FOOD PRESERVATION BY FERMENTATION
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Fermentation makes new and desirable product/s, with preservative effects
Fermentation breakdowns CHO and other constituents

- Production:- alcohol, acid and energy
- Proteolysis (protein breakdown) : peptides, polypeptides, NH_4^+
- Lipolysis (lipid breakdown) : fatty acids

Benefits of Fermentation

1. Preservative effect**:** acid and alcohol production
2. Safe pH<4.6:
   - No pathogens
   - No food poisoning bacteria (including *C. botulinum*)
3. Nutritive value:
   - Breakdown of complex compounds
   - Synthesis of vit. B_{12}, riboflavin, vit. C precursor
   - Enz. breakdown of cellulose and hemicellulose
4. Improve the textural and sensory properties of food

Microbial Changes

- Proteolytic bacteria: Anaerobic degradation of protein
  - Produce other nitrogenous compounds
  - Putrid flavours and odours
  - NaCl limits the putrefactive MOs
- Lipolytic bacteria: Breakdown fats, phospholipids etc.
  - Rancid, fishy odours and flavours
- Fermentative bacteria
  - Breakdown CHOs :- acid and/or alcohol + CO_2
  - Inhibit proteolytic and lipolytic bacteria
  - Encourage only acid producing MOs

Combined and balanced activities of these 3 MOs are important

Common Fermentation Activities

- Ethanolic fermentation ex: wine and beer and bread

$$C_6H_{12}O_6 \xrightarrow{\textit{S. cerevisiae or S. ellipsoideus}} C_2H_5OH + CO_2 + \text{energy}$$

- Alcoholic and acid fermentation ex: vinegar from cider/wine

$$C_2H_5OH + O_2 \longrightarrow CH_3COOH + H_2O \; \textit{Acetobacter aceti}$$

- Lactic acid fermentation ex: yoghurt, curd, cheese etc.

Lactose ⟶ Lactic acid ***Steptococcus lactis***

Controlling of Fermentation in Various Foods

Foods are contaminated with naturally occurring MOs.

Control: *Desirable fermentation process*
Support the activity of desirable MOs

Common controls:

1. Acid level
2. Level of oxygen
3. Alcohol level
4. Amount of salt
5. Use of starters
6. Temperature

1. Acid

- ❖ Added to food
- ❖ Naturally constituent of the foods
- ❖ Produced by fermentative MOs

- Fermentation can be controlled:
  - ➢ *by addition of acid*
  - ➢ *by natural acid fermentation*

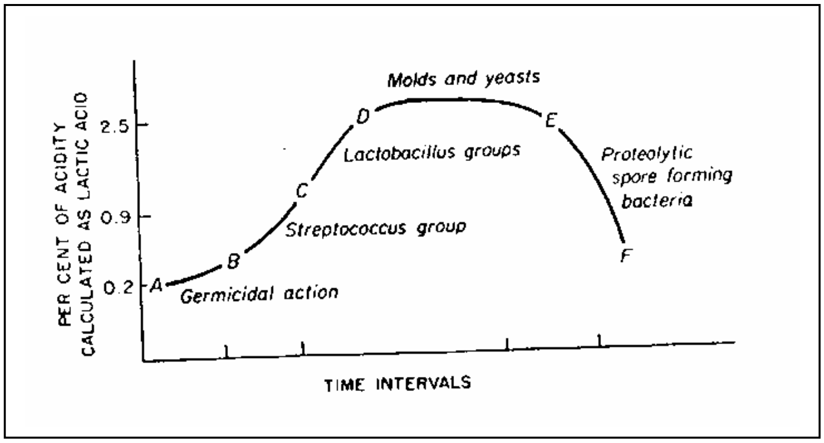
1. Moulds ferment the acid (@ O_2)
2. Effect of acid is lost
3. Next: proteolytic and lipolytic organisms start to grow

- Certain yeasts tolerant to low pH: produce alkaline end products (eg. NH_3)

Raw milk fermentation

- ♣ Freshly milk has germicidal action for short period
- ♣ *Streptococcus lactis* dominates and produce lactic acid
- ♣ Inhibit the other MOs
- ♣ *S. lactis* is inhibited by its own acidity
- ♣ *Next: Lactobacillus* takes over
- ♣ High acidity itself inhibit *Lactobacillus*
- ♣ *Next:* Yeast produce alkaline end products (proteolysis)
- ♣ Favourable for the Proteolytic and lipolytic bacteria

