MICROBIAL BIOTECHNOLOGY

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Lecture-32
Lec 32: Industrial Fermentation and Health Aspects of Fermented Beverages

Hello friends, welcome to my course on microbial biotechnology. We are in Module 9, where we are discussing food production involving microorganisms and their products. Today, we will be discussing fermentation at a large scale, or industrial fermentation, and the health aspects of fermented beverages, including their safety aspects. So, the lecture is divided into two sections. The first section deals with industrial fermentation processes,

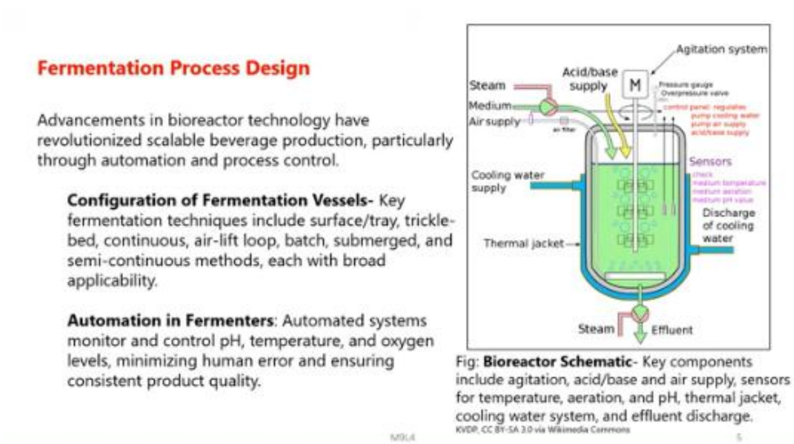
and in the second section, we will be dealing with the health and safety aspects of fermented beverages. So, we begin with scale-up and commercialization processes. Mostly, fermentation is generally experimented with or standardized at the laboratory level on a very small scale. Then, it is taken to a pilot-scale level and finally for commercial purposes, it has to be scaled up to a very large scale.

But it is a very challenging process, and there are several issues that are crucial in this entire industrial-level scaling up. For example, what is the consumer demand and the packaging impact? So, unless a product is in high demand, scaling up is not taken up. Increasing demand for nutritious, high-quality fermented foods mostly drives the novel processes of scaling up, and advanced packaging is useful for extending the shelf life and also ensuring safe distribution of those fermented foods. Meeting the growing market demand requires improved fermentation processes and distribution systems to handle larger production volumes effectively.

Process translation is very, very important. Optimizing bioreactor conditions to ensure consistent product quality across diverse applications and the source of raw materials is very, very important. Scaling up is a very costly affair. So, the investment costs are to be considered and innovations are important for cutting down the cost.

High initial cost for advanced technologies can be therefore a barrier but innovations like multi-starter culture and encapsulations improve efficiency and product stability. So, here is a schematics of a bioreactor. Some of the key components include the agitation system which will mix up the media. Then the supply of acid and base to Maintain the pH is very, very important as well as the supply of air is very, very important, particularly for aerobic fermentation.

Then there are areas of sensors for temperature, pH and including understanding the air flow and then these are helpful in monitoring the reaction conditions from time to time. Then there is a thermal jacket for cooling and finally a effluent discharge system can be there. So, advancements in these biovector technology have revolutionized scalable beverage production particularly through automation and process control key fermentation techniques include surface tray trickle bed continuous air lift loop batch submersed and semi-continuous methods each with broad applicability and then automated systems monitor the different parameters and also control them like pH, temperature and oxygen levels and minimize human error and thereby ensure consistent product quality.

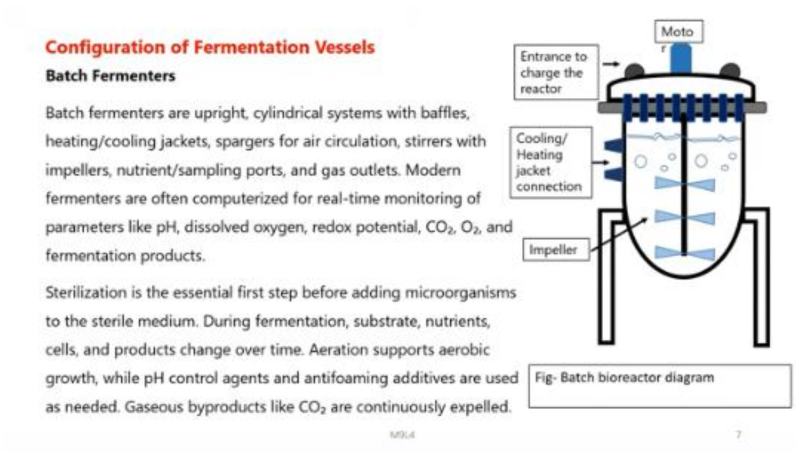


Process control is very important; therefore, real-time monitoring and adjustments, such as oxygen supply regulation, maximize efficiency, especially in large-scale production. The self-cleaning features of bioreactors, particularly technologies like self-cleaning, micro-spurges, and foam breakers, reduce downtime and contamination risks, improving production cycles. The impact on product quality is also another important issue. Automation and control lead to uniform flavor profiles and consistent quality, essential for beverages like vinegar, for example. Then, there are economic benefits from this entire process.

Reduced labor costs and optimized processes through automation increase profitability while maintaining high-quality standards. So, let us look into the configuration of a fermentation vessel. So here, you can see a motor. Then, this is the entrance to charge the machine. Then, we have a cooling-heating jacket connection.

We have discussed this cooling system in the earlier diagram. Then, there is an impeller you can see over here. These batch fermenters are generally upright cylindrical systems with baffles. They include heating, cooling jackets, purgers for air circulation, stirrers with impellers, nutrient sampling ports, and gas outlets. Modern parameters are often computerized for real-time monitoring of parameters like pH.

Dissolved oxygen, redox potential, carbon dioxide, oxygen, and fermentation products. Sterilization is the first step before adding the microorganisms to the sterile medium. During fermentation, substrate, nutrients, cells, and products change over time. Aeration supports aerobic growth, while pH control agents and anti-foaming additives are used as needed.



