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Review Article

Fermentation as a Method of Food Processing and Fermented Food as Probiotics: A Review

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Abstract

Fermented foods are classified as foods or drinks produced through controlled microbial growth, and the conversion of food components through enzymatic activity. In recent years, fermented foods have gained popularity, mostly due to their health benefits. The main objective of this review is to illustrate and classify common fermented foods (kefir, kombucha, sauerkraut, tempeh, natto, miso, kimchi, sourdough bread), their mechanism of action (including impact on the microbiota), and there role on gastrointestinal health and illness in humans. Since ancient time fermentation have been carried out for many foods including meat, fish, dairy, vegetables, soybeans, other legumes, cereals and fruits. The aim of this review is to describe and characterise common fermented foods (kefir, kombucha, sauerkraut, tempeh, natto, miso, kimchi, sourdough bread). Therefore, LAB produced from fermented foods can be used as a source of probiotics, to replace antibiotics in treating pathogenic bacteria. Some of the ways in which probiotics can benefit humans are: help reduce the effects of stress, reduce incidence of diarrhea and other digestive upsets, help improved immunity and impart resistance to disease, help to supply of digestive enzymes and reduce absorption of cholesterol.

Keywords: Fermentation; Food processing; Probiotics

Introduction

As the beginning of civilization humans recognized, probably by chance, that under certain circumstances, when raw food from plant and animal sources were stored for future use, they might change to different but desired products with extended storage stability. The chance of such an incident occurring might have been after they gain an understanding to produce more foods than they could use immediately and thus needed storage. It was probably the period during which they discovered agriculture and animal husbandary, as well as making baskets and pottery to keep the excess products. On the basis one can presume that fermented food most likely originated ca. 7000-8000 B.C. in the tropical area of mesopotamia and the Indus Vally. As a result other civilization also started producing fermented foods from different raw materials. The fermented foods were produced particularly to preserve those food that were seasonal and thus available in abundance only for a short harvesting period and therefore the fermented foods can be stored for a longer period of time. Milk fermentation, from fruits and certain grain production of alcoholic beverages and leavening of breads became popular among the early civilization in the Middle East and in the Indus Vally and later among the Egyptians, Greeks, and Romans. Presently, more than 3500 different fermented foods are consumed by humans worldwide; many fermented foods are ethnic and produced in small quantities to meet the needs of a group in a particular region. At present some fermented foods are produced commercially, and only a few are produced by large commercial producers. There is growing interest in consumption of many types of fermented foods other than cheese, bread, pickles and alcoholic beverages. One reason for the increase of consumption of fermented food is because it is natural and healthy food. Countries where many types of fermented foods have been consumed since long time, but mostly produced in small amount, have started commercially producing some fermented food products in large volumes. In the future it is expected that consumption and production of many fermented foods will increase worldwide [1]. With the evidence of fermentation of barley in beer the production and consumption of fermented food date back to many thousand years. In food biotechnology it is an age old process. Microbial or enzymatic action takes place in order to produce significant modifications in the food by biochemical changes in the food fermentation process [2]. Organic substrates mostly, carbohydrates are oxidized and act as an electron accepter in fermentation process. Microorganisms such as bacteria, yeasts and molds in anaerobic conditions convert carbohydrates to alcohol, lactic acid, carbon dioxide (CO2) or organic acids during food processing. In food fermentation process involving the production of ethanol by yeasts or Lactic Acid Bacteria (LAB) producing organic acids are included.

- Microorganism converts a carbohydrate such as starch and sugar into alcohol and/or acid during fermentation which is a metabolic process.
- Glucose and other six carbon sugars (also, disaccharides of six-carbon sugars, e.g. sucrose or lactose) are converted into cellular energy and the metabolite lactate during Lactic acid fermentation which is a metabolic process.

Bread Fermentation

Saccharomyces cerevisiae also referred to as baker's yeast, is the primary leavening agent in the production of bread in its numerous forms [3]. Microorganisms are useful in two chief ways in bread making: (1) They may produce gas to leaven or raise the dough giving the bread the desired loose, porous texture, and (2) they may produce desirable flavoring substances. They may function in the conditioning

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of the dough. Bread is a baked dietary item that is obtained from the fermentation of wheat flour sugars liberated from starch by the action of natural flour enzymes [4]. The nutritional composition of bread as well as its sensory, texture, and shelf life features depend on the bread formulation (type of flour used to produce the bread, addition of fortifying ingredients, choice of the leavening agent) [4-6]. Microorganisms are useful in two chief ways in bread making: (1) They may produce gas to leaven or raise the dough giving the bread the desired loose, porous texture and (2) they may produce desirable flavoring substance. They also may function in the conditioning of the dough.

