What is Fermentation? Fermentation is the chemical transformation of organic substances into simpler compounds by the action of enzymes, complex organic catalysts, which are produced by microorganisms such as molds, yeasts, or bacteria.
Human beings are known to have made fermented foods since Neolithic times. Why? Then and Now:

- For food preservation
- More nutritious
  - Africa: Fermented sorghum (beer)- Source of Vitamin B Vitamin in areas with poor nutrition
  - Korea: Pickled, fermented cabbage (Kimchi)- source of Vitamin C year round
- Create a “new” food. Transform milk to cheese
- For flavor
# Types of fermentations

<table>
<thead>
<tr>
<th>Bacterial: LAB</th>
<th>Yeast (Y)</th>
<th>Mold (M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lactic Acid Bacteria</td>
<td>Beer</td>
<td>Mold ripened cheese (blue, surface)</td>
</tr>
<tr>
<td>• Cultured dairy</td>
<td>• Wine</td>
<td></td>
</tr>
<tr>
<td>• Sauerkraut</td>
<td>• Cider</td>
<td></td>
</tr>
<tr>
<td>• Salami</td>
<td>• Bread</td>
<td></td>
</tr>
<tr>
<td>• Cheese</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LAB and Y</th>
<th>LAB/Y/M</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Kombucha tea</td>
<td>• Traditional Soy Sauce – fermented soybeans, roasted wheat and brine</td>
</tr>
<tr>
<td>• Kefir</td>
<td></td>
</tr>
<tr>
<td>• Lambic beer</td>
<td></td>
</tr>
<tr>
<td>• Salami</td>
<td></td>
</tr>
</tbody>
</table>
Food safety perspective…

- **pH < 4.6**
- **Aw < 0.85**
- **Temp < 4°C**
37°C • Optimal pathogen growth

20°C to 25°C • LAB fermentation
What makes LAB products safe?

- Low pH
- Organic acids
- Bacteriocins
- Hydrogen peroxide
- Ethanol
- Diacetyl
- Nutrient depletion
- Low redox potential
- COMPETITIVE MICROFLORA
What makes fermented products safe (safer)?

CHEESE & DAIRY: Not just pH

- Most cheeses have a pH > 4.6
- Salt level alone (~2% depending on variety) not high enough to be inhibitory
- Water activity alone not low enough to be inhibitory (Parmesan: 0.87-0.92, cheddar: 0.95, Camembert: 0.98, most cheeses: 0.95 to 0.98 range)
- Combination of low’ish pH, low’ish $A_w$, and COMPETITIVE MICROFLORA (LAB)
What makes fermented products safe (safer)?

**MEAT: Not Just $A_w$**

- **Water activity ($A_w$):**
  - Cured meat (Ham): 0.91 to 0.95
  - Fermented sausage (salami): 0.87 to 0.91
  - Beef jerky: 0.75 to 0.80
What makes fermented products safe (or not)

LAB: Should see a good healthy active fermentation i.e. bubbles occurring within 24 hours indicative of a lowering pH

FERMENTATION MUST START 24 hrs → 3 days max.

After this period, if pH is not lowered, harmful bacteria may have a chance to grow that are acid tolerant.
Lactic acid fermentations

**Pickles**
- Brine 3 to 10% NaCl
- Vinegar added to brine
- Ferment 2 - 4 wks

**Sauerkraut**
- Brine 2-3% NaCl
- Acetic acid develops from ferment
- Ferment 2 – 4 wks

**Kimchee**
- Brine 2-3% NaCl
- Acetic/lactic acid develops from ferment
- Ferment 2 – 3 days
<table>
<thead>
<tr>
<th>High-salt Cucumber ferments</th>
<th>Low-salt Cucumber ferments</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Salt stock ferments</td>
<td>• Dill pickles</td>
</tr>
<tr>
<td>• Generally 5 to 8%</td>
<td>• 3 to 5% plus dill / spices</td>
</tr>
<tr>
<td>• Selective for LAB and yeasts</td>
<td>• Takes 4 to 8 weeks</td>
</tr>
<tr>
<td>• Ferment occurs w/in brine &amp; cucumbers (failures → bloaters, CO₂ can’t escape)</td>
<td>• pH usually between 3.2 and 3.6, with 0.7 to 1.2% lactic acid</td>
</tr>
</tbody>
</table>
Sauerkraut production

Why is salt amount so important?
Not enough salt (<2%) → the cabbage will soften

Too much salt (>3%) → correct microbial sequence is not obtained

w/w means % weight/weight

One cabbage ~2 to 2.5 lbs or ~1kg
25g salt required = 5 teaspoons of salt

(use pickling salt, kosher salt)
Fermentation cycle for sauerkraut

Start:
LAB <1% of bacteria w/in 48 hrs LAB log 8 count >90% of total bacteria

Acid produced, pH drops, inhibits other bacteria

Leuconstoc $\rightarrow$ CO2 $\rightarrow$ anaerobic $\rightarrow$ acetic acid $\rightarrow$ heterofermentive lactobacilli $\rightarrow$ homofermentive lactobacilli Lactobacillus

