Fermented Foods

Laura Bauer, PhD, RD & Marisa Bunning, PhD
Dept. of Food Science and Human Nutrition
Colorado State University
Date: November 2, 2015
Overview

- Background – how CSU became involved
- The relationship between food safety and fermentation
- Nutrition and health benefits
- Kombucha – a gateway fermented product
- Kimchi - As one eats kimchi, one eats the universe, and in so doing becomes part of the universe and universe becomes part of man"

Korean proverb
Zymology/Zymurgy: The workings of fermentation. Louis Pasteur was the first zymologist when he connected yeast to fermentation.

Pasteur demonstrated that yeast was responsible for fermentation to produce alcohol from sugar, and that air (oxygen) was not required. He also demonstrated that fermentation could also produce lactic acid.
FTEC 210: Science of Food Fermentation

Course Description:
Science, history, culture, gastronomy, safety, health, and nutrition aspects of fermented foods and beverages.

Fermented Foods

- Important component of global foodscape
- Belong to local biocultural heritage, which has evolved through centuries of interactions between local societies and their environment – promoted food security and gastronomic ‘sense of place’
- New trajectories in gastronomy have embraced fermentation in terms of interesting tastes and perceived health value

1Souland et al. 2015
Going down the Fermentation Path(ways)

(a) Lactobacillus

(glucose) → fructose diphosphate

2 ATP → 2 ADP

2 ADP → 2 phosphoglyceric acid → 2 triose phosphate

2 NADH₂ → 2 NAD

2 ATP → 2 pyruvic acid → 2 lactic acid

(b) Saccharomyces

(glucose) → fructose diphosphate

2 ATP → 2 ADP

2 ADP → 2 phosphoglyceric acid → 2 triose phosphate

2 NADH₂ → 2 NAD

2 ATP → 2 pyruvic acid → 2 alcohol

2 CO₂

Graphic: textbookofbacteriology.net
Food Safety & Food Fermentation go Hand in Hand

For both:

- To understand, need to think on a microscopic level
- Sanitation steps are critical
- Acidity, salt, alcohol, CO₂, lack of oxygen, antimicrobial compounds, can be used as preventive controls
Hygienic practices
Temperature control
Ingredient standards
Using proper methods
Recordkeeping

Food Safety Fermentation

Acids
Alcohol
CO₂
Antimicrobial compounds¹
Microbial ecology

¹Ross et al. 2002
Images: http://buffalonickelblog.com/, www.completecocktails.com
Bonding with Good Microbes

Bacteria (microbes) are effective coevolutionary partners because they are highly adaptable and mutable – they continually monitor their external and internal environments and make adjustments…
FDA:

**Acid foods** are foods that have a **natural** pH of 4.6 or below. Examples of acid foods include most fruits.

**Fermented foods** are low-acid foods subjected to the **action** of acid-producing microorganisms to reduce the pH of the food to 4.6 or below. Examples of fermented foods include some kinds of sauerkraut, cucumber **pickles**, and green olives.

**Acidified foods** are low-acid foods to which **acid(s)** or **acid food(s)** are **added** to reduce the pH of the food to 4.6 or below. Examples of acidified foods include many salsas, pickled beets, and cold-pack **pickles**.

http://www.fda.gov/Food/NewsEvents/ConstituentUpdates/ucm228244.htm
Fermentation

We use the term ‘fermentation’ to refer to the transformative effect of microorganisms and their products (especially enzymes, alcohols, CO₂, and organic acids) on food as employed by humans in food preparation.¹

¹Souland et al. 2015
Traditional Fermented Plant Foods

Plants from more than 20 botanical families used in traditional fermented vegetables in Eastern Europe

Fig. 4. Proportions of the kind of different fermented preparations recorded.

