- **Food Microbiology is the study of the microorganisms that inhabit, create or contaminate food , including the study of microorganisms causing food spoilage.**

- **Food safety is a major focus of food microbiology. Pathogenic bacteria, viruses and toxins produced by microorganisms are all possible contaminants of food. However microorganisms and their products can be used to combat these pathogenic microbes.**

- **Though preparation of food including proper cooking eliminates most bacteria and viruses, however toxins produced by contaminants may not be heat - labile and some are not eliminated by cooking.**

The field of modern food microbiology, includes recent developments in the procedures used to assay and control microbiological quality in food. It covers the three main themes of the interaction of micro-organisms with food-spoilage, foodborne illness and food fermentation and gives balanced attention to both the positive and negative aspects which result. It also discusses the factors affecting the presence of micro-organisms in foods, as well as their capacity to survive and grow.

Modules :

1) Microorganisms and food.
2) Harmful effects of microbes.
3) What is food fermentation?
4) Microbes in Food and Beverage Production

What are microorganisms?
Microbes : Friend & Foe

Microbes are sub- microscopic organisms so tiny that millions can fit into the eye of a needle. They are the oldest form of life on earth. Most microorganisms are harmless to humans. You swallow millions of microbes everyday with no ill-effects. In fact we are dependent on microbes to help us digest our food.

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THERE WAS THIS HUGE EYE THAT WOULDN'T STOP STARING AT ME!
IT'S JUST THE MICROSCOPE DREAM AGAIN... GO BACK TO SLEEP!
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The Microbe World: Helpful or Not?

There are approximately 100 trillion microbes in our bodies – 500 to 1,000 different species of them in every human. "The current estimate is that humans have 10 trillion human cells and about 100 trillion bacterial cells," says Dr. Martin J. Blaser at the New York University School of Medicine.

They make up to 3 to 5 kilograms of our total body weight.

Most of them live in the colon, the location of 70% of our immune system activity; billions of others live in the mouth, lungs, skin, and the female birth canal.

- **We need microbes for our survival and maintaining good health. In fact, there are “good” and “bad” microbes.**
- **The good ones fight viruses and infections, break down fibers, harvest calories and nutrients, and strengthen our immune systems.**
- **One of the most important things microbes do for us is to help with digestion. The mix of microbes in your gut can affect how well you use and store energy from food.**
- **But also there are “bad” microbes that threaten our survival by causing obesity, diabetes, inflammatory bowel disease, allergies, accelerated aging, and even depression. "There is a constant war going on between good and bad microbes in each of us.**
- **Winning the microbe war is essential to our well-being – in fact, to our very lives,“ according to the current research.**
- **Doctors and researchers are finding that rather than treating the symptoms of these diseases, it is far more effective to treat the cause, which lies in an imbalance of the micro-biota.**
- **When the microbial world in our bodies is balanced and in harmony, we no longer experience an increased level of bad microbes and the endotoxins they produce. How do we achieve this balance and win the war of microbes?**

What Are the Harmful Effects of Microorganisms? Microbes as Foe:

- **Microorganisms can affect food, air and water. These tiny cellular structures can spread diseases and infections. They are found in soil, water, and animals as well as inside our bodies.**
- **Any number of germs from raw waste to the flu can be spread through thousands of these invisible to the naked eye carriers.**
- **Microorganisms can cause food to spoil, water to be tainted and both humans and animals to become sick. The microbes that threaten us come in a vast variety of shapes, sizes, and lifestyles.**
- **They stand ready to invade the body, feed off our bodies' cells, grow and reproduce, causing an infection. Microbes are constantly changing, adapting to new environments, finding new places to live and survive.**

- **Foods contaminated with pathogenic microorganisms usually do not look bad, taste bad, or smell bad. It is impossible to determine whether a food is contaminated with pathogenic microorganisms without microbiological testing.**

- **To avoid potential problems in foods, it is very important to control or eliminate these microorganisms in food products. Pathogenic microorganisms can be transmitted to humans by a number of routes.**

- **Diseases which result from pathogenic microorganisms are of two types: infection and intoxication.**

Did you know?

A drop of seawater can contain millions of one-celled organisms called microbes. While the microbes that cause illnesses get much of the attention, most microbes are beneficial to life on Earth. In fact, microbes living in the ocean generate much of the oxygen we breathe!

What is food fermentation?