- ➢ Proteolysis ⟶ milk pH increase
- ➢ milk get clots
- ➢ Mold and yeast growth: gassy, putrefied, off-odour



Bread making:

Sugars in dough —Yeast→ alcohol + acid+ CO_2

1. "Conditioning " of dough: gluten mature (elastic)
2. Retain max. CO_2 & leaven: loose and porous texture
   - "conditioning" action on gluten caused by
     1. proteolytic enzymes form by yeast
     2. reduction of pH by formed acids
   - Flavour : Alcohol, acids, esters and aldehydes etc.

Sour breads - fermentation using *Lactobacillus* spp.
Acid inhibit the spore forming *Bacillus* genus
Germination of spores : produce gummy or ropy bread
During baking:

Kill the yeasts | *Expand the gas gelatinisation of starch*
Inactivate enzymes | *Set the structure of loaf*

2. Alcohol

Preservation depends on the conc. of alcohol
Wine production:

- Alcohol level in wine depends on:
  - Sugar in grapes
  - Types of yeast
  - Fermentation temp.
  - Level of oxygen
- Yeast can not tolerate their own alcohol
- Alcohol by volume
  Natural wine 9 -13% by volume: mild pasteurisation needed
- Fortified wine
  Wine -20% alcohol: do not need pasteurisation
- WINE making process: see potter food science
- Beer Brewing : see potter food science

3. Starters

- Better control on fermentation
- Domination of desired organism right from the beginning
- Cultures : dehydrated and concentrated frozen forms

- Wine
- Cheese
- Yoghurt
- Pickles
- Vinegar
- Beer
- Sausage
- Bread
- Other ferm. foods

- Culture strains are resistant to traces of antibiotics and pesticide residue

4. Temperature

- Each MO has optimum growth temperature
- Control of temp.: encourage the growth of desirable MO

Sauerkraut(e) production

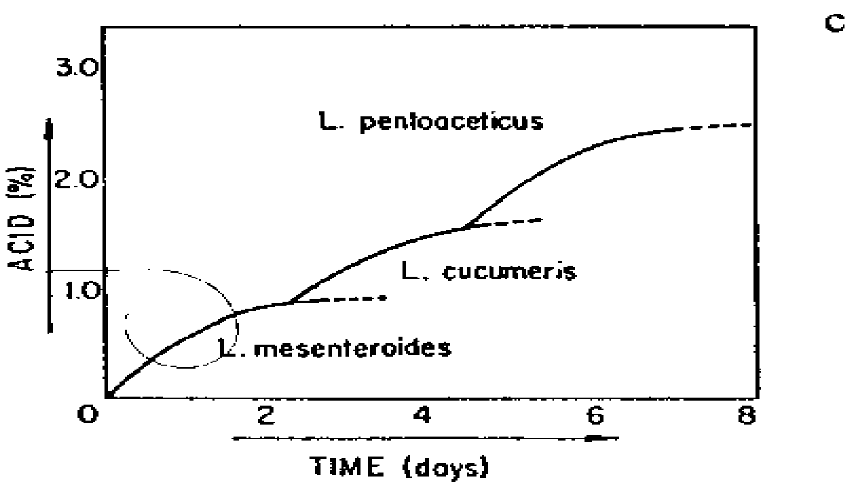
- Sauerkraut(e) fermentation sensitive to temperature

Cabbage sugar —(*3 types of bacteria*)→ acids

acids + alcohols → esters (final flavour)

- *Leuconostoc mesenteroids*: acetic acid, lactic acid, alcohol and CO_2
  optimum temp is 21°C and 2.5% salt
- *Lactobacillus cucumeris*: produce lactic acid
  optimum temp >21°C
- *Lactobacillus pentoaceticus:* still more lactic acid

Sequence of acid fermentations in sauerkraut production



5. Oxygen

- *Acetobacter* – requires O_2 for vinegar production
- Yeast - alcohol production under anaerobic condition

- aerobic condition: produce more cell masses
- Commercial production of yeast - air bubbling system

<u>Vinegar production:</u>

Two-step process

(1) * *Aerobic condition:* growth and increases cell mass
* *Anaerobic condition:* fermentation sugar to alcohol

$$C_6H_{12}O_6 \xrightarrow[\ ]{\textit{S. cerevisiae var. ellipsoideus}\quad 25^{o}\,C} 2CO_2 + 2C_2H_5OH$$

(2) *Aerobic condition:* alcohol to acetic acid (oxidative ferm.)

