Optimization of flavour in foods: fermented flavour meets AI

Bridge2Food

04-06-2025 Martijn Bekker, Sanne Wiersma & Nicolo Ferretti

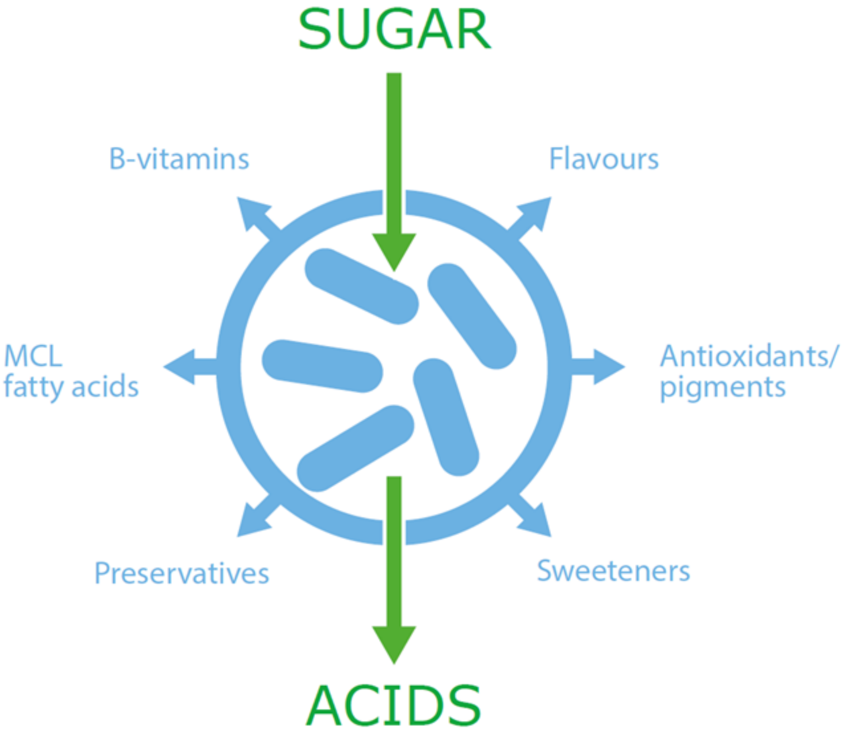
WAGENINGEN
UNIVERSITY & RESEARCH

Fermentation and food: a long tradition

~3000 BC

~7000 BC

>10000 BC



Microbes and food production

1. "Classical" fermentation

Microorganisms change aspects of ingredients or convert raw materials to foods

2. Microbial biomass

Cultivating microorganisms directly for consumption, either fractionated or as whole biomass

3. (Recombinant) proteins

Using microorganisms as cell factories to generate animal-identical or "specialty" proteins

Fermentation: a classical example

Soy bean fermentation

The most commonly used plant-protein soy can be fermented by varying micro-organisms resulting in very different textures

Soy beans

bacteria (*Bacillus* sp.)

Natto

fungi (*Rhizopus* sp.)

Tempeh

Textural properties of starting materials can be altered by fermentation by improving cross-linking properties of proteins resulting from proteolytic activity or by production of polysaccharides

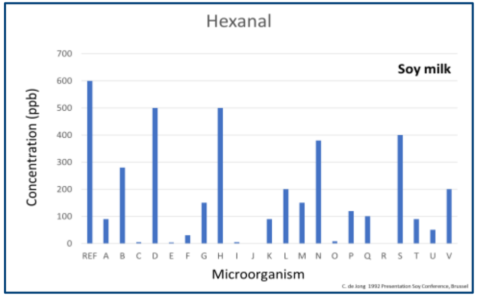
WAGENINGEN UNIVERSITY & RESEARCH

Fermentation: flavour modulation

Towards a soy yoghurt

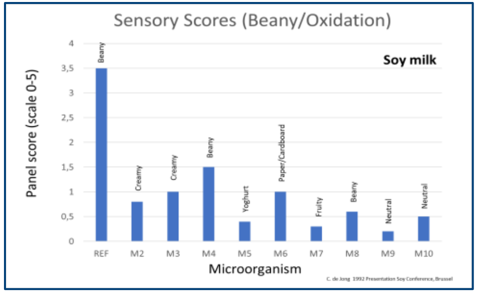
The aldehydes present in soy milk can be reduced to alcohols by fermentation. This results in a reduction of the off-flavour score in in a test-panel score