Fermentation is used in the food and beverage industry to convert carbohydrates into alcohol, carbon dioxide and organic acids (i.e. lactic acid and acetic acid).
The fermentation process often takes place in an anaerobic environment – which means no oxygen is present.
Microorganisms are important in the food industry, not only as producers of certain foods but as contaminants of others.

Food Microbes-classification

- Bacteria
- Yeast (*Saccharomyces, Pichia, Torula ,Rhodotorula, Candida)*
- Mold (*Pencillium, Aspergillus, Fusarium*,)
- Viruses (Norwalk virus, Hepatitis virus, Bacteriophages)
- Prions

Bacteria

- Gram Negative
  - Aerobes (*Pseudomonas, Xanthomonas, camplyobacter, Helicobacter*)
  - Facultative Anaerobes (members of *enterobacteriacae ;Enterobacter, Escherichia,Hafnia, Klebsiella, Proteus, Salmonella, Shigella*

Bacteria

- Gram Positive
  - cocci (Micrococci, Streptococci, Staphylococci)
  - Sporeforming rods (*Bacillus* sp., *Clostridium* sp.,)
  - Non-sporeforming regular rods (*Lactobacillus, Listeria, Carnobacterium*)
  - Non-sporeforming irregular rods (*Bifidobacterium, corynebacterium, Brevibacterium*)

Role of Food Microbes

Beneficial

- Starters
- probiotics

Undesirable

- Spoilage organisms
- pathogens

Beneficial Microbes

Foods typically contain a variety of bacteria of which some may be beneficial, such as those preserving foods through products of fermentation, and others may be harmful by causing human illness or food spoilage.

Beneficial Microbes :

Microbes serve many useful purposes to humans.
We use them inside our bodies for natural digestion, in industry and food production, dairy products. Food like cheese, pickles, chocolate, bread, wine, beer and soy sauce are all made with the help of different types of bacteria and yeast.
In most of these food products, bacteria play a major role because they produce lactic acid. Fermentation of food is commonly used to process food for making alcoholic beverages, leavening of bread and preserving foods.

Starters

- These are initiators of fermentation.
- Used in production of fermented foods.
- Yoghurt, Cheese, Buttermilk, Lassi (LAB)
- Kefir (*Torula sp.*)
- Swiss Cheese (*Propionibacterium shermanii*)
- blue cheese (*Pencillum roquefortii*)

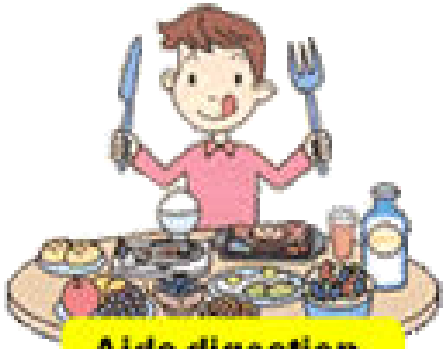
- ✓ **Lactic acid bacteria are among the most important groups of microorganisms used in food fermentations and are largely included in the genera *Carnobacterium, Enterococcus, Lactobacillus, Lactococcus , Leuconostoc, Oenococcus, Pediococcus, Streptococcus, Tetragenococcus, Vagococcus, and Weissella*.**
- ✓ **The essential feature of lactic acid bacteria metabolism is efficient carbohydrate fermentation coupled to substrate-level phosphorylation.**
- ✓ **These bacteria can degrade a variety of carbohydrates, with lactic acid being the predominant end product.**
- ✓ **Many lactic acid bacteria also produce bacteriocins that have antimicrobial activity that is antagonistic to other bacteria, especially toward bacteria closely related to the bacteriocin-producing strain. Bacteriocins are peptides that are produced ribosomally by bacteria and released extracellularly.**

- ✓ **Starter cultures, which are largely comprised of lactic acid bacteria, are food-grade microorganisms that are used to produce fermented foods of desirable appearance, body, texture, and flavor.**
- ✓ **Types of fermented foods for which commercial starter cultures are currently used include dairy products (cheese, sour cream, yogurt), meat products (sausages), and vegetable products (pickles, sauerkraut, olives).**
- ✓ **For starter cultures to be effective during food fermentations, they must dominate over naturally occurring microflora and produce the desired end products of fermentation.**
- ✓ **Many of the activities essential for food fermentations, including lactose metabolism, proteinase activity, oligopeptide transport, bacteriophage-resistance mechanisms, bacteriocin production and immunity, bacteriocin resistance, exopolysaccharide production, and citrate utilization, are encoded on plasmids harbored by lactic acid bacteria.**
- ✓ **Advances in molecular technology have enabled the construction of superior strains of starter cultures for food fermentations.**
- ✓ **Improved features of these strains include bacteriophage resistance, genetic stability, and reduced variation and unpredictability in performance.**

Probiotic

- Microorganism able to give health benefit and colonise the animal gut
- *Lactobacillus acidophilus*
- *Bifidobacterium* sp.
- *Sacchromyces boulardii*
- *B. subtilis*

They reach the intestine alive.