Soukand et al. 2015
<table>
<thead>
<tr>
<th>Improperly Fermented Food</th>
<th>Date</th>
<th>Pathogen or Toxin</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Beans</td>
<td>March 2006</td>
<td><em>Bacillus cereus</em></td>
<td>Zhou et al. 2014</td>
</tr>
<tr>
<td>Cassava</td>
<td>Aug 2015</td>
<td>Linamarin</td>
<td>ProMED</td>
</tr>
<tr>
<td>Kimchi</td>
<td></td>
<td><em>E. coli</em> ETEC O169</td>
<td>ProMED, Cho et al. 2014</td>
</tr>
<tr>
<td>Milk (colostrum)</td>
<td>Jul 2005</td>
<td><em>Clostridium botulinum</em></td>
<td>ProMED</td>
</tr>
<tr>
<td>Pruno (Prison brewed alcohol made from fruits, veg....)</td>
<td>Multiple years</td>
<td><em>Clostridium botulinum</em></td>
<td>ProMED, Vugia et al. 2009, MMWR 2013</td>
</tr>
<tr>
<td>Sausage</td>
<td>Fall, 2002</td>
<td><em>E. coli</em> O157:H7</td>
<td>Sartz et al. 2008</td>
</tr>
<tr>
<td>Seafood</td>
<td>Multiple years</td>
<td><em>Clostridium botulinum</em></td>
<td>Fagan et al. 2011</td>
</tr>
<tr>
<td>Seal Flapper</td>
<td>May 2015</td>
<td><em>Clostridium botulinum</em></td>
<td>ProMED</td>
</tr>
<tr>
<td>Fermented Fish</td>
<td>Aug 2014</td>
<td><em>Clostridium botulinum</em></td>
<td>ProMED</td>
</tr>
<tr>
<td>Salmon</td>
<td>Aug 2005</td>
<td><em>Clostridium botulinum</em></td>
<td>ProMED</td>
</tr>
<tr>
<td>Tempeh (soybeans)</td>
<td>May 2012</td>
<td>*Salmonella Paratyphi B</td>
<td>ProMED, Griese et al. 2013</td>
</tr>
<tr>
<td>Tofu (soybean curd)¹</td>
<td>12/2006; 3/2012</td>
<td><em>Clostridium botulinum</em></td>
<td>ProMED, MMWR 2007, 2013</td>
</tr>
<tr>
<td>Turshi (fermented vegetables)</td>
<td>Dec 2013</td>
<td><em>Clostridium botulinum</em></td>
<td>ProMED</td>
</tr>
<tr>
<td>Yogurt</td>
<td></td>
<td><em>Mucor circinelloides</em> (fungi)</td>
<td>ProMED</td>
</tr>
</tbody>
</table>

Gagne et al. 2015, *Food Microbiology*: contamination of sauerkraut by enteric viruses (murine norovirus-1) cannot be mitigated by fermentation
Why Ferment?

• **Lowers pH**
  - Preservation of food: improved shelf life and safety
  - Reduces risk of pathogen growth

• **Food security**
  - Reduce resource (energy, agriculture) expenditure

• **Desirable changes to substrate**
  - Produces new product: organoleptic, function
  - Enhances health benefits

Soybeans + *Aspergillus oryzae* = Miso

Katz (2012); van Boekel, et al. (2010); Battcock, Azam-Ali, & FAO (1998); Mothershaw & Guizani (2007); Stanton, et al. (2005); Raes, et al. (2014)
Health Benefits of Fermented Foods

Source of probiotic and live organisms
  • Improve gut health

Pre-digestion
  • Increase bioavailability of carbohydrates, minerals, lactose, gluten, etc.

Nutritional enhancement
  • Vitamin synthesis: K and B vitamins
  • Phytochemicals

Detoxification
  • Phytates in grains, legumes, seeds, and nuts
  • Nitrate and oxalic acid in vegetables

Acid production
  • Organic acids and modulated compounds*
  • Short chain fatty acids are nutrition for colonocytes

*Selhub et al. 2014, Journal of Physiological Anthropology
Ecosystem

A community of living organisms together with the non-living components of their environment.
Ecosystem

A community of living organisms together with the non-living components of their environment.
Factors That Affect Microbial Growth

**Intrinsic**
- pH
- Moisture content (water activity $a_w$)
- Oxidation-Reduction potential
- Nutrient content
- Antimicrobial properties
- Biological structures

**Extrinsic**
- Temperature
- Relative humidity
- Atmosphere (gases)
- Presence and activities of other microorganisms
What is Kombucha?

