FERMENTATION:
PAST, PRESENT AND FUTURE

A review of an old technique which will be a solution for tomorrow

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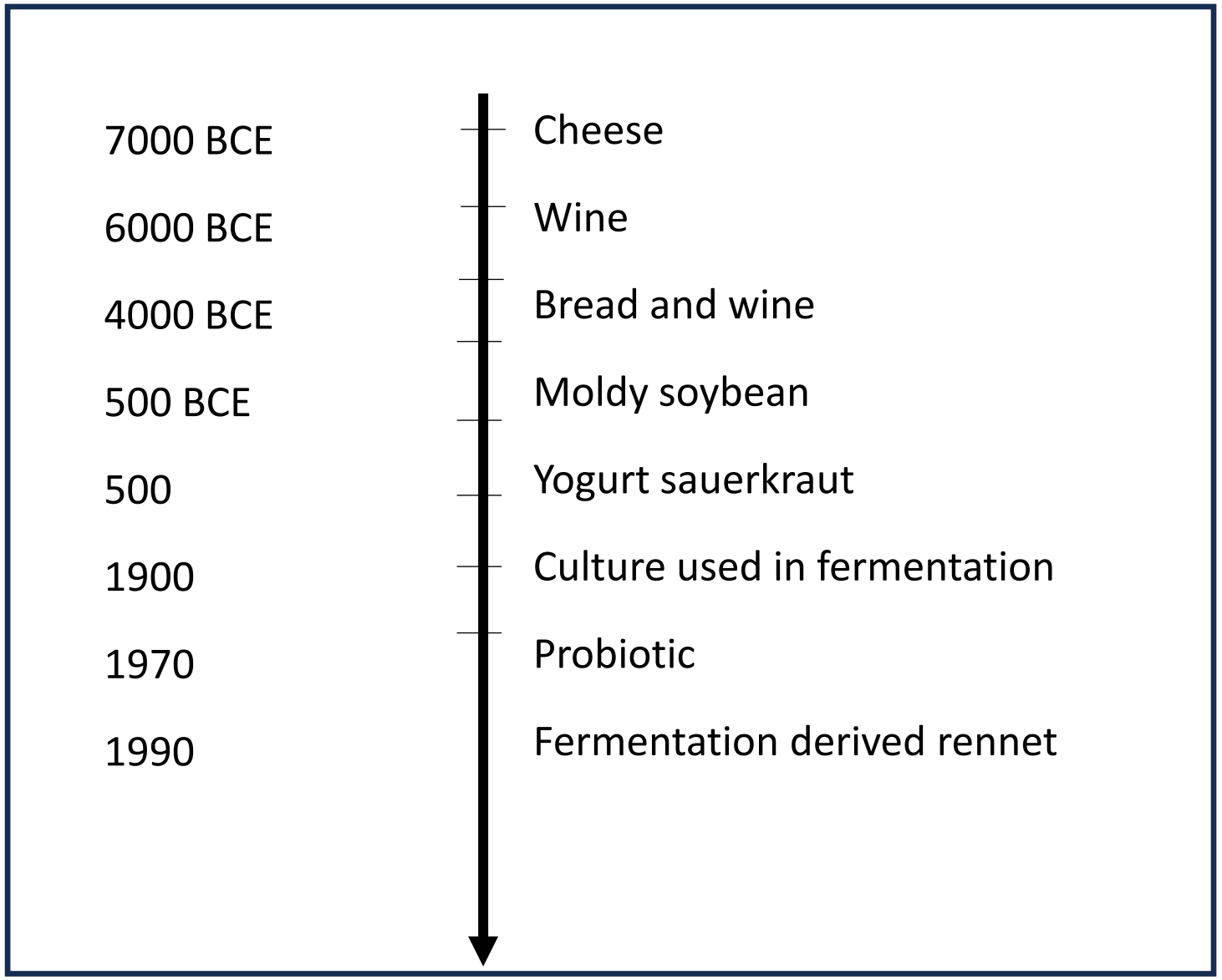
Agenda

1. Definition, History, Needs, Benefits
2. Three ways of fermentation
3. Regulations
4. Takeaway home

What is the Fermentation?