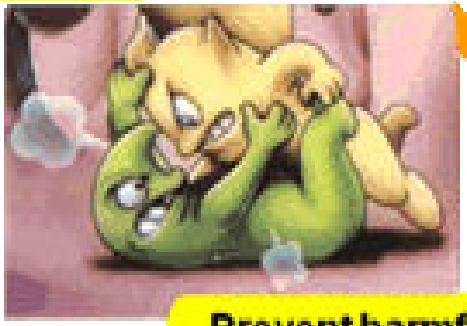


Aids digestion.

It improves bowel movement.

Probiotics

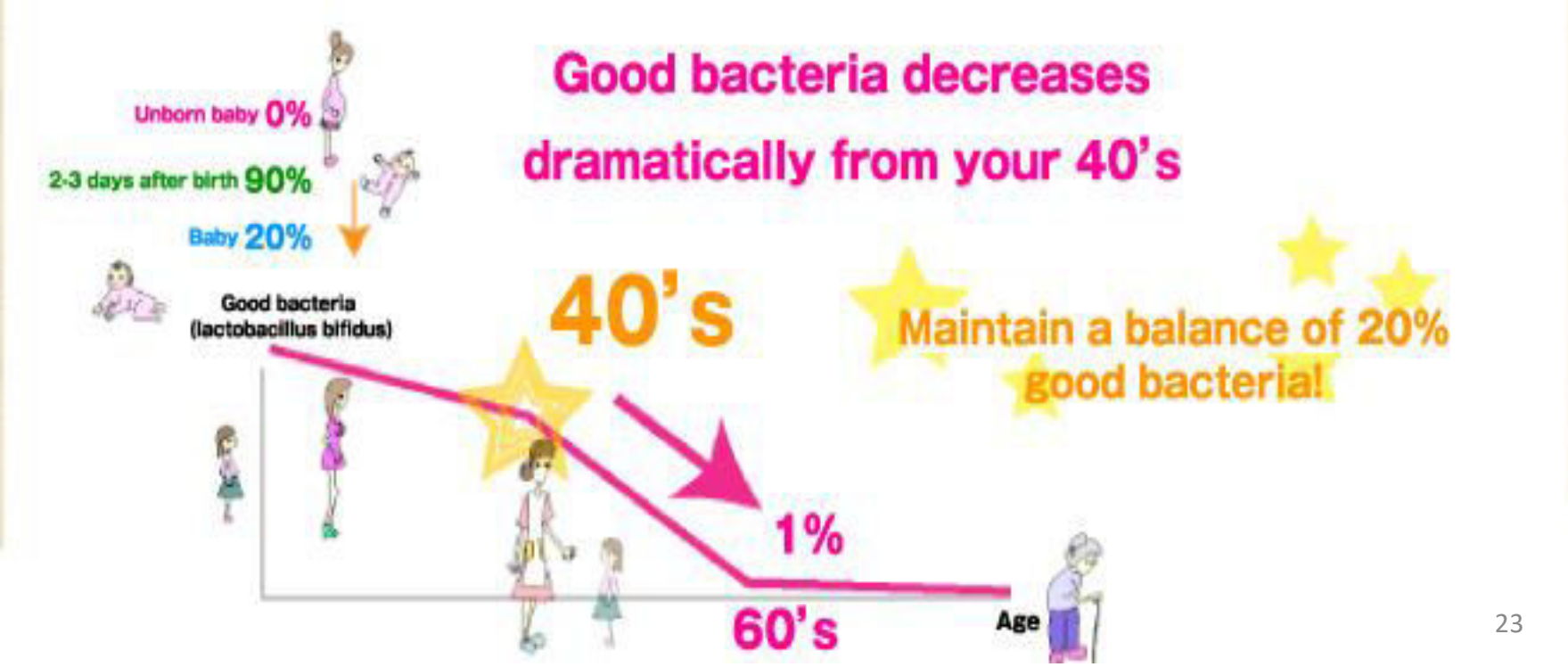
They can be ingested as food.