Leavening Agent

Bread yeasts is used for leavening of dough, which ferment the sugar in the dough and produce mainly carbon dioxide and alcohol. However other actively gas forming microorganisms such as wild yeasts, coliform bacteria, saccharolytic Clostridium species, heterofermentative lactic acid bacteria, and various naturally occurring mixtures of these organisms can also leaven bread (Figure 1).

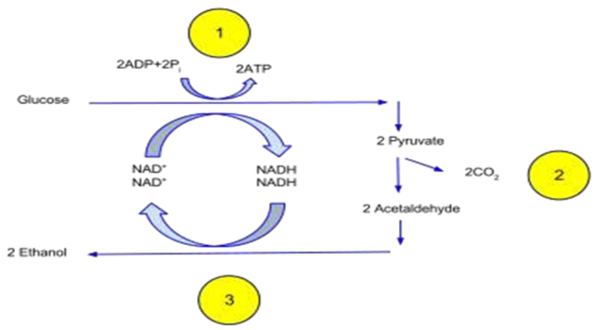

Figure 1: Steps of glucose fermentation process.

Fermented Milks

Fermented milk products, also known as cultured dairy foods, cultured dairy products, or cultured milk products, are fermented with Lactic acid bacteria such as Lactobacillus, Lactococcus and Leuconostoc. The fermentation process increases the shelf-life of the product enhances the taste and improves the digestibility of milk. Out of total dairy product in the market 2.3% is in the form of fermented dairy product. The medicinal benefits and nutritional value of fermented milk is very high (Table 1).

Constituents	Level (%)
Dry matter	14-18
Protein	Min 2.7
Fat	Less than15
Lactose	2-3
Lactic acid	Min 0.3
Carbohydrates	5-25

Table 1: The typical composition of fermented milk as per Codex standard (243-2003).

Fermented Milk Products

Yoghurt, Dahi, Kefir, Kumiss, Bulgarian Sour Milk, Acidophilus Milk, Cultured Buttermilk, Cultured Sour Cream, Leben, Taette (Scandinavian Ropy Milk), Skyr, Cheese (Figure 2).

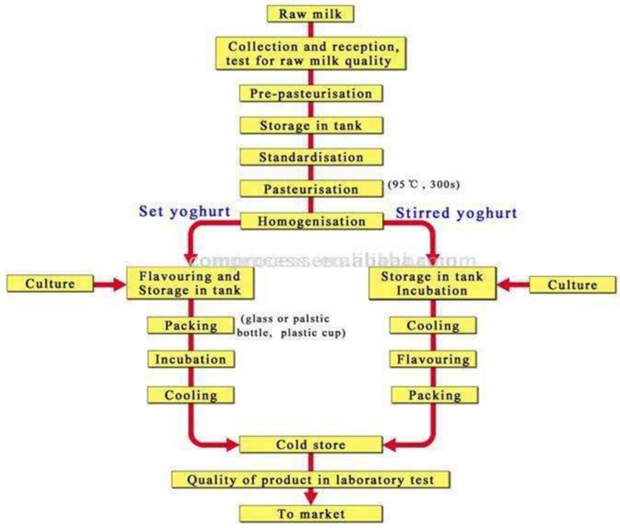

Figure 2: Steps of yogurt production.

Dahi

Lactic acid bacteria is used to prepare dahi which is a fermented milk product made by fermenting milk of the cow or water buffalo milk. The starter culture used for the fermentation of dahi are lactic acid bacteria which is a mixture of S. thermophilus, Lc. lactis subsp. lactis, Lc. lactis subsp. cremoris, Lc. lactis subsp. Lactis (biovar. diacetylactis), Lb. helveticus, Lb. casei, and Lb. acidophilus. The pH is 4.5-4.7. Titratable acidity 0.7% Coliform count <10/g , Yeast & mold count <100/g (Table 2).

Constituents	Level (%)
Water	85-88
Fat	5-8
Protein	3.2-3.4
Lactose	4.6-5.2
Ash	0.7-0.75
Lactic acid	0.5-1.0
Calcium	0.12-0.14
Phosphorous	0.09-0.11

Table 2: Composition of dahi.