Acetobacter aceti OR
Gluconobacter spp.

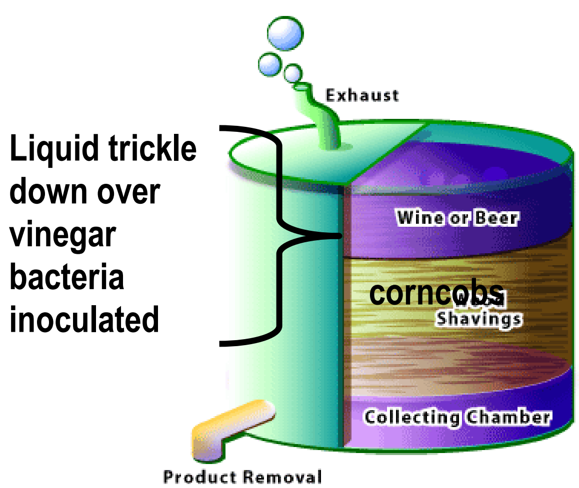
$$C_2H_5OH + O_2 \longrightarrow CH_3COOH + H_2O$$

in a vinegar vat

Vinegars:
1. Fruit juices: apples, grapes, orange, pears
2. Starchy vegetables: potato or sweet potato
3. Malted cereals: barley, wheat, rice, corn etc.
4. Sugars: molasses, honey, syrups, etc.
5. Spirits or alcohol: waste liquor, toddy etc.

1. Slow method: Natural process – poor yield and quality
   - *Fermentation*: fruit juice
   - *Acetification*: in fermentation barrel open with bunghole
2. Quick method: Vinegar generator (wooden vat) - 3 parts
   Upper, *Middle* and *Bottom*

   Submerged fermentation method
   - When acetic acid conc. 4% - 8% vinegar is removed
   - Matured in an airtight storage system
   - Maturing (aging): esterification and improve the flavour
   - Bottled vinegar pasteurised at 65 ^{o}C



6. Salt

- MO classified : salt tolerance
- lactic acid bacteria tolerant up to 10-18% salt
- proteolytic and other spoilage MO not tolerant > 2.5% salt
- Salt add to vegetable
  - ➢ draws water and sugar out
  - ➢ lactic acid bacteria diffusion into vegetable tissue
  - ➢ avoided spoilage

Sauerkraut production	Salt	2 - 2.5% + acid
Olive fermentation	Salt	7 - 10%
Cucumber fermentation	Salt	15 - 18%

- Salt added in cheese - prevention from proteolytic bacteria

INTERMEDIATE MOISTURE FOODS (IMF)

MOs cannot grow a_w < critical a_w
Pathogenic MOs cannot grow $a_w < 0.9$
Yeasts and moulds not growth $a_w < 0.62$
Intermediate moisture foods (IMF) a_w 0.6-0.90
Moisture content of IMF = 10 - 50%
IMF aw 0.65 - 0.90: aw primary hurdle to MOs activity
Staphylococcus aureus tolerate aw 0.83-0.86: significant MO in IMF

- But microbial control in IMF also depend on pH, Eh, F and T values preservatives
- IM fruits preserved a_w = 0.65 - 0.9 and MC = 15%-40%
- IMF stable at room temperature
- It can be generally eaten without rehydration
- Advantages:
- IMF easy to prepare and store without refrigeration
- Energy efficient and relatively cheap
- Not readily subject to spoilage even if packages is damaged

Disadvantages:

- Some IMF foods contain high levels of additives i.e.: nitrites, sulphites etc.
- High sugar content: concern about high calorific intake
- Lack of sensory properties of the food

HURDLES TECHNOLOGY

"Food preserved by combined methods (hurdles) remains stable and safe even without refrigeration and is high in sensory and nutritive value due to the gentle process technique"

- The hurdles:

Temperature, a_w, redox potential (Rh), modified atmosphere (MA/CA), preservatives, etc.