Prevent harmful bacteria from multiplying in the intestine.

They produce beneficial effect on health.

- ✓ **Another application for beneficial microbes used in foods is adding probiotic microorganisms to provide a health benefit to consumers.**
- ✓ **Many beneficial health effects for probiotics have been reported and include protection against enteric pathogens, improved digestion by means of enzymes to metabolize otherwise indigestible food nutrients (e.g., lactase to hydrolyze lactose in lactose intolerant consumers), stimulation of the intestinal immune system, and improvement of intestinal peristaltic activity.**



- ✓ **Lactic acid bacteria are the most common types of probiotic microbes being used.**
- ✓ **Probiotics have been largely delivered in fermented foods such as yogurt and fermented milk products; however, growing consumer interest in probiotics is leading to using other types of foods such as fruit and vegetable juices, cereal-based products, and even ice cream, as delivery vehicles.**
- ✓ **Fermented foods are an important part of the food processing industry and of many consumers' diets and are largely produced by lactic acid bacteria that have been selected for their ability to produce desired products or changes in the food.**
- ✓ **Many advances have been made during the past decade in developing improved bacterial strains for starter culture application, which largely have been made possible through advances in molecular technology.**

- ✓ **The use of lactic acid bacteria to enhance the quality and safety of foods is a rapidly evolving field.**

- ✓ **With the discovery of new bacteriocins and the development of more efficient approaches to deliver them to foods, the importance of lactic acid bacteria in preserving and providing enhanced safety of food will continue to increase for the foreseeable future.**

- ✓ **Lactic acid bacteria have been used to ferment or culture foods for at least 4000 years. They are used in particular in fermented milk products from all over the world, including yoghurt, cheese, butter, buttermilk, kefir and koumiss.**
- ✓ **Lactic acid bacteria refers to a large group of beneficial bacteria that have similar properties and all produce lactic acid as an end product of the fermentation process.**
- ✓ **They are widespread in nature and are also found in our digestive systems. Although they are best known for their role in the preparation of fermented dairy products, they are also used for pickling of vegetables, baking, winemaking, curing fish, meats and sausages.**

- ✓ The manufacture involves a microbial process by which the milk sugar, lactose is converted to lactic acid.
- ✓ As the acid accumulates, the structure of the milk protein changes (curdling) and thus the texture of the product.
- ✓ Other variables such as temperature and the composition of the milk, also contribute to the particular features of different products.