Gaseous byproducts like amylase are continuously expelled from the reactor system. Batch fermentors such as receptacle bioreactors are widely used for aerobic processes like acid and antibiotic production. However, they are less efficient for large-scale production due to capacity limitations and operational inefficiencies compared to continuous systems. Batch systems are particularly suitable for processes requiring minimal contamination risk, small-scale production, or operations involving diverse products. Batch fermentation has several advantages: there is a lower risk of contamination or genetic mutation due to short processing times, reduced capital risks compared to continuous systems, greater adaptability

for different products and microorganisms, higher product yield due to precise process control. However, it also has many drawbacks, like lower efficiency due to downtime for sterilization, filling, and cleaning; high labor and operational costs due to repeated sterilization and subculture preparation; and increased risk in industrial-scale sanitation, including potential exposure to harmful microbes. So, we have other types of bioreactors, for example, continuous bioreactors, which are similar to batch fermenters but feature continuous inflow of nutrients and outflow of products, maintaining a steady state. The constant conditions lead to consistent product quality and higher efficiency. Continuous fermenters are ideal for large-scale production particularly for products like vinegar, wastewater treatment, and baker's yeast, where consistent output is required.

Batch fermenters, such as receptacle bioreactors, are widely used for aerobic processes like acid and antibiotic production. However, they are less efficient for large-scale production due to capacity limitations and operational inefficiencies compared to continuous systems

Batch systems are particularly suitable for processes requiring minimal contamination risk, small-scale production, or operations involving diverse products.

Advantages of Batch Fermentation	Drawbacks of Batch Fermentation
Lower risk of contamination or genetic mutation due to shorter processing times.	Lower efficiency due to downtime for sterilization, filling, and cleaning.
Reduced capital risk compared to continuous systems.	High labor and operational costs due to repeated sterilization and subculture preparation.
Greater adaptability for different products and microorganisms.	Increased risks in industrial-scale sanitation, including potential exposure to harmful microbes.
Higher product yield due to precise process control.	

Continuous bioreactors have many advantages like automation potential reduces labor and downtime for cleaning and refilling, stable conditions ensure consistent product quality, lower risks to operators due to mechanization but it has many disadvantages like limited flexibility to adjust the process parameters, high capital investment for automation and equipment, increased costs for maintaining sterile conditions and replenishing substrates, higher contamination risk due to prolonged operation. So, there is another type of bioreactor, which is the semis-continuous fermenters, which combine both the batch and continuous operation processes. Initially, this is run as a batch system. Substrates are later added in a controlled manner, either at intervals, batch mode, or continuously, the continuous mode.

Semi-continuous systems are useful when batch or continuous methods are efficient, inefficient or impractical, especially for sensitive organisms. It has many advantages like increased yield by optimizing environmental conditions during specific growth or production phases. Stability during the culture's development reduces contamination risks. However, it has also many disadvantages like time consuming process for filling, cleaning and sterilizing. It is a complex process, control requirements, higher labor and operational costs.

Semi-Continuous Bioreactors- Semi-continuous fermenters combine batch and continuous operations. Initially run as a batch system, substrates are later added in a controlled manner, either at intervals (batch mode) or continuously (continuous mode).

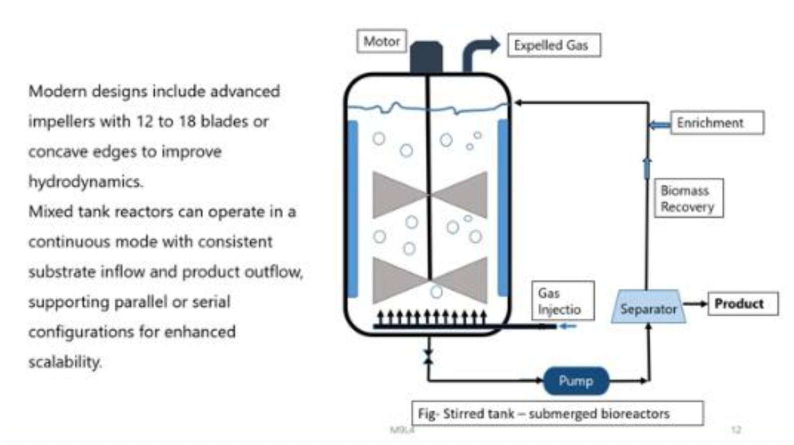
Semi-continuous systems are useful when batch or continuous methods are inefficient or impractical, especially for sensitive organisms.

Advantages	Disadvantages
Increased yield by optimizing environmental conditions during specific growth or production phases.	Time-consuming processes for filling, cleaning, and sterilizing.
Stability during the culture's development reduces contamination risks.	Complex process control requirements. Higher labor and operational costs.

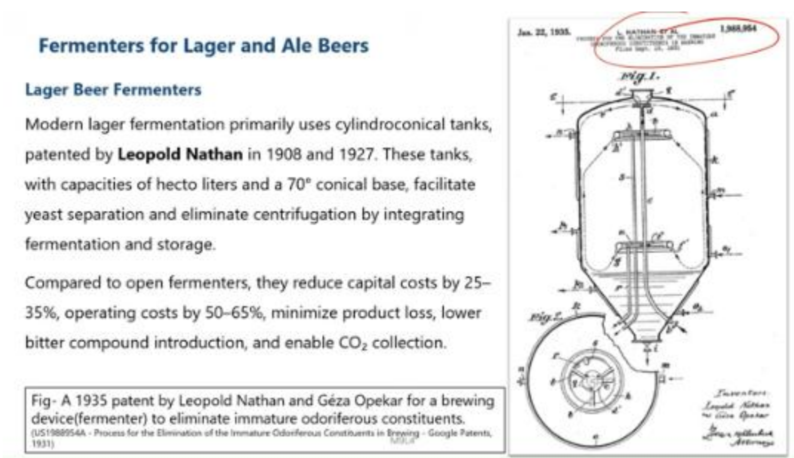
Let us now discuss about mixed tanked submerged bioreactors. Reactor is the most common aerobic bioreactor widely used for industrial scale applications due to its low capital and operational cost. Small scale versions are typically made of glass while stainless steel is used for large scale operations. The design and operation of mixed tank submers bioreactors Features a height to diameter ratio tailored to product removal needs.

Equipped with an agitator, baffle, and air injection at the base for efficient mixing. Temperature is controlled via warm or cold water circulating through baffles. Gas exhaust is at the top while products are collected at the bottom. So, here the gas is expelled, and then gas is injected from below. Then you have biomass recovery, where a separator isolates the product, which is then enriched and reintroduced into the system. Then you have a motor here, as you can see.