Steps of Manufacture of Dahi

Following are the steps for the manufacture of dahi:

Receiving milk

Preheating (35-40°C)

Filtration/clarification

Standardization (SNF 9-11%)

Preheating (60°C) Homogenization (176kg/sq.cm) Pasteurization (80-90°C/15-30min) Cooling (22-25°C)

Inoculation (1-3% lactic starter) Packaging

Incubation (22-25°C/16-18h) Dahi

Cooling & storage (5°C)

Kefir

Kefir "grains", made with a mixture of yeast and bacteria and kefir is a fermented milk drink that originated in the north Caucasus Mountains. Traditional kefir, which originates from the Caucasus Mountains, is a fermented milk drink with a creamy texture, sour taste and subtle effervescence. It is produced by adding a starter culture termed "kefir grains" to milk. Kefir grains consist of symbiotic lactose-fermenting yeasts (e.g., *Kluyveromyces marxianus*) and non-lactose fermenting yeasts (e.g., *Saccharomyces cerevisiae*, *Saccharomyces unisporus*), as well as lactic and acetic acid producing bacteria, housed within a polysaccharide and protein matrix called kefiran [7]. A wide range of microbial species have been identified in kefir grains, commonly including *Lactobacillus brevis*, *L. paracasei*, *L. helveticus*, *L. kefiranofaciens*, *L. plantarum*, *L. kefiri*, *Lactococcus lactis*, *Streprotcoccus thermophiles*, *Acetobacter lovaniensis*, *Acetobacter orientalis*, *Saccharomyces cerevisiae*, *S. unisporus*, *Candida Kefyr*, *Kluyveromyces marxianus* and *Leuconostoc mesenteroides* [8-10] (Figure 3).

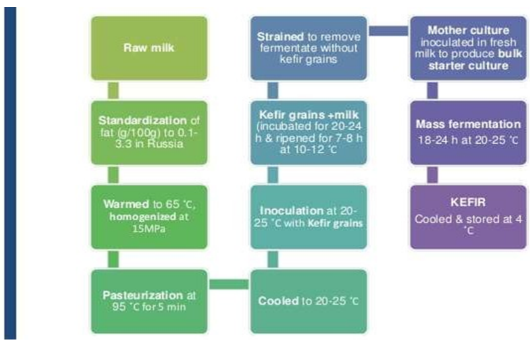

Figure 3: Manufacture of kefir.

Kumiss

Kumiss is a type of fermented dairy product made from mare's milk. Produced from a liquid starter culture. Kumiss has a higher alcohol content than kefir. Organism- *Lactobacillus/Bacterium orienburgii, Lactobacillus bulgaricus, L. acidophilus*, yeast (Figure 4).

Composition of Kumiss

Lactic acid - 0.7-1.8%

Alcohol - 1-2%

Carbon dioxide - 0.5-0.9%

Ethanol - 1.3%

Lactose - 2.3%

Fat - 1.5%

Protein - 2.0%

Bulgarian Sour Milk

Bulgarian sour milk comes under the general category of yogurts which contain live bacteria. It is a wonderful probiotic food. It is prepared-using a combination of the two strains: Lactobacillus Bulgaricus and Streptococcus Thermophilus.

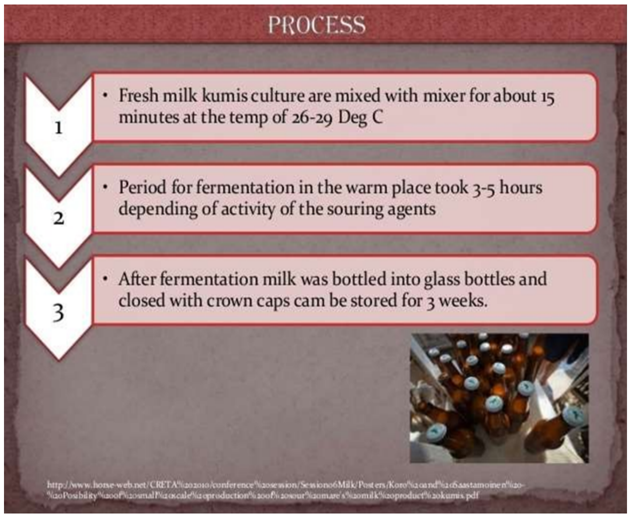

Figure 4: Steps of manufacture of kumiss.

Manufacture of Bulgarian Sour Milk

Sour milk (goat or cow's milk). Inoculation (*L.bulgaricus & S. thermophilus* culture) Ripening (40-45°C). Incubation (37°C). Storage & packaging (7°C).