Sugar-sweetened brewed tea fermented by a combination of yeasts and bacteria. Including:

- *Gluconacetorhacter* spp.
- *Lactobacillus* spp.
- *Zygosaccharomyces* spp.

Composition varies, but all contain gluconic acid, acetic acid, and fructose.

Each is unique: tastes slightly tangy, cider-like, and effervescent.

1. Yeast Fermentation

Sugar $\rightarrow$ Alcohol

- Metabolize sucrose to glucose and fructose
- Convert glucose to organic acids, carbon dioxide, and ethanol
Symbiotic Culture of Bacteria and Yeast

2. Bacterial Fermentation

Alcohol → Acetic acid

- Convert ethanol to form acetaldehyde and acetic acid
- Use yeast-derived glucose to synthesize cellulose and gluconic acid
Kombucha Risk Analysis

Boiling water will kill vegetative pathogens
Active culture will outcompete sporeformers
Fermentation will decrease pH ≤ 4.2, endpoint ≤ 2.5
Refrigeration will prevent spoilage from molds
CO₂ will minimize mold growth

Nummer, J. of Environmental Health, 74 (4) 8-12
Kombucha Producers: Alcohol Concern

John J. Manfreda
Administrator
Alcohol and Tobacco Tax and Trade Bureau
1100 North Capitol Street, NW, Room 112
Washington, DC 20204

Dear Administrator Manfreda,

It has come to our attention that many retailers have started to promote the preparation and sale of kombucha tea, a natural probiotic drink, which involves the fermentation process. This process primarily uses the microorganisms present in the kombucha tea to produce beneficial substances.

However, this process also involves the production of alcohol, which is not regulated or taxed by the Alcohol and Tobacco Tax and Trade Bureau (TTB). This has raised concerns about the potential for alcohol content in the kombucha tea, which may be harmful to consumers.

It is important to note that the alcohol content in kombucha tea can vary significantly, depending on the fermentation process and the type of tea used. Therefore, it is crucial to develop a comprehensive approach to regulating kombucha tea to ensure the safety and quality of the product.

We appreciate your attention to this matter and look forward to your response.

Sincerely,
[Signature]
[Name]
[Title]
What is Kimchi?

What is Kimchi?

From original Korean name *chimchae* meaning “salted vegetable”

A group of fermented vegetable dishes: more than 200 varieties

Kimchi can be made from cabbage, radish, scallion, cucumber, salt, brine, garlic, ginger, spices, fish sauce and/or shrimp sauce

Kimchi and rice are at center of Korean diet: Koreans eat Kimchi every day with nearly every meal
Kimchi

Historical evidence from over 4000 years ago

- Observed favorable use of red pepper in fermentation process

Variations in ingredients and preparations influence studied health effects, including:

- Anticancer, antioxidative, antiatherosclerotic, antidiabetic, antiobesity, antiaging, antimicrobial, immunity boosting, and nitrate level reduction (cabbage).

Lactic acid bacteria – 13 types of Korean kimchi

Park et al. 2014.
Future Work

Palani et al. 2016. *Food Chemistry*: glucosinolate compound degradation in sauerkraut - maximum of health beneficial compounds after fermentation (7-9 days) in contrast to raw cabbage or stored sauerkraut.

- Similar study with kimchi?
- Accessing pH changes with traditionally made kimchi
What do home fermenters need to know?

Food Safety is in Your Hands!

- Follow good hygiene practices
- Adhere to methods* and recipes
- Monitor temperatures and times
- Observe results

* Safe fermentation vessels

Image: www.touchofembellishment.com
References


References


References


Questions