Modern designs include advanced impellers with 12 to 18 blades or concave edges to improve hydrodynamics. Mixed reactors can operate in continuous mode with consistent substrate inflow and product outflow, supporting parallel or serial configurations for enhanced scalability. Let us now discuss fermenters for lager and ale beers. Modern lager fermentation primarily uses cylindroconical tanks. These were patented by Leopold Nathan way back in 1908 and another

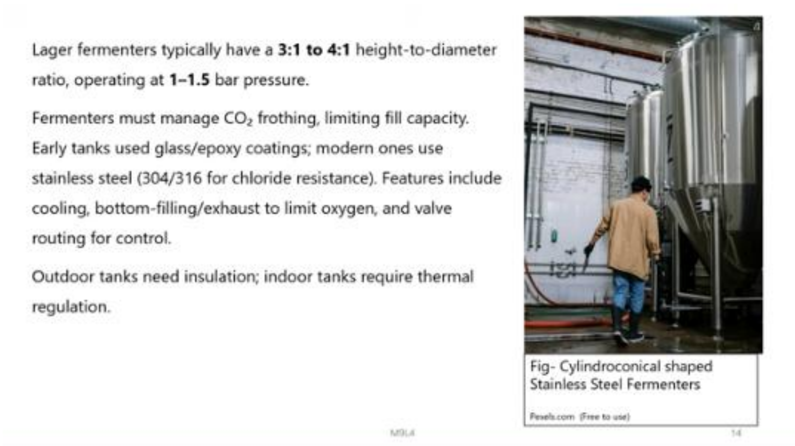


In 1927, these tanks, with capacities ranging from 100 to several thousand hectoliters and a 70-degree conical base, facilitated yeast separation and eliminated centrifugation by integrating fermentation and storage. So, in this picture, you can see the process for the elimination of immature oliviparous constituents in brewing. This is a patent filed by Nathan et al. This design has since inspired many other bioreactor designs. Compared to open fermenters, this reduces capital costs by around 25 to 35 percent, operating costs by 50 to 65 percent, minimizes product loss, lowers beta compound introduction, and enables carbon dioxide collection.



So, here you can see very tall fermenters over here. These are lager fermenters, which have a 3-to-1 or 4-to-1 height-to-diameter ratio and operate around 1 to 1.5 bars of atmospheric pressure. These fermenters must also manage carbon dioxide frothing, limiting field capacity. Early tanks used glass epoxy coatings. Modern ones use stainless steel 304 and 316 for chloride resistance.

Some of the features include cooling, bottom filling to limit oxygen, and valve routing for control. Outdoor tanks need insulation. Indoor tanks require thermal regulation. Let us now discuss the fermenters in which ale beer is produced. Unlike lager beer fermenters, they use top-fermenting yeast and are often fermented in open Yorkshire square tanks.

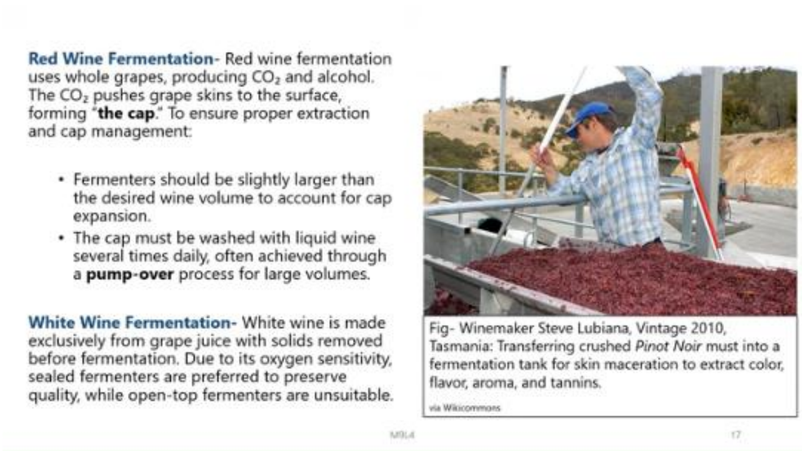


Originally, these were made from stone and slate. Modern Yorkshire squares are made of stainless steel, typically grade 304. These tanks include a slanted deck, funnels, and vents to aid yeast removal. So, in this figure, you can see round Yorkshire squares made to modern designs for easier cleaning and better temperature control. Now, let us discuss fermenters used in winemaking—stainless steel tanks (inox), popular since the 1970s for ease of cleaning and cooling compatibility.

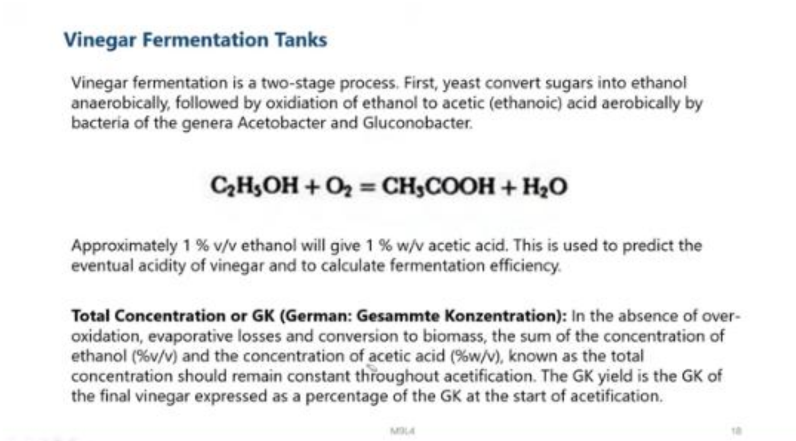
Two grids are commonly used, the grid 304 which is ideal for red wine fermentation than grade 316 which is more resistant to erosions suitable for both red and white wines. Inox tanks come with open or sealed tops with fermentation locks, variable limit tanks, having a floating metal top with an inflatable plastic rim. Allowing use when partially filled, chemically alert and beverage safe. They are easy to clean especially with removable tops.

Many include built-in cooling through these at cost. There are alternative materials also which have been used like fiberglass tanks. This is a cost-effective option while wooden tanks once phased out in the 20th century are regaining popularity in small and medium wineries for their unique impact on wine flavor. Then the red wine fermentation uses whole grapes producing carbon dioxide and alcohol. The carbon dioxide pushes grape skins to the surface forming the cap to ensure proper extraction and cap management.

Fermenters should be slightly larger than the desired wine volume to account for cap expansion. The cap must be washed with liquid wine several times daily, often achieved through a pump over process for large volumes. In the case of white wine fermentation, white wine is made exclusively from grape juice with solid removed before fermentation. Due to its oxygen sensitivity, sealed fermenters are preferred to preserve quality while open top fermenters are not used because they are not suitable. Now, let us discuss about the vinegar fermentation tanks.