Figure 9.10 Chemical and microbiological changes during sauerkraut production. ● Total bacterial count; ○ lactic acid bacteria; △ pH; □ total titratable acidity (principally lactic plus acetic); ■ volatile acidity (principally acetic).
(Adapted from Stamer, 1974.)
Fermentation specific food safety advice

1. Use a standardized recipe.
2. Remove the outer layer on the produce before starting the fermentation (e.g. remove outer leaves of cabbage).
3. Produce should be fully submerged under the brine liquid during fermentation.
4. Each fermentation should begin fresh – do not “top up” previous ferments with new product.
5. Salt content in lactic acid bacteria fermentations are typically 2-3% of weight of vegetables. Do not reduce the amount of salt in the recipe. Salt is needed to promote growth of beneficial bacteria during the ferment.
6. A healthy fermentation should occur within 24 to 72 hours, and the process should be consistent from batch to batch. A pH of less than 4.6 must be achieved within the first 72 hours, otherwise harmful bacteria that are acid resistant may have an opportunity to establish.
7. Check each batch visually for spoilage. If there are no bubbles with 48 to 96 hours, or if produce is spoiling, discard entire batch.
8. Do not ferment food products to below a pH of 3.2
9. Refrigerate fermented products once fermentation cycle is completed.
10. Boiling water (open kettle) canning is recommended after fermentation to ensure the best seal between the glass jar and lid for product quality.

“Raw food handling to limit existing hazards” http://www.bccdc.ca/health-info/food-your-health/food-safety/food-issue-notes
Fermented Dairy Products (e.g. Yogurt)

• What makes fermented dairy products “riskier”?
  • Milk is perfect growth medium for pathogens
  • Temperature used: optimum or close to optimum for most pathogens
• Even minute contamination will be multiplied several fold
• Process conditions need to be “perfect”
Yogurt Production

Control Points

- **CCP**: Cool within 1 hr
- **CCP**: Check pH is 4.5 or lower
- **CCP**: Cooked, RTE or pasteurized ingred.
- **CCP**: Use within 7 days
Kombucha Tea

“the MOTHER”

SCOBY

Symbiotic culture of bacteria and yeast

Brew tea

Add sugar

Add SCOBY

Ferment
Types of Fermentations

LAB          Yeast            LAB + Yeast

Sauerkraut   Kombucha         Alcohol

Glycolysis

- GLUCOSE
  - Small amount of energy
  - Two 3-CARBON MOLECULES
    - Anaerobic bacteria
    - Yeast

Fermentation

- Lactic acid fermentation
  - 2 LACTIC ACID
- Alcohol fermentation
  - 2 ETHANOL + 2 CO₂

Alcoholic Fermentation: Yeast → sugar → alcohol

Lacto Fermentation: Lactobacilli Bacteria → sugar → lactic acid

Acetic Acid Fermentation: Acetobacter Bacteria → alcohol → acetic acid
Kombucha hazards & risks

• Contamination of tea before LAB acidification
• Acidosis (2 cases, 1995)
  • Cardiac arrest in 2 women
  • 14 day ferments
  • One death
  • Perforated intestines
• Too much alcohol (if >1%, product comes under Liquor control)

Control Points

• Sanitation and proper cooling
• pH > 2.5, monitor pH to ensure a pH of < 4.2 reached in 7 days or discard batch
• Serving size suggestion for consumers
• Pasteurize or refrigerate with preservative agents

Tempe (tempeh)

Fresh tempe (fermented soybean cake)  
Surono, 2016

http://nordicfoodlab.org/blog/2015/11/20/tempe-part-1-traditional-fermentation-fungal-trials-and-regional-seeds
Tempe hazards & risks

- Heat labile toxin growth (S. aureus, B. cereus) during 1st step – soaking of soybeans before dehulling
- *Rhizopus* starter culture contamination (*Salmonella* spp.)
- Toxic metabolites (potential); bonkrek acid

Acidify
LAB pH < 4.6

Acidify

Rhizopus releases ammonia
Optimal pH=7.2 (6.8 to 8.0)

Refrigerate
Sell by date 7 days
Do not eat raw

Clean whole dry soybeans
Wash; Soak in hot (initially 100°C) or room temp. water; 8-22 hours
Drain and wet dehull
Float and pour off some hulls (optional)
Boil in acidified water; skim off hulls 45-60 min
Drain, dewater, and cool to body temperature
Mix with mold inoculum
4.5 million viable counts/lb. dry soybeans
Pack into tempeh containers (perforated polyethylene bags)
Incubate at 31°C (88°F)
70-85% relative humidity; 22-26 hours
Fresh tempeh cakes

Pasteurize refrig.
2 weeks

Figure from Shurtleff and Aoyagi, 1979.
Food safety perspective

- It’s the process that matters, that’s what you need to assess:
  - To ensure certain critical limits are met (that will eliminate or control the hazards), and
  - To ensure that the process is such that no additional hazards will be created or added (hygiene, etc.)
SAFER FOOD

- pH<4.6
- Aw<0.85
- Properly cooked or fermented
- Temp <4°C