Soy milk



Hexanal reduction

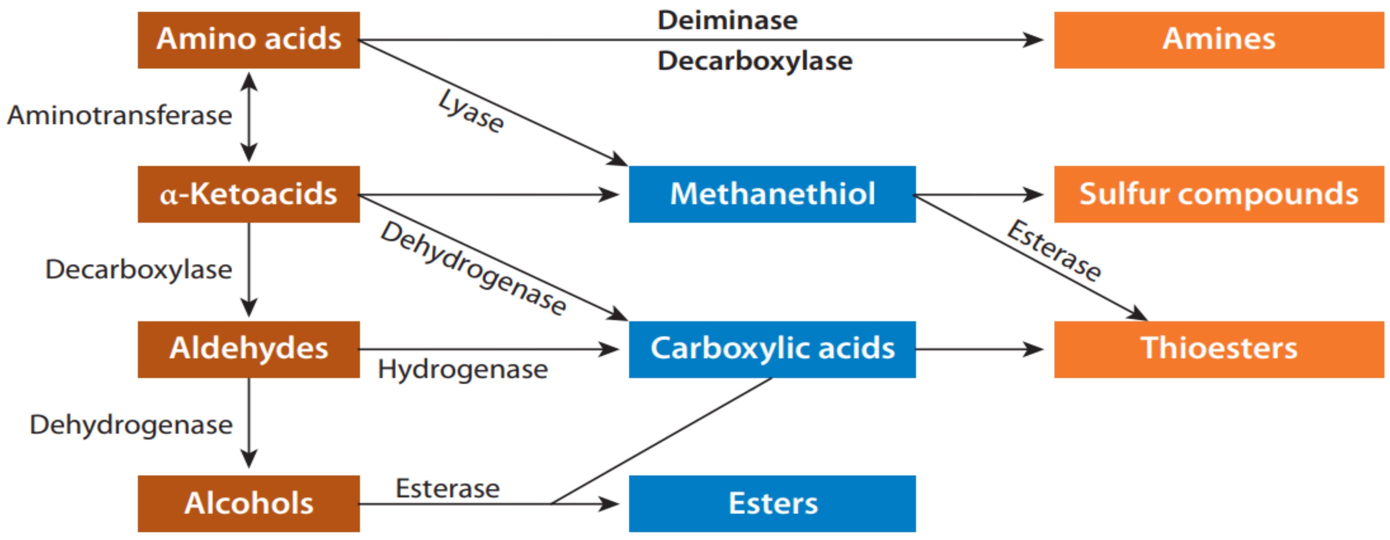
The flavour properties of food can be modulated by conversion of off-flavors to molecules with a higher sensory threshold and biosynthesis of flavour molecules



Off flavour reduction

WAGENINGEN
UNIVERSITY & RESEARCH

Flavour volatile synthesis in microorganisms



Smid & Kleerebezem, (2014), Annu. Ev. Food Sci. Technol. 5, 313-326

Flavour in food: Key food odorants

226 molecules clearly surpass *odor threshold** across various types of food/beverages