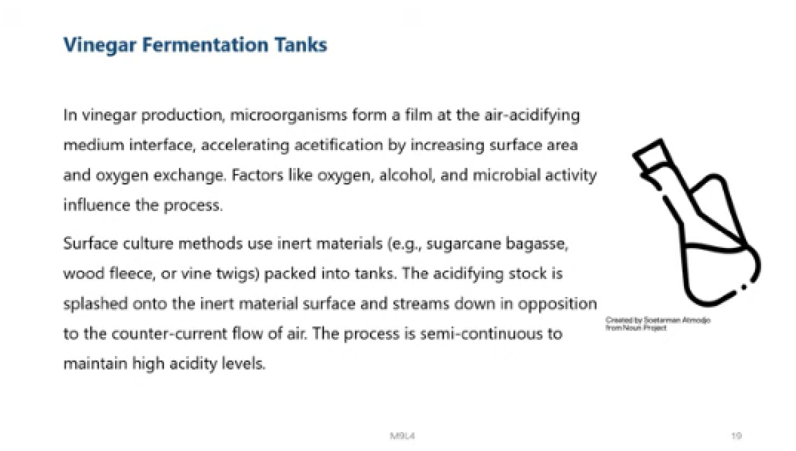


Vinegar fermentation is a two-stage process. Firstly, yeast converts sugars into ethanol anaerobically, followed by the oxidation of ethanol to acetic acid aerobically by bacteria of two genera: Acetobacter and Gluconobacter. And you can see this conversion of ethanol to acetic acid. Approximately, from this equation, we can find that 1% volume by volume ethanol will yield around 1% weight by volume of acetic acid.



This is used to predict the eventual acidity of vinegar and to calculate fermentation efficiency. Now let us recall a term called GK, which comes from the German word 'Gesamte Konzentration' or total concentration. In the absence of over-oxidation, evaporative losses, and conversion to biomass, the sum of the concentration of ethanol (percentage volume by volume) and the concentration of acetic acid (percentage weight by volume), known as the total concentration, should remain constant throughout acidification. This total concentration or GK yield is the GK of the final vinegar, expressed as the percentage of the GK at the start of the acidification.

So, in vinegar production, microorganisms form a film at the air-acidifying medium interface, accelerating acidification by increasing surface area and oxygen exchange. Factors like oxygen, alcohol, and microbial activity influence the process. Surface culture methods use inert materials, for example, sugarcane bagasse, wood shavings, or vine twigs, packed into tanks. The acidifying stock is splashed onto the inert material surface and streams down in opposition to the counter-current flow of air. The process is semi-continuous to maintain high acidity levels.



Let us have an overview of the vinegar fermentation process, which is broadly divided into two types: the traditional fermentation method and the modern fermentation method. So, here we start with the raw material, and we can choose any of these methods: the traditional and the modern. There is a difference between the two. In the traditional method, we use tanks, barrels, lagers, or surface film formation, and acidification necessarily takes place there. In the modern case, we may have two different processes: the fast process and the submerged process.

In the case of the submerged process, for example, the fringe excitator, the self-pippering aerator is deployed. In the first process, we have temperature control tanks, and to these, we add inert material. So overall, in these fermentations, we need to monitor the GK or total concentration, which was discussed earlier. Then we need to control and monitor the oxygen supply, pH, and temperature, for which the process may be automated in certain cases. Apart from these, we have many variations of alcoholic fermented beverages.

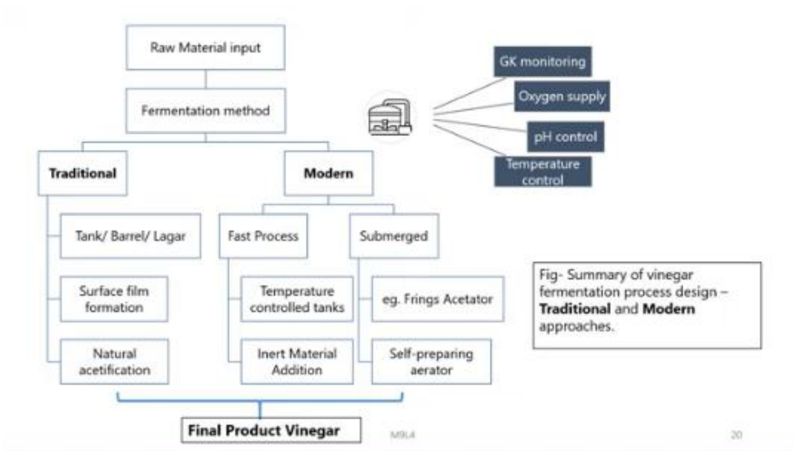


Fig- Summary of vinegar fermentation process design – **Traditional** and **Modern** approaches.

For example, we have alcoholic beverages from coffee byproducts. The beverage industry is exploring coffee byproducts such as pulp, husk, silver skin, residual water, and spent grounds as substrates for alcoholic beverages due to their rich chemical composition. These byproducts, often discarded as waste, are promising for ethanol and spirit production because of their high carbohydrate, organic matter, and aromatic compound contents. From the climate science point of view, converting waste into wealth and thereby contributing toward a circular economy concept is also driving many innovations in such waste utilization. The fermentation potential can be understood from this point of view

of Saccharomyces cerevisiae, which is commonly used for fermentation. But yeasts like Pichia and Hanseniaspora can also convert sugars in coffee byproducts into ethanol. For instance, H. uvarum produces significant ethanol and aromatic compounds to enhance flavors. Then we have coffee pulp and husk, which are rich in sugars and create uniquely flavored spirits.

Fermenting spent coffee grounds yields a spirit with coffee-like aromas, while pulp fermentation produces ethanol with floral and citrus notes. Then there is also alcoholic fermentation from whey, which is a byproduct of cheese production, containing around 90% of milk's volume. and retains 55% of nutrients, including lactose, protein, minerals, and lipids. Its high biological oxygen demand can lead to pollution if not reused, prompting its processing into powders, protein concentrates, or fermentation into alcohol. Concentrated whey, with 60 to 70 grams per liter of lactose, is ideal for fermentation, typically using Kluyveromyces yeast at 28 to 30 degrees Celsius.

Alcoholic Beverages from Coffee By-Products

The beverage industry is exploring coffee by-products—such as pulp, husk, silver skin, residual water, and spent grounds—as substrates for alcoholic beverages due to their rich chemical composition. These by-products, often discarded as waste, are promising for ethanol and spirit production because of their high carbohydrate, organic matter, and aromatic compound content.

Fermentation Potential: ***Saccharomyces cerevisiae*** is commonly used for fermentation, but yeasts like ***Pichia*** and ***Hanseniaspora*** can also convert sugars in coffee by-products into ethanol. For instance, ***H. uvarum*** produces significant ethanol and aromatic compounds that enhance flavor.

Spirit Production: Coffee pulp and husk are rich in sugars and create unique-flavored spirits. Fermenting spent coffee grounds yields a spirit with coffee-like aromas, while pulp fermentation produces ethanol with floral and citrus notes.

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Sweeteners and fruit pulps can also enhance flavor. For example, Kluyveromyces marxianus fermentation yields a 35.4% alcoholic distillate with fruity esters, while K. fragilis produces spirits with toasted aromas. However, there are many challenges. For example, whey's perishability requires rapid use or cold storage.