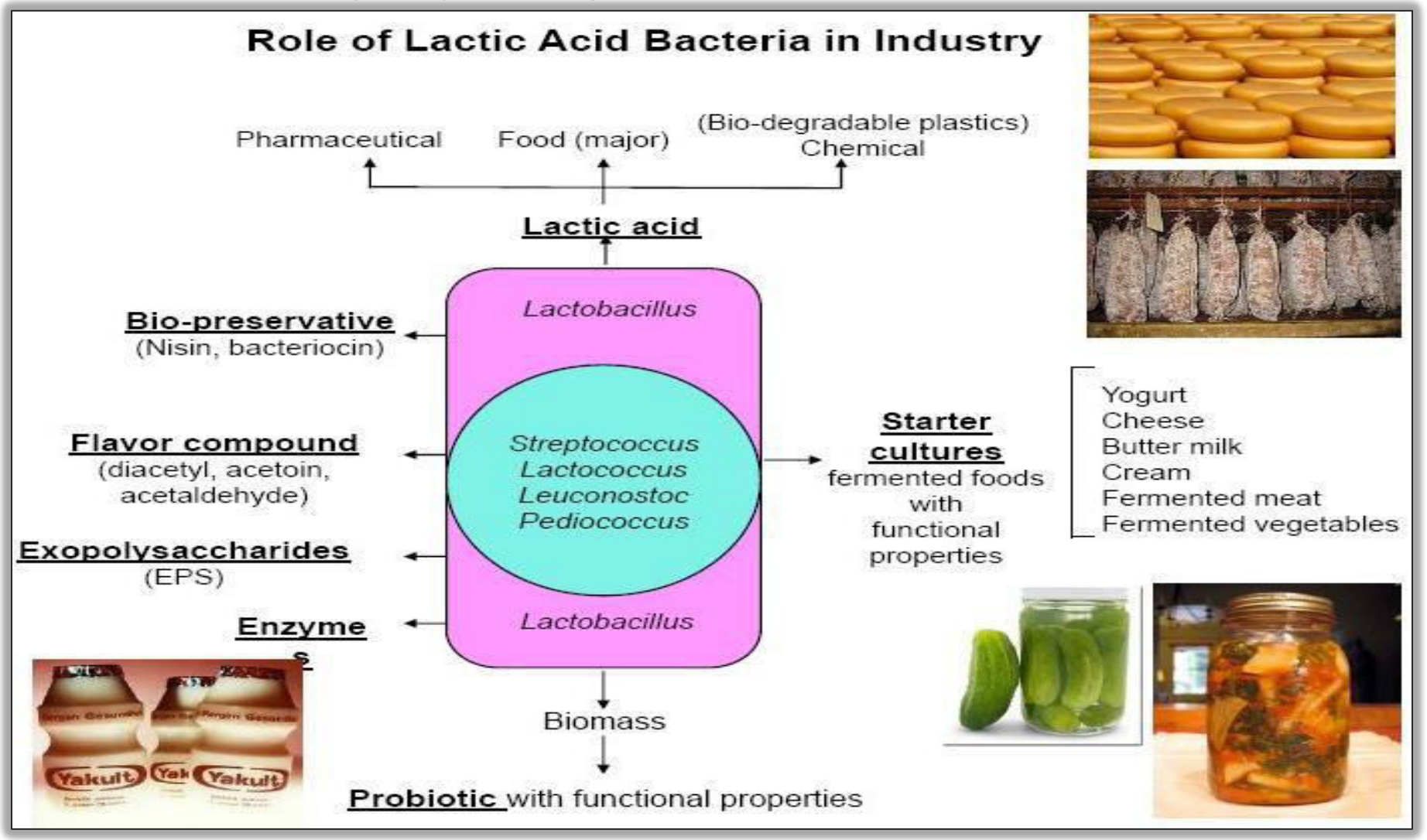
- ✓ Lactic acid also gives fermented milks their slightly tart taste. Additional characteristic flavours and aromas are often the result of other products of lactic acid bacteria. For example acetaldehyde, provides the characteristic aroma of yoghurt, while diacetyl imparts a buttery taste to other fermented milks.
- ✓ Additional micro-organisms such as yeasts can also be included in the culture to provide unique tastes. For example, alcohol and carbon dioxide produced by yeasts contribute to the refreshing, frothy taste of kefir, koumiss and leben.
- ✓ Other manufacturing techniques such as removing the whey or adding flavours, also contribute to the large variety of available products.

- ✓ **For yoghurt, the manufacture depends on a symbiotic relationship between two bacteria, *Streptococcus thermophilus and Lactobacillus bulgaricus*, where each species of bacterium stimulates the growth of the other.**

- ✓ **This interaction results in a shortened fermentation time and a product with different characteristics than one fermented with a single species.**

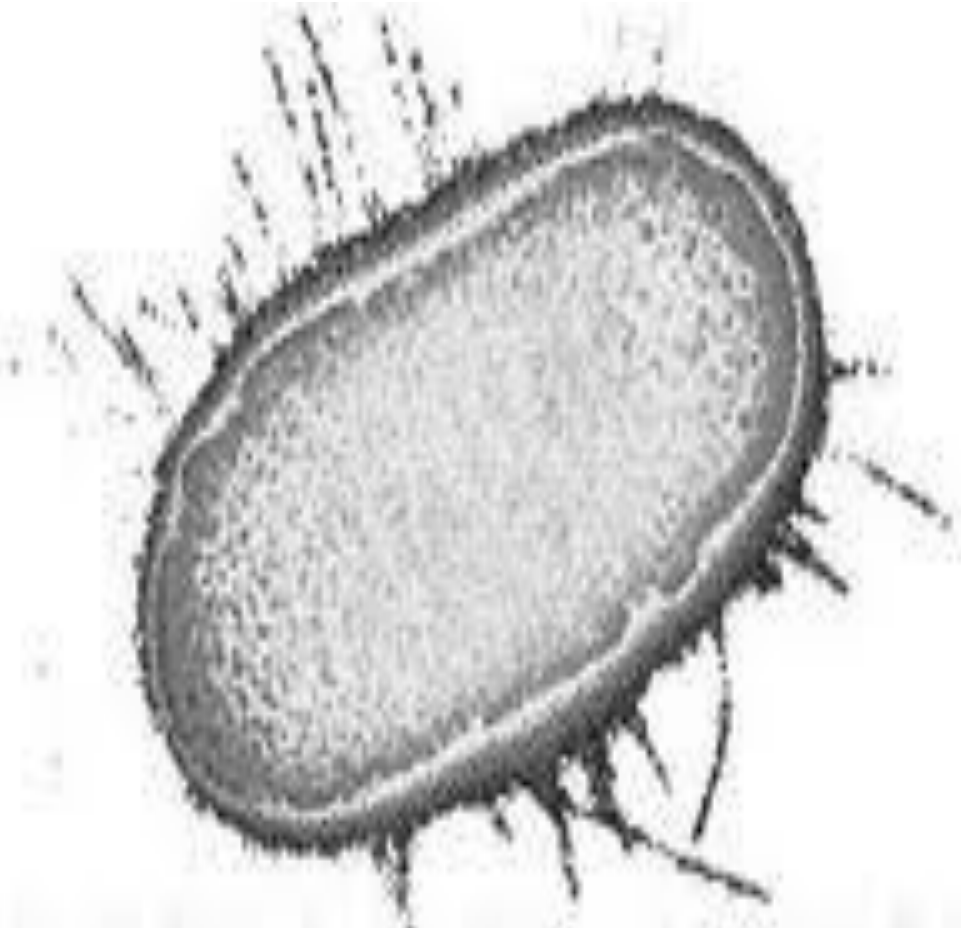
- ✓ **With yoghurt and other fermented milks there are considerable opportunities for exploiting lactic acid bacteria as probiotic cultures.**
- ✓ **These supplement and help our normal gut bacteria to function more efficiently. The world-wide market for these products continues to increase in response to the demands of an increasingly health-conscious public.**