↓

key food odorants

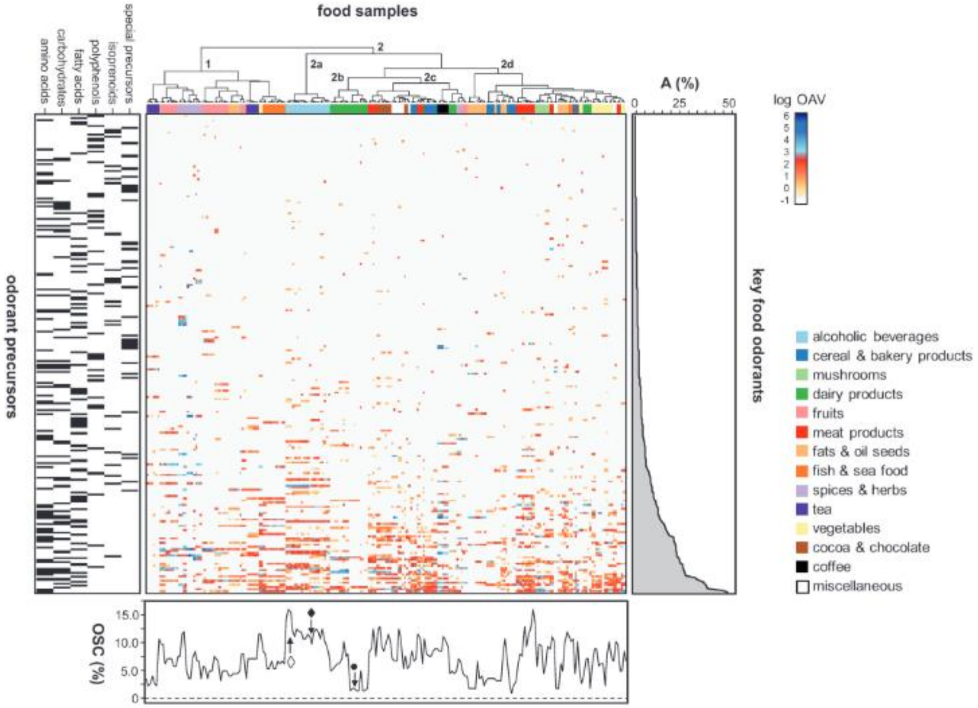


Figure 1. Heatmap displaying the odor activity values (OAVs) and the relative abundance (A, [%]) of the 226 key food odorants (KFOs) characterized in 227 food samples. The odorant space coverage (OSC, [%]) defines the percentage of the olfactory space (226 KFOs) covered by the number of KFOs in the individual food samples; as examples, cognac (◇; 36 KFOs), beer (◆; 18 KFOs), and cultured butter (●; 3 KFOs) are highligthed with an arrow. Precursor molecules leading to KFOs are grouped into classes and are given in the Supporting Information, Table S1. The assignment of the 227 individual food samples as well as the source literature can be found in the Supporting Information, Figure S1.

WAGENINGEN UNIVERSITY & RESEARCH

Challenge: targeted improvement of flavour

Part of PPP

All Informed

How can we go from plant-based ingredients…

…to tasty meat and dairy alternatives with less off-flavours and more recognizable taste?

Can we make R&D for new fermentation processes more efficient?