Alcoholic Fermented Beverages from Cheese Whey

Cheese whey, a by-product of cheese production, contains 90% of milk volume and retains 55% of nutrients, including lactose, protein, minerals, and lipids. Its high biological oxygen demand (BOD) can lead to pollution if not reused, prompting its processing into powders, protein concentrates, or fermentation into alcohol.

Fermentation Process: Concentrated whey (60–70 g/L lactose) is ideal for fermentation, typically using *Kluyveromyces* yeasts at 28–30°C. Sweeteners and fruit pulps can enhance flavor. For example, *K. marxianus* fermentation yields a 35.4% alcohol distillate with fruity esters, while *K. fragilis* produces spirits with toasted aromas.

Challenges: Whey's perishability requires rapid use or cold storage. Only 2% of yeasts can ferment lactose; enzymatic breakdown is often necessary. Combining ***Kluyveromyces lactis*** for lactose hydrolysis with ***Torulaspora delbrueckii*** fermentation can produce flavorful whey-based alcoholic beverages.

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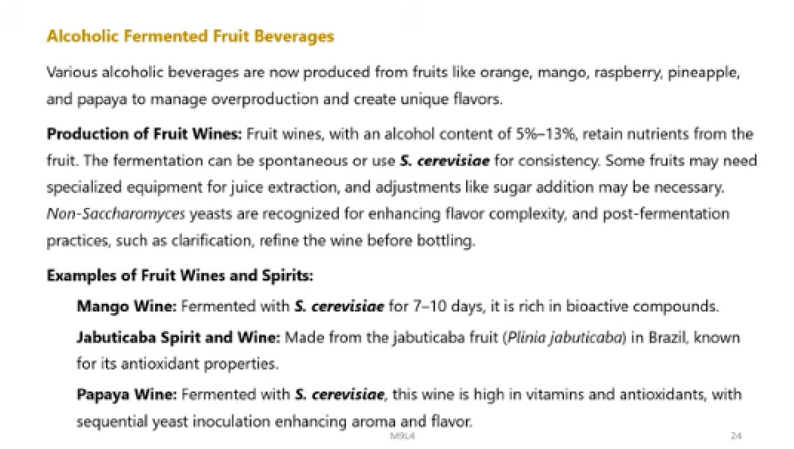
Only 2% of yeast can ferment lactose. Enzymatic breakdown is often necessary. Combining Kluyveromyces lactis for lactose hydrolysis with Torulaspora delbrueckii fermentation can produce flavorful whey-based alcoholic beverages. There have also been alcoholic fermentations of fruit beverages. Various alcoholic beverages are produced from fruits like orange, mango, raspberry, pineapple, and papaya to manage overproduction and create unique flavors.

Fruit wines with an alcohol content of 5% to 13% retain nutrients from the fruit. The fermentation can be spontaneous or use Saccharomyces cerevisiae for consistency. Some fruits may need specialized equipment for juice extraction, and adjustments like sugar addition may be necessary. Non-Saccharomyces yeast are recognized for enhancing flavor complexity in post-fermentation practices such as clarification. Refining the wine before bottling.

Some examples are mango wine, which is fermented with Saccharomyces cerevisiae for 7 to 10 days. It is rich in bioactive compounds. Then we have jabuticaba spirit and wine made from the fruit Plinia. Jabuticaba in Brazil is known for its antioxidant properties. Then we have papaya wine, fermented with Saccharomyces cerevisiae, which is high in vitamins and antioxidants, with sequential inoculation enhancing aroma and flavor.



Let us now move into section 2 of this lecture, where we will be dealing with the health and safety aspects of fermented beverages, probiotics, and functional beverages with fast-paced lifestyles and changing food habits. Health-conscious consumers are increasingly turning to functional foods, which contain bioactive compounds. to prevent diseases. These foods include probiotics, prebiotics, and symbiotics, which are known to improve gut health by promoting beneficial bacteria and restoring intestinal balance. Functional foods were first developed in Japan for health benefits beyond basic nutrition; they fall into three categories.

Foods with naturally occurring bioactive substances, such as dietary fiber; foods supplemented with bioactive substances, like probiotics; and foods containing added functional ingredients, like prebiotics. These foods are commonly found in products like yogurt, sports drinks, and fermented milk. Probiotics are defined as live microorganisms that, when consumed in adequate amounts, confer health benefits and are primarily associated with gut health.

Probiotics and Functional Beverages

With fast-paced lifestyles and changing food habits, health-conscious consumers are increasingly turning to functional foods, which contain bioactive compounds to prevent diseases. These foods include **probiotics, prebiotics**, and **synbiotics**, known to improve gut health by promoting beneficial bacteria and restoring intestinal balance.

Functional Foods

Functional foods, first developed in Japan, offer health benefits beyond basic nutrition. They fall into three categories:

- Foods with naturally occurring bioactive substances (e.g., dietary fiber).
- Foods supplemented with bioactive substances (e.g., probiotics).
- Foods containing added functional ingredients (e.g., prebiotics).

These foods are commonly found in products like **yogurts**, **sports drinks**, and **fermented milks**.

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Common sources include yogurt, seeds, and fermented products like kimchi and sauerkraut. Major probiotic strains include Lactobacillus, Bifidobacterium, and Saccharomyces boulardii. Prebiotics are non-digestible food ingredients that stimulate the growth of beneficial bacteria. Common sources include oats, soybeans, barley, and inulin. Symbiotics combine prebiotics and probiotics to enhance the growth and survival of healthy gut bacteria.

Examples include fermented milk, and supplements containing lactobacillus and bifidobacterium, strains combined with oligosaccharides like FOS or inulin, symbiotics of health benefits such as improved gut microbiota, balanced liver function, immune response and reduced infections in surgical patients. So here we can see some invading bacteria but then these are common cell gut bacteria. So, they will help in improving the gut health and will safeguard the individual from these invading bacteria. So, the human gut hosts a diverse bacterial population of over 1,000 species, playing a crucial role in immune balance, pathogen resistance, and nutrient absorption.

Probiotics: Probiotics, defined as "live microorganisms that, when consumed in adequate amounts, confer health benefits," are primarily associated with gut health. Common sources include **yogurt**, **cheese**, and fermented products like **kimchi** and **sauerkraut**. Major probiotic strains include *Lactobacillus, Bifidobacterium, and Saccharomyces boulardii.*

Prebiotics: Prebiotics are non-digestible food ingredients that stimulate the growth of beneficial gut bacteria. Common sources include **oats**, **soybeans**, **barley**, and **inulin**.