- Cooking with microbes
- Converting sugar to acid by microbes in anaerobic
- Transformative action of microorganisms by enzyme (with or without O_2)

A technique from 9K years ago



Fermentation: a need

Past

Future

- To preserve food
- To add flavour to food
- To get health benefits
- To make functional ingredients
- To make animal alternative foods

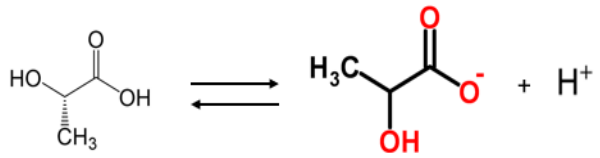
Preserving

- Acidification: lactic or acetic acid
- Alcohol
- Producing other antibacterial chemicals: hydrogen peroxide
- Crowding out

Minimum inhibitory concentration of undissociated lactic is well known e.g. ***11mM*** *MIC for E.coli O157:H7 and 140mM to achieve 5 LR*

Henderson-Hasselbach equation:

$$[undissociatedacid] = \frac{[dissociatedacid]}{(1 + 10^{pH-pKa})}$$



Delicious

3 ways

1. Spices
2. Cooking
3. Fermentation

- *Carbohydrate: ketones diketones*

  Diacetyl –buttery

  Lactones – fruity

- *Proteins:*
  - *Umami: glutamic acid and its salt*
  - *Kokumi: a flavour modifier: small peptides (Glutathione)*
- *Lipids: free fatty acids*

Health Benefits

- **Easy digestion**
    - Lactose intolerance
- **Nutritional enhancement**: vitamins B2, B3 Niacin
- **Detoxification:**
    - Phytates in grains → phytase in sourdough release minerals
- **Probiotics:** keep population and diversity of gut microbiota
    - Gut bacteria → immune response in lung[1]

[1]National Academy of Science

Functional Ingredients & Animal Alternative Food

- To make sustainable **high-value** flavour ingredients or **high-volume** ingredients for end products in a circular economy model
  - **High value:** Organic acids, vitamins, gum, colour, enzymes, flavours, flavour enhancement. Example: rennet, citric acid, xanthan gum.
  - **High volume:** Milk proteins, Egg proteins

Functional Ingredients & Animal Alternative Food

- Food Security and Climate Change
- Agriculture: 1/3 of GHG
- By 2040: 40-50% more Food + Water + Energy

Milk is the most problematic: carbon footprint: 25 kg feed + 200L water /day

Fermentation: Three ways

1. **Traditional**
   - Preserve, improve functionality and taste
   - Cost: ingredients and fermentation duration
   - More than thousands years
2. **Biomass**
   - High protein content fast growth
   - Cost: in downstream processing
   - few decades
3. **Precision**
   - Alternative protein products
   - Cost: in downstream processing
   - few decades

Microbial Derived Ingredients

Traditional

Type of fermentation based on By-Products

1. **Lactic**: Bacterial (LAB) No O_2 Sugar→ Lactic Acid Dairy, Vegetables
2. **Alcoholic**: Yeast No O_2 Sugar → Alcohol + CO_2 Wine, Beer, Sourdough
3. **Acetic:** Bacterial AAB, O_2 Alcohol → Acetic acid Vinegar, Kombucha
4. **Enzymatic:** Fungus O_2 Proteins→ Amino acids Koji, Tempeh, Miso
   Lipid → Fatty acids
   Carbohydrates → Sugar

Yeast + LAB

SCOBY

Secondary fermentation

Secondary fermentation

Traditional

Type of fermentation based on source of microorganism

1. **Wild:** Selective environment

   LAB Yeast AAB

   - Vegetable: LAB 2% salt
   - Vanilla: Bacillus Heat
   - Coca: LAB->Yeast->AAB->Fungi
   - Coffee: Ethanol Fungi->AAB/LAB->Spore forming Fungi