Building the first fermented flavour database

Part of PPP

All Informed

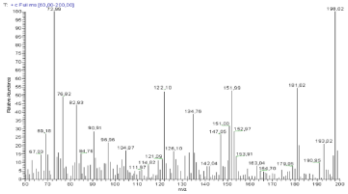
protein isolates

300^{+} micro-organisms

screening model

- temperature control
- pH in time

>200 fermentations per week & multiple flavour profiles over time



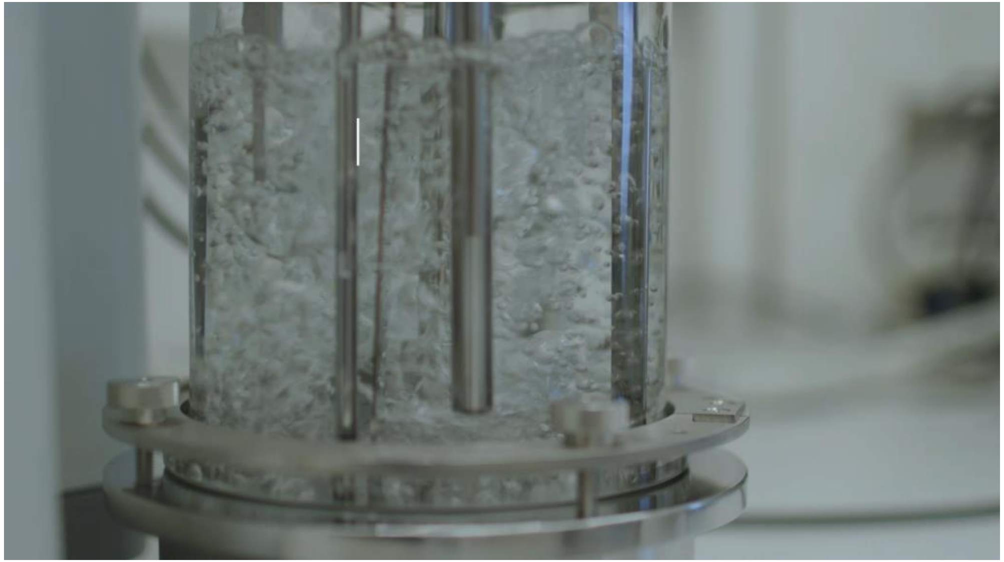
Orbitrap-MS analysis:
Obtain flavour profiles

40 sec / sample

AI tool

Leverage AI tool to predict optimal process inputs and parameters for flavour formation

Harnessing AI for efficient screening of flavour profiles

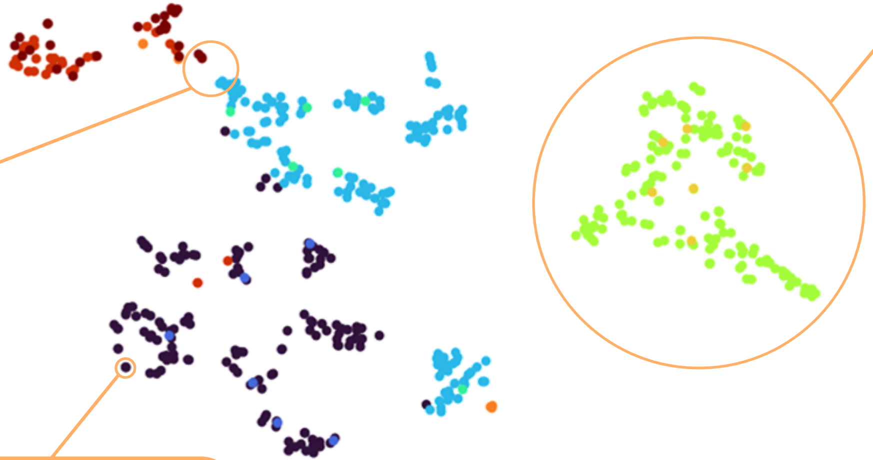


match flavour
profiles of
any kind of ingredient
fermentations
to those of
target products