Synbiotics: Synbiotics combine prebiotics and probiotics to enhance the growth and survival of healthy gut bacteria. Examples include **fermented milk** and supplements containing *Lactobacillus and Bifidobacterium* strains combined with **oligosaccharides** like **FOS** or **inulin**. Synbiotics offer health benefits such as improved gut microbiota balance, liver function, immune response, and reduced infections in surgical patients.

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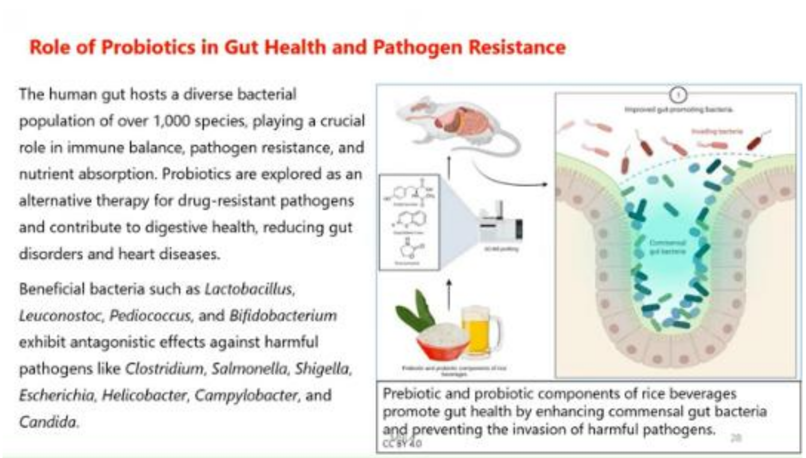
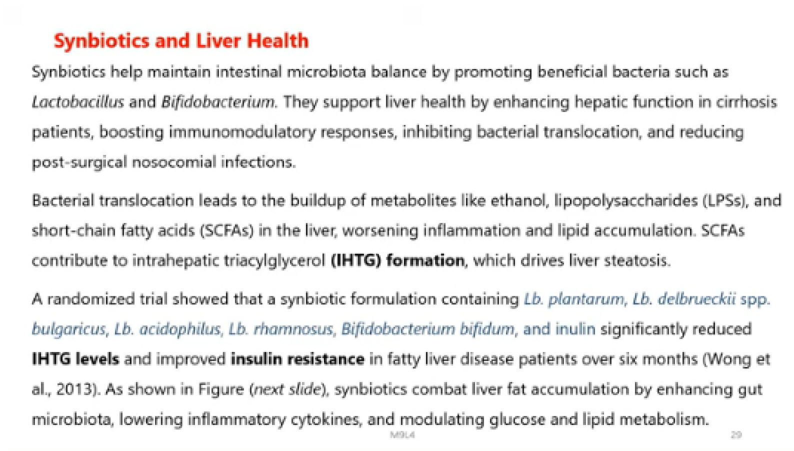
Probiotics are explored as an alternative therapy for drug-resistant pathogens and contribute to digestive health, reducing gut disorders and even heart diseases. Bacteria such as Lactobacillus, Leukonostoc, Pediococcus, Bifidobacterium, exhibit antagonistic effects against harmful pathogens like Clostridium, Salmonella, Sigella, Escherichia, Helicobacter, Campylobacter, and Candida. Symbiotics and Liver Health Symbiotics help maintain intestinal microbiota balance by promoting beneficial bacteria such as Lactobacillus and Bifidobacterium. They support liver health by enhancing hepatic functions in cirrhosis patients, boosting immunomodulatory responses, inhibiting bacterial translocation, and reducing post-surgical nosocomial infections.

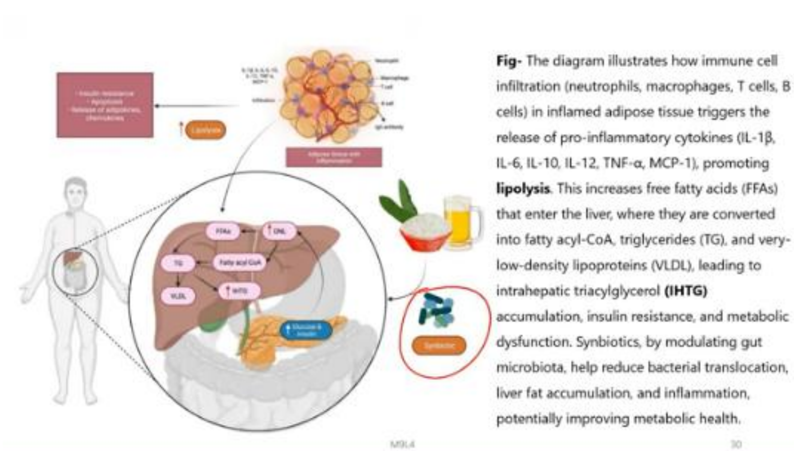


Bacterial translocation leads to the buildup of metabolites like ethanol, lipopolysaccharides, and sorts of fatty acids, SCFAs, in the liver, worsening inflammation and lipid accumulation, SCFAs, Contribute to intrahepatic triglycerol formation which drives liver statosis. A randomized trial showed that a symbiotic formulation containing LB plantarum or lactobacillus plantarum, Delbrucki species bulgaricus and acidophilus, rhamnosus, bifidobacterium, bifidium and inulin significantly reduce the intrahepatic triglycerol levels and improved inulin resistance in fatty liver disease patients over 6 months. As shown in the next slide, synbiotics combat liver fat accumulation by enhancing gut microbiota, lowering inflammatory cytokines and modulating glucose and lipid metabolism.

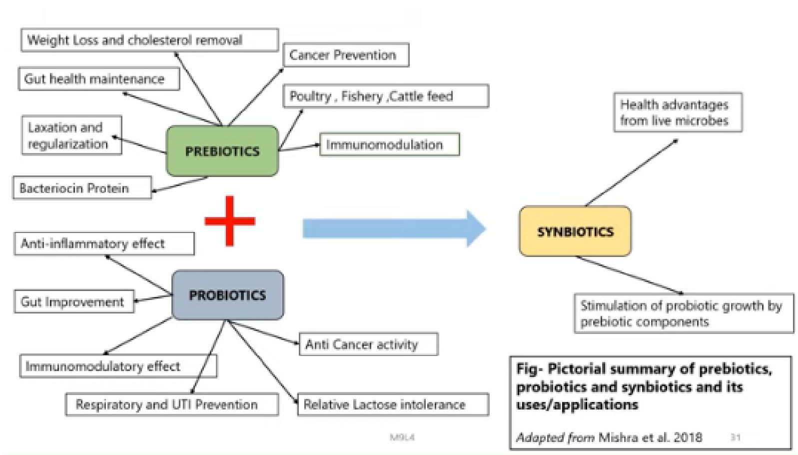


So, here in this diagram, you can see that in the magnified portion. How immune cells infiltrate in inflamed adipose tissue triggers the release of pro-inflammatory cytokines interleukin 1B, 6, 10, 12 and TNF-alpha and MCP-1 promoting lipolysis. Here in this figure, these increased free fatty acids then enters the liver where they are converted into fatty acyl coenzyme triglycerides and very low density lipoproteins VLDL. Leading to intrahepatic triacylglycerol accumulation, insulin resistance and metabolic dysfunction. Seen biotics by modulating gut microbiota

help reduce bacterial translocation, liver fat accumulation and inflammation, potentially improving metabolic health. So, here is a pictorial summary of prebiotics, probiotics and symbiotics and its uses and applications. Prebiotics helps in the immunomodulation. It can be added to poultry, fish, cattle feed. It helps in preventing cancer and weight loss and cholesterol removal.