   Succession

2. **Culture (starter):** pure or co-existing microorganisms

Biomass and Precision

Precision fermentation

Input	Production	Processing	Food/Ingredient
Microorganism express endogenous or genetically modified for food-ingredient target	Microorganism produces food using feedstock	**Extraction** and **filtration** of the target food-ingredient from substrate or from the cell	Formulate ingredient in food

Biomass fermentation

Input	Production	Processing	Food/Ingredient
Microorganism with **high content** of the target food-ingredient selected	Rapid growth of microorganism on feedstock	Harvest intact or goes with **minimally process** (griding, mixing, dewatering)	Formulate ingredient in food

Good Food Institute. 2022 State of the Industry Report

Biomass and Precision

Target selection: which food/ingredient/molecules to select

1. Biological
2. Technological
3. Sustainability
4. Market
5. Target molecule end function
6. Application
7. Similarity to other products
8. Regulatory pathway
9. Price

Biomass and Precision

Strain development: select best microorganism

1. Metabolism
2. Protein trade
3. Cell morphology
4. Cell reproduction
5. Potential of genetic modification

Yeasts like ***Saccharomyces sp.*** and ***Pichia sp.,*** and filamentous fungi ***Aspergillus niger.***

Biomass and Precision

Feedstock optimization: select best substrate

1. Reduce cost
2. Reduce waste
3. Improve sustainability

- Much of the substrate relies on processed fermentable sugars from crops.
- Lignocellulosic biomass from municipal solid waste pulp.
- Microbial production from gas feedstocks like CO2.

Biomass and Precision

Bioprocess design: critical to reduce the cost and high sustainability

1. Downstream yield
2. Upstream medium recycle
3. System control

Regulations

Biomass and precision fermentation

Pre-market Authorization

1. Requesting a novelty determination
2. Request a pre-submission consultation with Health Canada
3. pre-market safety assessment - Food from microorganisms
    1. *Substances*
    2. *Process*
    3. *Genetic modified*

Novel Food Information: β-Lactoglobulin protein from yeast strain Komagataella phaffii yRMK-66

On this page

Regulations

Traditional fermentation

- **Regulated provincially**
  - pH<4.6 in certain time specified by the culture manufacturer.
- **Meat fermentation**
  - CFIA preventive control recommendation.

- **Ethyl Carbamate**: Cariogenic, Health Canada set max level for *sake, distilled spirits, fruit brandies, and liqueurs table wine and fortified wines*.
  - Sake: 4 drinks per week
  - Fruit brandy: 2 drinks per week

Regulations

Culture

Regulation:

- Live bacterial cultures are food ingredients under FDR provision.
- No specific regulations refer to probiotic

Declaration:

- Bacterial Culture, Mold Culture

Regulations

Fermented Food

Product description

- Standard of Identity (SOI): sauerkraut, cheese
- No specific regulation for naming non-animal proteins. General provision of FDR is applied (truthful and not misleading)

Alcohol declaration

- Ethanol in non-alcoholic fermented foods such as Kombucha and kefir:
    - Federal: No alcohol on the label when <1.1%
    - Provincial: No alcohol on the label when <0.5%