Harnessing AI for efficient screening of flavour profiles

Similar substrates/samples form clusters

Samples close to one another have more similar volatile profiles



One complete flavour profile, composed of measurements of >40 KFOs

Optical spectroscopy for reproducible scaling

Part of PPP

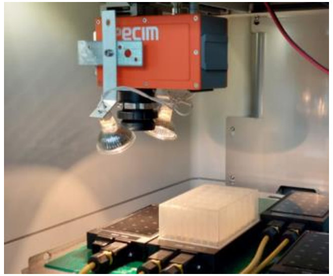
All Informed

protein isolates

300^{+} micro-organisms

screening model

- temperature control
- pH in time



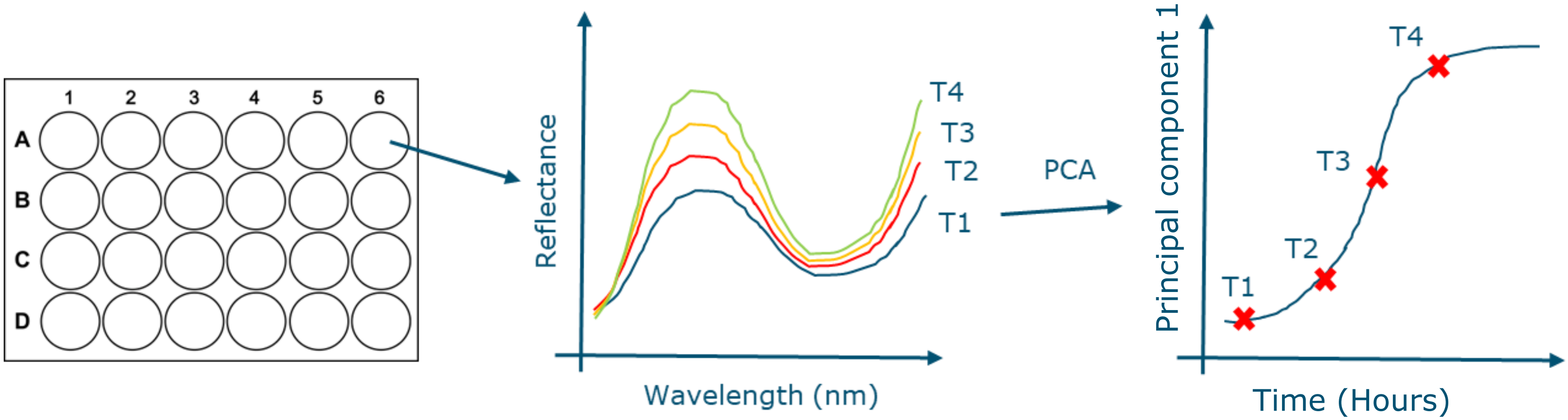
NIR (every 60 minutes)

AI tool

>200 fermentations per week & multiple flavour profiles over time

Leverage AI tool to predict optimal process inputs and parameters for flavour formation

Unsupervised analysis NIR analysis for tracking growth



Conclusions & Future Outlook

- Clustering using a tSNE approach allows for quick generation of insights into complex data sets
- Optical spectroscopy can be leveraged in specific conditions for high throughput monitoring of fermentations -> this is an evolving discipline

- Novel PPP “Robiots” on developing Raman spectroscopy-based assays for high throughput process monitoring and continuous process control
- Initiating novel PPP “FermFinder” on extending the above with an *in silico* pre-screen for correct selection of micro-organisms

Optimizing flavour – how do we approach novel challenges?

Feasibility strategy

- Detailed information session
- Assess potential biochemical pathways for relevant flavours
- Determination of WFBR and/or partner capabilities to perform the experimental work
- Advise on how to proceed

Develop & benchmark screening strategy

- **Develop relevant screening platform**
  small-scale model of industrial process
- Assessment on **potential for screening** to develop and/or optimize process
- **Report** containing all relevant information

Screening

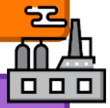
- **Design of experiment**
  maximize the screening capabilities with limited sample size
- **Screening of fermentations**
  1000s of conditions
- **Vary process critical conditions**
  pH, oxygen, substrate concentration, medium composition, etc

AI data interpretation

- Leverage our AI empowered predictive tool for efficient selection of promising prospects
- Get access to our web-based AI solution to assess and scrutinize your data

Pilot scale cultivation

Translate to industrial production



Thank you!

Let’s connect!

Sanne Wiersma
Microbial Cell Factories – Project leader
sanne.wiersma@wur.nl

Martijn Bekker
Microbial Cell Factories - Expertise leader
martijn.bekker@wur.nl

WAGENINGEN UNIVERSITY & RESEARCH