It maintains the gut health, relaxation and regularization and it's helping the bacteria in protein. And in the case of probiotics, we have benefits like anti-inflammatory effects, gut improvement, similarly immunomodulatory effect. It also helps us in the anti-cancer activity, relative lactose intolerance, then respiratory and UTI prevention. And in the case of symbiotics, we have many health advantages from the live microbes, stimulation of the probiotic growth by prebiotic components. So, what are some of the probiotics used in fermented foods and beverages?

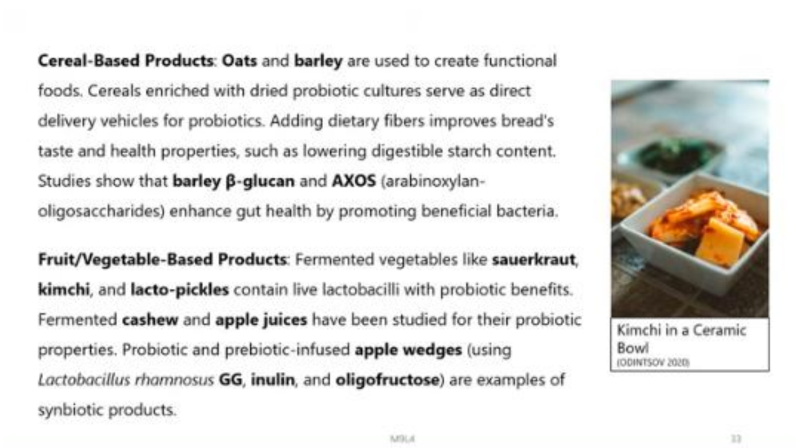


Probiotics not only enhance taste but also provide significant health benefits. However, maintaining stability during production and storage is crucial for effectiveness. Some examples of probiotic applications in various food products are milk-based products. Probiotic dairy products like yogurt, fresh and ripened cheeses are well established. Prebiotic lactulose in skimmed milk boosts probiotic counts, lactic acid production, and reduces fermentation time effectively.

Probiotic ice cream, known since the 1960s, uses lactobacilli and inulin to improve nutritional and sensory qualities. Other fermented dairy products like sour milk, kefir, and buttermilk are less popular compared to yogurt. This is a probiotics bar, and these are some of the newly packaged food innovations. We have cereal-based products like oats and barley, which are used to create functional foods. Cereals enriched with dried probiotic cultures serve as direct delivery vehicles for probiotics.

Adding dietary fibers improves bread's taste and health properties, such as lowering digestible starch content. Studies show that barley beta-glucan and arabinoxylan oligosaccharides enhance gut health by promoting beneficial bacteria. Then we have fruit and vegetable products. Fermented vegetables like sauerkraut, kimchi, and lacto-pickles contain live lactobacilli with probiotic benefits. Fermented cashew and apple juices have been studied for their probiotic properties.

Probiotic and prebiotic-infused apple wedges using Lactobacillus rhamnosus. GZ insulin and oligofructose are examples of symbiotic products. Then we have the root and tuber-based products. Traditional fermented products such as sinki from radishes in India and Nepal and kanji from purple carrots in India and Pakistan contain various Lactobacillus species like Lactobacillus fermentum, Lactobacillus brevis, and Lactobacillus plantarum, offering probiotic benefits. And then there are functional beverages, which include non-alcoholic drinks fortified with vitamins and nutrients.



Examples include cholesterol-lowering drinks with omega-3 and soy and bone health drinks with calcium and inulin. In Estonia, fortified juices like Largo contain inulin, L-carnitine, and vitamins to offer health benefits. In this table, we have traditional or novel food fermentations with probiotic organisms as listed. We have the species listed in the first column and fermented foods that reproducibly contain high cell counts of the strains of the species. For example, we have

Roots and Tuber-Based Products: Traditional fermented products such as **sinki** (from radishes in India and Nepal) and **kanji** (from purple carrots in India and Pakistan) contain various Lactobacillus species like *Lb. fermentum, Lb. brevis, and Lb. plantarum*, offering probiotic benefits.

Beverages: Functional beverages include non-alcoholic drinks fortified with vitamins and nutrients. Examples include **cholesterol-lowering drinks** with omega-3 and soy, and **bone health drinks** with calcium and inulin. In Estonia, fortified juices like **Largo** contain **inulin**, **L-carnitine**, and **vitamins** to offer health benefits.

Kanji is a traditional North Indian Punjabi drink made with carrots, spices, and water. Tahir mq, CC BY-SA 3.0, via Wikimedia Commons

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Lactobacillus acidophilus, Lactobacillus casei in NS lab, long-ripened seeds, Lactobacillus zonsoni in kefir, Lactobacillus fermentum in bushera, ting, and other African cereal porridges and beverages. Lactobacillus plantarum in salami, sauerkraut, kimchi, olives, and others. Then we have Lactobacillus paracasei in salami, vas, then NS lab in long-ripened seeds. Then we have Lactobacillus rhamnosus in hilly fermented oatmeal. Let us have a very brief discussion on food ethics, safety, and regulations of functional food.