- The concept:

Given food the MOs should not be able to "jump over" all of the hurdles present

- ➢ Combined methods for preservation of fruits &vegetables
- ➢ Different hurdles have a synergistic or additive effect
- ➢ Replacing ability of hurdles: e.g.: nitrite in meats could be partially replaced a_w
- ➢ Hurdle could be used without affecting the integrity of food e.g.: high pressure (HPP) for juices
- ➢ Consumer demand for fresh quality *: "Minimally processed products (MP)"*

- MP Products:

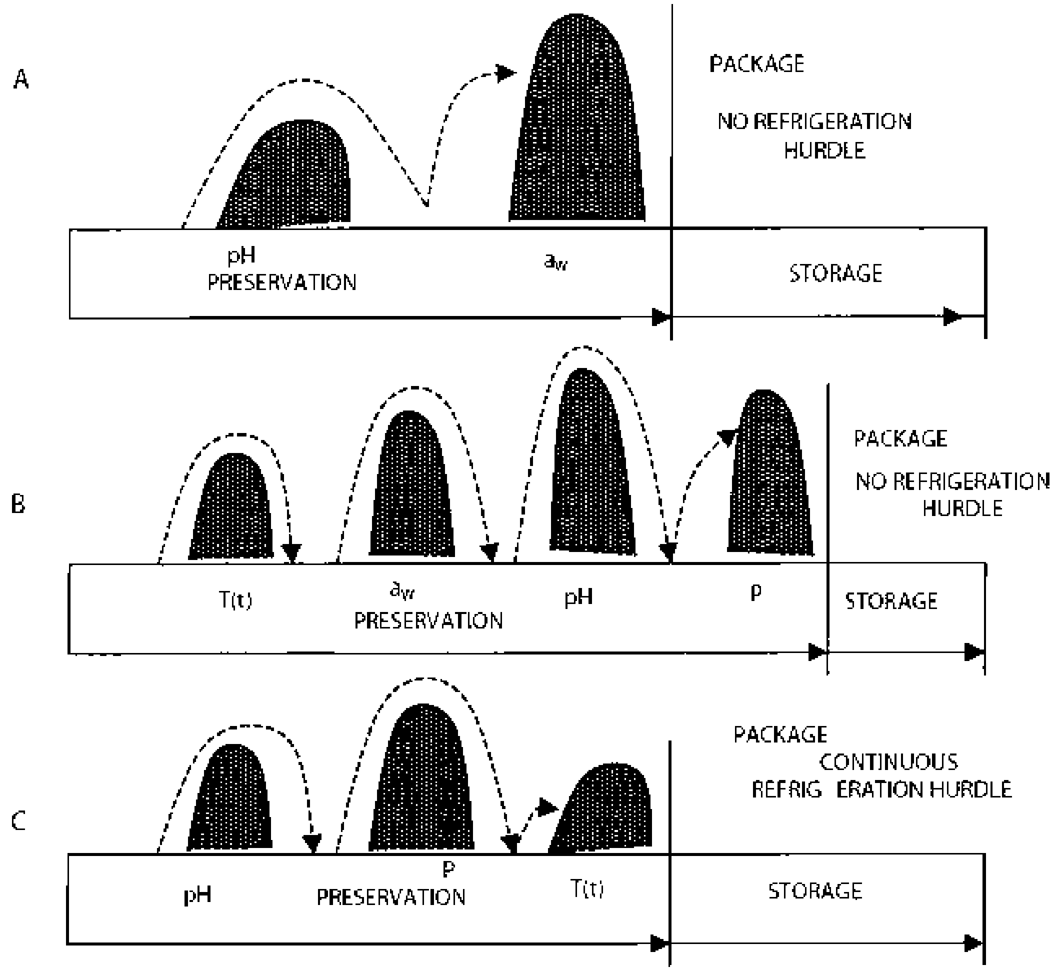
- ❖ Pre-cut refrigerated fruits,
- ❖ Peeled refrigerated fruits
- ❖ Pre-heated vegetables and fruits
- ❖ Cloudy and clarified refrigerated juices
- ❖ Freshly squeezed juices
- ❖ Packaging etc

MP refrigerated products can be raw, respiring and biochemically active: rapid senescence and/or quality changes

SCHEMATIC REPRESENTATION OF HURDLES

Water activity (a_W), pH, preservatives (P), and slight heat treatment T(t), involved in three fruit preservation systems

(A) Intermediate moisture fruit product (IMF)
(B) High-moisture fruit product (HMFP)
(C) Minimally processed refrigerated fruit product (MPR)



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