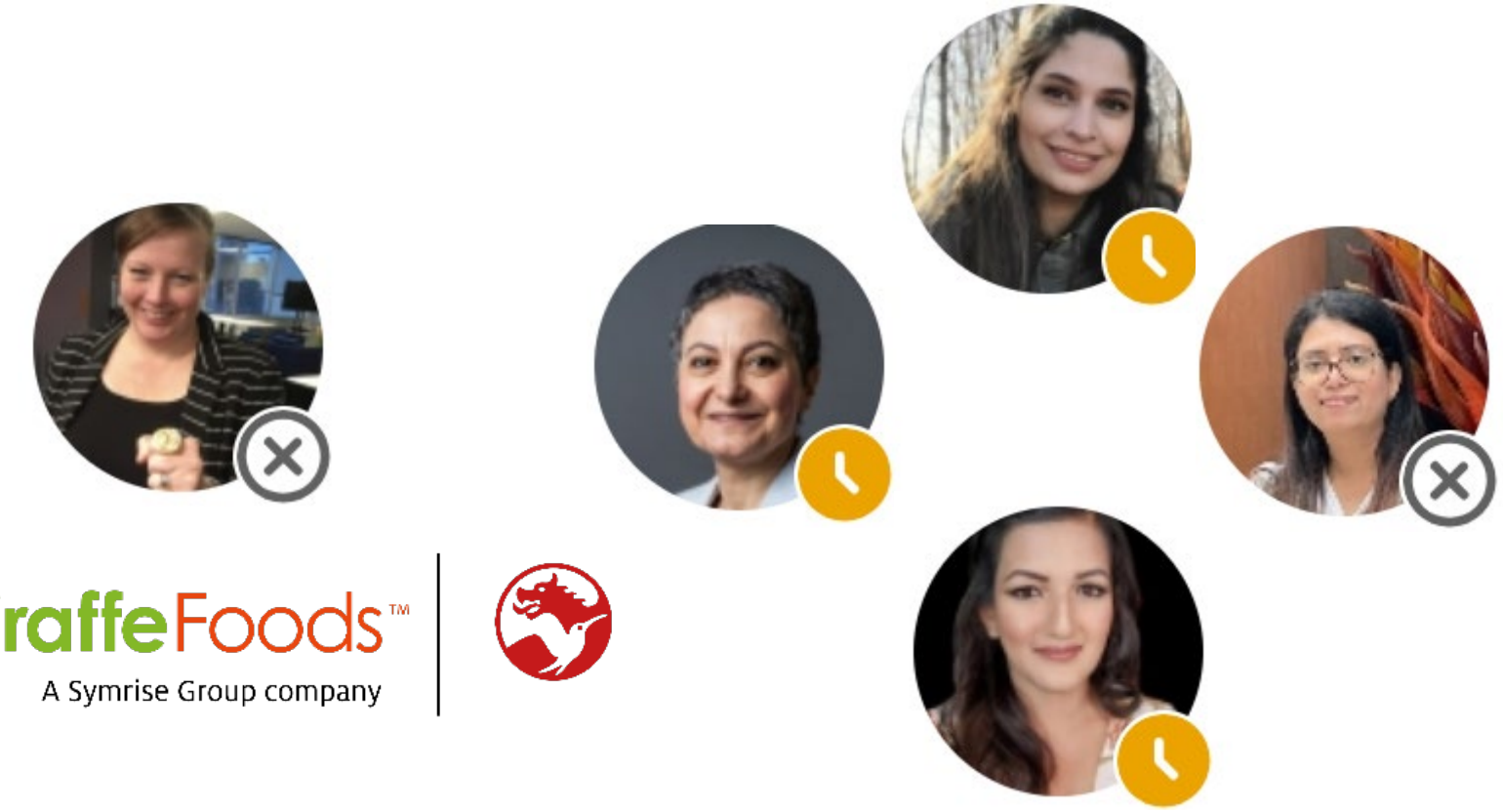
Takeaway

- Fermentation is more than a historical technique—it is a vital solution for the future
- Academia, industry, and government must collaborate
  - Academia to drive cutting-edge research to explore new microbial development, feedstock optimization and process efficiency
  - Industries to prioritize **sustainable** production methods and materials and to invest on **R&D and Regulatory** for end food application and food safety assessment
  - Governments to implement clear, timely regulatory frameworks that ensure safety and provide support for innovation.

References

1. Good Food Institute. 2022 State of the Industry Report | *Fermentation: Meat, seafood, eggs, and dairy*
2. *The Art of Fermentation, Sandor Ellix Katz, 2012*
3. *Dinner on Mars, Lenore Newman and Evan Fraser*
4. *The Noma Guide to Fermentation, Rene Redzepi & David Zilber, 2018*
5. *Food Fermentation: The Science of Cooking with Microbes, HarvardX, e-Course*

THANK YOU



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Questions?

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