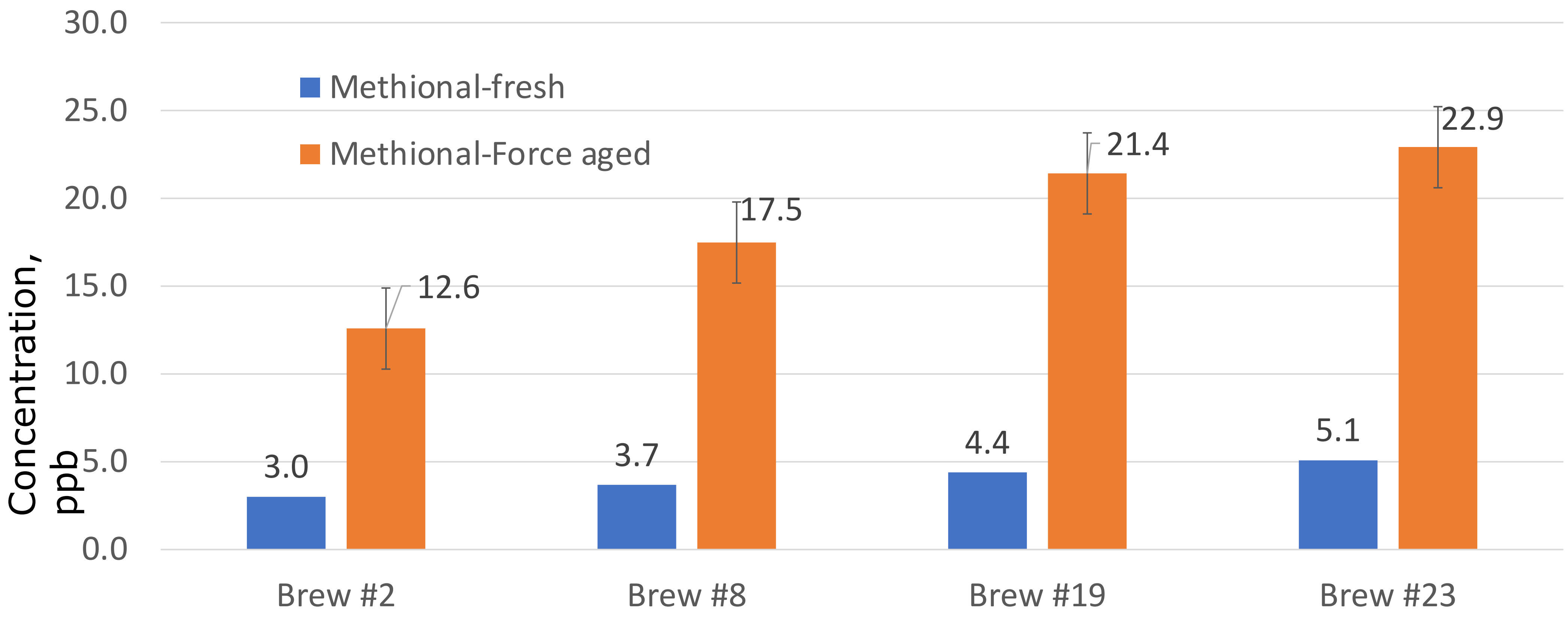



# How much FAN does yeast need?

**TABLE 8.3.** Studies on increasing free amino nitrogen (FAN) requirement as the gravity of the wort increases[a]

| Wort gravity | Optimal FAN (mg/L) | Equivalent of FAN in mg/L/°P[b] | Reference |
|---|---|---|---|
| 12 °P | 160 | 13.3 | Casey and Ingledew, 1986 |
| 18 °P | 280 | 15.5 | Casey and Ingledew, 1986 |
| 20 °P | 350 | 17.5 | McCaig et al., 1992 |

# Methional levels in fresh and force-aged lager samples*




*Methional - Meaty/cooked potato notes
Bench fermented; force ageing at 70 °C for 12 hrs

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# Side effects and balancing acts in managing malting to improve flavor stability of consequent beers

| Mechanism involved | Preventative measure on malt | Side effect and balancing act |
|---|---|---|
| **Thermal-load promoted formation of furfural and HMF** | **Control curing** intensity of base malt (EPR and TBI) | Low heat in malt curing favors survival of undesirable **LOX and peroxidases** (POD).<br><br>Balance of color and thermal-load in **malt formulation in brewhouse** |
| **Strecker degradation of amino acids** | Target **FAN level** starting from barley protein and proteolysis in malting | Watch the malt FAN, particularly for all-brewing, but balance with low **β-glucan** content |

Continued … …

# Side effects and balancing acts in managing malting to improve flavor stability of consequent beers … Continued

| Mechanism involved | Preventative measure on malt | Side effect and balancing act |
|---|---|---|
| **LOX-catalyzed formation of trans-2-nonenal (T2N) precursors** | Low LOX and POD **genotypes** of barley<br><br>Intensive **curing**<br><br>Adequate **malt aging** | Malt curing at high temperature induces high color and thermal load, reduces other desirable **enzymes** like amylases and consume **high energy**. Control depth of **malt bed** in kilning and denature LOX and POD at **onset of mashing** |
| **Free radical catalyzed oxidation of unsaturated fatty acids** | Control radical development in color production process, particularly in specialty **malt roasting**.<br><br>Monitor the extractable iron in malt | Changing heating patterns may lead to flavor deviation. Achieve the **color target** with low potential of **free-radical** in malt.<br><br>Optimize malt formulation between **base malt and color malt** to produce target color but with **low values for thermal-load** indicators (TBI or EPR) |

# Resources


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**What is the leading staling manifestation in my beer and mechanism behind, hence what in the malt I shall start to control?**

# 1 ONE THING

## That You'll Apply

# Acknowledgements

technicalservices@rahr.com

website: https://bsgcraftbrewing.com/rahr-technical-center/

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# Q&A