Lactic acid bacteria are therefore excellent ambassadors for an often maligned microbial world. They are not only of major economic significance, but are also of value in maintaining and promoting human health.

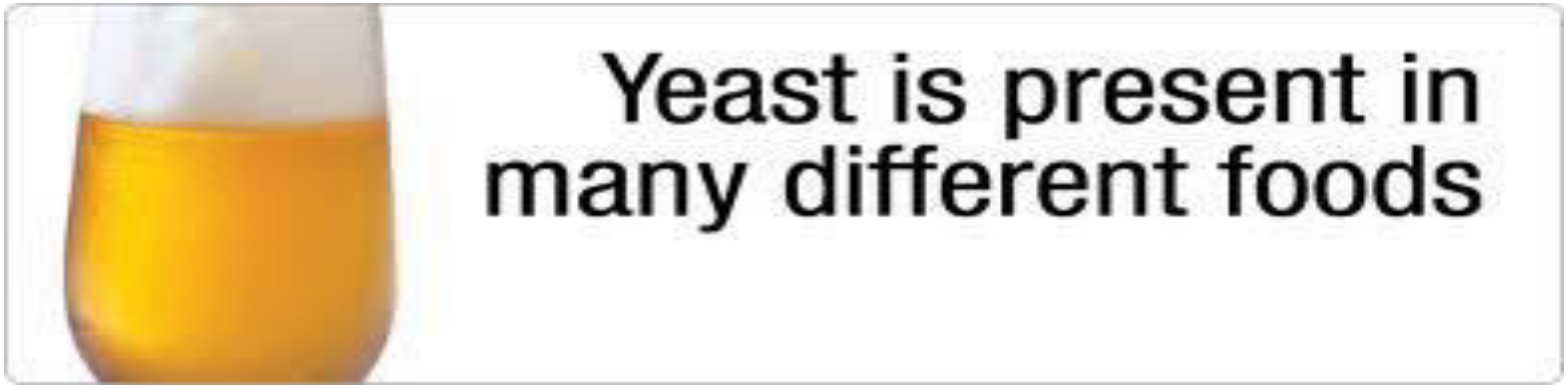


Food	Raw Material	Fermentor
Pickles	Cucumber	*Leuconostoc mesenteroides* *Lactobacillus*
Chocolate	Cacao bean	*Saccharomyces cerevisiae* *Candida rugosa* *Kluyveromyces marxianus*
Bread	Flour	*Saccharomyces cerevisiae*
Coffee	Coffee bean	*Erwinia dissolvens*
Sauerkraut	Cabbage	*Leuconostoc plantarum*
Soy sauce	Soya bean	*Aspergillus oryzae*