Table- Traditional or novel food fermentations with probiotic organisms (Marco et al. 2017)

Species with recognized probiotic activity	Fermented foods that reproducibly contain high cell counts of strains of the species
Lactobacillus acidophilus, Lactobacillus casei	NSLAB long ripened cheese
Lactobacillus johnsonii	Kefir
Lactobacillus fermentum	Bushera, ting and other African cereal porridges and beverages
Lactobacillus plantarum	Salami, sauerkraut/kimchi, olives, others
Lactobacillus paracasei	Salami, kvass, NSLAB in long-ripened cheese
Lactobacillus rhamnosus	'Villi', fermented oatmeal

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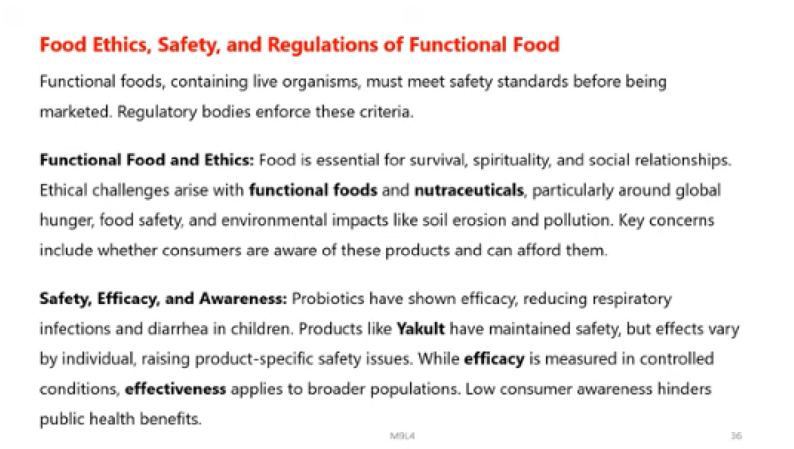
Functional foods, we now know, contain live organisms. Therefore, they must meet standards before being marketed. Regulatory bodies enforce many criteria. Functional food is an ethical issue. Food is essential for survival, spirituality, social relationships, and ethical values.

Challenges arise with functional foods and nutraceuticals, particularly around global hunger, food safety, and environmental impacts like soil erosion and pollution. Key concerns include whether consumers are aware of these products and can afford them.

Safety, efficacy, and awareness are also very, very important. Probiotics have shown efficacy in reducing respiratory infections and diarrhea in children.

Products like Yakult have maintained safety, but effects vary by individual, raising product-specific safety issues. While efficacy is measured in controlled conditions, effectiveness applies to broader populations. Lower consumer awareness hinders public health benefits. Then there are legislative problems and regulations in the USA. Functional foods are regulated by the FDA alongside conventional food with no distinct definition.



Food Ethics, Safety, and Regulations of Functional Food

Functional foods, containing live organisms, must meet safety standards before being marketed. Regulatory bodies enforce these criteria.

Functional Food and Ethics: Food is essential for survival, spirituality, and social relationships. Ethical challenges arise with **functional foods** and **nutraceuticals**, particularly around global hunger, food safety, and environmental impacts like soil erosion and pollution. Key concerns include whether consumers are aware of these products and can afford them.

Safety, Efficacy, and Awareness: Probiotics have shown efficacy, reducing respiratory infections and diarrhea in children. Products like **Yakult** have maintained safety, but effects vary by individual, raising product-specific safety issues. While **efficacy** is measured in controlled conditions, **effectiveness** applies to broader populations. Low consumer awareness hinders public health benefits.

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A 2006 GAO report called for better oversight to ensure functional foods meet their claims. Key issues include safety, efficacy, and health impact. The marketing approach is also very crucial. Consumer health awareness drives the global functional food market. The USA, Japan, and Europe lead

in sales volumes, while India's probiotic market is growing at 22.6% annually, primarily through the sale of supplements. Some major global brands include Yakult Japan, Actimel Danone France, and Vifit Campina Netherlands. Overall, Japan leads the nutraceutical market in Asia, while India's market is growing as health-conscious consumers seek more fortified foods. Here are some of the probiotic products currently available in the market. You can see the brand names.

Legislative Problems and Regulations: In the **USA**, **functional foods** are regulated by the **FDA** alongside conventional foods, with no distinct definition. A 2006 **GAO** report called for better oversight to ensure functional foods meet claims. Key issues include safety, efficacy, and health impact.

Marketing Approach: Consumer health awareness drives the global functional food market. **USA**, **Japan**, and **Europe** lead sales, while India's probiotic market grows at 22.6% annually, primarily through supplements.

Global Probiotic Brands: Major brands include **Yakult** (Japan), **Actimel** (Danone, France), and **Vifit** (Campina, Netherlands).

Nutraceutical Market Overview: Japan leads in **Asia**, while **India**'s market is growing as health-conscious consumers seek fortified foods.

These are examples of some of the most successful products. Aciforce is a freeze-dried product containing several strains, such as Lactococcus lactis, Lactobacillus acidophilus, Enterococcus faecium, and Bifidobacterium bifidum. It is manufactured by BioHerma in the Netherlands. Then there is Actimel, a probiotic yogurt drink containing Lactobacillus casei, produced by Danone in France. Another product is Bactis Subtil, a freeze-dried product containing a Bacillus species strain, IP5832.

Some probiotic products available in the market

Brand/trade name	Food type	Sources/strains	Manufacturer company	Country
Aciforce	Freeze-dried product	*Lactococcus lactis, Lactobacillus acidophilus, Enterococcus faecium, Bifidobacterium bifidum*	Biohorma	Netherlands
Actimel	Probiotic yoghurt drink	*Lactobacillus casei Immunitas*	Danone	France
Bactisubtil	Freeze-dried product	*Bacillus sp. strain IP5832*	Synthelabo	Belgium
Jovita Probiotisch	Probiotic yoghurt	*Lactobacillus strain*	H & J Bruggen	Germany
Provie	Fruit drink	*Lactobacillus plantarum*	Skanemejerier	Sweden
Yakult	Milk drink	*Lactobacillus casei Shirota*	Yakult	Japan
Revital Active	Yoghurt and yoghurt drink	Probiotics	Olma	Czech Republic

Produced by Sintelabo in Belgium. Then, Jovita probiotic. It's a probiotic yogurt. It has the strain of lactobacillus. Produced by H&J Bruggen in Germany.

Then we have Provi, which is a fruit drink. It contains lactobacillus plantarum. Produced by Scanmajeria in Sweden. Then we have Yakult, which is a milk drink. It contains lactobacillus casei shirota.

Produced by the company Yakult in Japan. Then we have Revital Active, which is yogurt and a yogurt drink. It contains many probiotics, produced by Alma in the Czech Republic. Health benefits of moderate red wine consumption have also been reported. Moderate red wine consumption is linked to a 20-30% decrease in all-cause mortality, especially from cardiovascular diseases.

It increases plasma antioxidant capacity, reduces oxidative stress, lowers DNA damage, and decreases inflammation—key factors in heart disease, diabetes, neurodegeneration, obesity, and cancer. Thus, red wine is thought to be beneficial against many of these disease conditions, and it has also been shown to be associated with lower systolic blood pressure, contributing to exercise-related health benefits. With this, we come to the end of today's lecture. Thank you for your kind attention. Amen.