Food	Benefits				
Apples	Protects Your Heart	Prevents Constipation	Blocks Diarrhea	Improves Lung Cancer	Cushions Joints
Apricots	Combats Cancer	Controls Blood Pressure	Saves Your Eyesight	Shields Against Alzheimer's	Slows Aging Process
Artichokes	Aids Digestion	Lowers Cholesterol	Protects Your Heart	Stabilizes Blood Sugar	Guards Against Liver Disease
Avocados	Battles Diabetes	Lowers Cholesterol	Helps Stop Strokes	Controls Blood Pressure	Smoothes Skin
Bananas	Protects Your Heart	Quiets a Cough	Strengthens Bones	Controls Blood Pressure	Blocks Diarrhea
Beans	Prevents Constipation	Helps Hemorrhoids	Lowers Cholesterol	Combats Cancer	Stabilizes Blood Sugar
Beets	Controls Blood Pressure	Combats Cancer	Strengthens Bones	Protects Your Heart	Aids Weight Loss
Blueberries	Combats Cancer	Protects Your Heart	Stabilizes Blood Sugar	Boosts Memory	Prevents Constipation
Broccoli	Strengthens Bones	Saves Eyesight	Combats Cancer	Protects Your Heart	Controls Blood Pressure
Cabbage	Combats Cancer	Prevents Constipation	Promotes Weight Loss	Protects Your Heart	Helps Hemorrhoids
Cantaloupe	Saves Eyesight	Controls Blood Pressure	Lowers Cholesterol	Combats Cancer	Supports Immune System
Carrots	Saves Eyesight	Protects Your Heart	Prevents Constipation	Combats Cancer	Promotes Weight Loss
Cauliflower	Protects Against Prostate Cancer	Combats Cancer	Strengthens Bones	Banishes Bruises	Guards Against Heart Disease



"The role of the infinitely small in nature is infinitely large"
Louis Pasteur (1822-1895)



Yeasts :

- ✓ Yeasts can be responsible for the decomposition of food with a high sugar content. The same effect is useful in the production of various types of food and beverages, such as bread, yogurt, cider, and alcoholic beverages.
- ✓ Yeasts are able to grow in foods with a low pH (5.0 or lower) and in the presence of sugars, organic acids, and other easily metabolized carbon sources.
- ✓ During their growth, yeasts metabolize some food components and produce metabolic end products.
- ✓ This causes the physical, chemical, and sensible properties of a food to change, and the food is spoiled.
- ✓ The growth of yeast within food products is often seen on their surfaces, as in cheeses or meats, or by the fermentation of sugars in beverages, such as juices, and semiliquid products, such as syrups and jams.

- ✓ The yeast of the *Zygosaccharomyces* genus have had a long history as spoilage yeasts within the food industry.

- ✓ In the food processing industry, carefully cultured yeasts are used in the production of beer, wine and bread.
- ✓ The most common yeast associated with winemaking is *Saccharomyces cerevisiae* which has been favored due to its predictable and vigorous fermentation capabilities, tolerance of relatively high levels of alcohol and sulfur dioxide as well as its ability to thrive in normal wine pH between 2.8 and 4.
- ✓ Despite its widespread use which often includes deliberate inoculation from cultured stock, *S.cerevisiae* is rarely the only yeast species involved in a fermentation.
- ✓ This is mainly because these species can grow in the presence of high sucrose, ethanol, acetic acid, sorbic acid, benzoic acid, and sulphur dioxide concentrations, representing some of the commonly used food preservation methods.

Molds :

However, some molds are beneficial and are used in the production of antibiotics such as penicillin and in soy sauce production. Molds are specifically grown to create blue cheeses such as Roquefort and stilton and that which grows on the rind of camembert cheese providing distinct flavors.

Molds are essential components of several food products, such as some cheeses, sausages and soy sauce.

➢ Pharmaceuticals from molds:

Alexander Fleming's accidental discovery of the antibiotic penicillin involved the mold *Penicillium*, although the species identity is disputed (*Penicillium notatum, Penicillium chrysogenum or Penicillium rubens).*

Several of the statin cholesterol-lowering drugs (such as Lovastatin, from *Aspergillus terreus*) are derived from molds.

➢ Cheese making

Three main types of cheese rely on molds for their characteristic properties: blue cheese, soft ripened cheese and rind-washed cheese.
To make blue cheese, the cheese is treated with a mold, usually *Penicillium roqueforti,* while it is still in the loosely pressed curd form. As the cheese matures, the mold grows, creating blue veins within it which gives the cheese its characteristic flavour. Examples include Stilton, Roquefort and Gorgonzola.

Soft ripened cheese such as Brie and Camembert are made by allowing *Penicillium camemberti* to grow on the outside of the cheese, which causes them to age from the outside in. The mold forms a soft white crust, and the interior becomes runny with a strong flavour.

➢ Molds in Meat fermentation :

A wide variety of molds (i.e. *Penicillium chrysogenum and Penicillium nalgiovense*) are used to ripen surfaces of sausages. The mold cultures plays a role in aroma formation and improve the texture of the sausages. They also contribute to shortening of the ripening period and preserving the natural quality and in that way expanding the shelf life of the meat product.
Inoculations of sausages with molds were traditionally done with the indigenous flora of the slaughters, the so called house flora.

➢ Soy sauce:

Traditional soy sauce is made by mixing soybeans and other grains with a mold – either *Aspergillus oryzae or Aspergillus sojae* – and yeast. Historically, this would have been left to ferment in the sun, but nowadays it is mostly made under industrial conditions. The key flavour ingredients formed in this process are salts of the amino acid glutamic acid, notably monosodium glutamate.

Contaminants

- Harmless but cause spoilage and off-flavours or taints
- Bacillus sporeformers (*B. licheniformis, B. coalgulans*)
- *Pseudomonas fragii* sp.
- *Leuconostocs*
- Yeast and mold

Pathogens

- Cause food illness
- May produce toxins
- *Salmonella, Shigella, Campylobacter*
- *S. aureus, L. monocytogenes, Yersinia pestis*
- *Aspergillus flavus (Aflatoxin)*
- *Penicillium ochraceus (Ochratoxin)*

Sources of Microorganisms in Food

- Raw material
- Equipment (Micrococci)
- Handlers (*Staphylococcus aureus*)
- Processing
- Packing
- Air (*Bacillus*, Yeast and Mold)
- Dust (*Bacillus sp.*, *Clostridium sp.*)
- Water (*Enterobacteriaceae*)

Fermented Food & Required Ingredients

Product	Raw Material	Starter Culture
Beer	Cereals	Yeast
Wine	Grape Juice	Yeast, Lactic acid bacteria
Vinegar	Wine	Acetic acid Bacteria
Bread	Grains	Yeast, Lactic acid bacteria
Soy sauce	Soybeans	Mold, Lactic acid bacteria
Sauerkraut, Kimchi	Cabbage	Lactic acid bacteria
Fermented sausages	Meat	Lactic acid bacteria
Pickled vegetables	Cucumbers, Olives	Lactic acid bacteria
Fermented milks	Milk	Lactic acid bacteria
Cheese	Milk	Lactic acid bacteria, Yeast, Mold

Yeast & Mold species commonly used in Fermenrtation

Genus	Species	Application
Aspergillus	*oryzae*	Soy sauce
Candida	*famata*	Meat
Candida	*Kefyr*	Fermented milk
Candida	*Krusei*	Fermented milk
Candida	*lipolytica*	
Candida	*Parapsilosis*	
Candida	*valida*	
Geotrichum	*candidum*	Cheese, Fermented milk
Penicillium	*album*	
Penicillium	*camemberti*	Cheese, meat
Penicillium	*chrysogenum*	Meat
Penicillium	*nalgiovense*	Meat
Penicillium	*roqueforti*	Cheese, meat
Saccharomyces	*bayanus*	Fermented milk
Saccharomyces	*cerevisiae*	Baker's yeast, brewing, wine-making, cheese,

Bacterial species commonly used in Food Fermentation

Genus	Species	Application
Acetobacter	*aceti*	Vinegar production
Bafidobacterium	*adolescentis*	Probiotics
Bafidobacterium	*animals*	Cheese, fermented milk, probiotics
Brevibacterium	*Linens*	Cheese, bioprotection
Carnobacterium	*Piscicola*	Meat, bioprotection
Enterococcus	*Faecium*	Cheese, fermented milk, Meat, Vegetables, probiotics, bioprotection
Kocuria	*Varians*	Meat
Lactobacillus	*Acidophillus*	Probiotics, cheese, fermented milk, meat, vegetables
Lactobacillus	*Casei*	Probiotics, cheese, fermented milk, meat, vegetables
Lactobacillus	*Delbrueckii sunsp.*	Fermented milk, cheese
Lactobacillus	*Plantarum*	Bread, meat, wine, vegetables, bioprotection
Lactobacillus	*Lactis lactis*	Cheese, fermented milk, bread, meat, vegetables, probiotics, bioprotection