Acidophilus Milk

Acidophilus milk is fermented by live cultures of the bacterium acidophilus and consumed especially to promote gut health. This fermented cultured milk product is usually low in fat and has a longer shelf life than ordinary milk. People who have immune system problems acidophilus milk is usually not recommended. Lactobacillus acidophilus is used as a starter culture to produce acidophilus milk.

Manufacture of Acidophilus Milk

Steps for the manufacture of acidophilus milk

Receiving milk (skim/whole/defatted)

Filtration/Clarification (35-40°C) Homogenization

Sterilization (115°C/15 min) Cooling (38-40°C)

Inoculation (3-5%)

Incubation (38-40°C/12-16h) Coagulation

Break-up of coagulum cooling (10°C)

Packaging & storage (5°C)

Cultured Buttermilk

Cultured buttermilk is a fermented dairy product produced from cow's milk and has a characteristically sour taste caused by lactic acid bacteria. This variant is made using different strains of bacteria-either *Lactococcus lactis* or *Lactobacillus bulgaricus*, *S. lactis subsp. diacetylactis Leuco.citrovorum* which creates more tartness, flavour and aroma. Acidity 0.8-0.85% LA. Fat 0.5-3%.

Manufacture of Cultured Buttermilk

Steps for the Manufacture of Cultured Buttermilk

Receiving skim milk

Filtration Pasteurization (82-88°C/30 min)

Cooling (22°C)

Inoculation (1-2%)

Incubation (21-22°C)

Coagulation (12-16 h) (0.80-0.90% LA)

Creaming

Break-up of coagulum

Adding butter granules

Cooling (5-10°C)

Packing & Storage (5-10°C)

Cultured Sour Cream

It has similar flavour and aroma of butter milk and is extremely viscous product with the fat content of 12-30%. The starter culture Lactococcus and Leuconostoc species are used to produce cultured sour cream. The pH should be 6.2-6.3. Sour cream typically has a clean acidic flavor with hints of diacetyl. It is consumed as a dressing of topping on other foods such as fruits.

Manufacture of Cultured Sour Cream

Steps for the Manufacture of Cultured Sour Cream

Fortification of whole milk with cream 20% fat)

Heating (80°C /30 min)

Homogenization (2000 psi) at 60-80°C

Cooling (21°C)

Inoculation (0.5-1.0 % butter starter)

Incubation

(21°C until acidity reaches 0.6%)

Cooling (5°C)

Packaging

Skyr

It is a traditional Icelandic milk product which contain 7.6% SNF, 8% sugar, 0.3% pectin, is homogenize and pasteurized at temperature 73°C for 20 sec. Skim milk is fermented with *S. thermophilus, L. bulgaricus , L. helveticus* lactic acid bacteria similar to those used for yogurt along with lactose- fermenting yeasts. Addition of rennet. pH should be maintained (Table 3).

Manufacture of Skyr

Steps for the manufacture of SKYR

Pasteurised skim milk

Rennet 0.01-0.1% fresh skyr (S. thermophilus + L. bulgaricus + L. helveticus)

Constituent	Level in	
	Skyr	Skyr whey
Dry matter %	16.72	5.66
Protein %	11.54	0.48
Fat %	0.19	-
Lactose %	4.41	4.40
Lactic acid %	1.75	0.94
Ash %	0.78	0.75

Table 3: Chemical composition of Skyr.

Fermentation (40°C)

Acid curd (4.65) Fermentation at 17°C for 16-18h (pH4.4)

Skyr curd in whey heating to 67°C/15sec cooling (30°C)

Separation in a quarg separator

Whey (5% dry material)

Skyr (16-17% dry material)

Ultrafiltration (50°C)

Retentate (16-17% dry material) Permeate

Whey drink with fruit juice

Leben

Leben is used across the Arab World (Middle East and North Africa), to refer to a food or beverage of fermented milk. Generally, there are two main products known as *leben*: in the Levant region, yogurt; and in Arabia and North Africa (Maghreb), buttermilk. There is a mixed microflora consisting of *S. lactis, S. thermophilus, L. bulgaricus and lactose fermenting yeasts.* Labneh has 7-10% fat.

Manufacture of Leben

Steps for the Manufacture of Leben

Milk (in earthenware containers)

Inoculation with sample from previous batch Incubation at ambient temperature until firm coagulum production

Churning with gradual addition of warm water

Heating

Butter Butter oil

Addition of Fenugreek seeds

Leben

Cooling Packing

Taette

Taette is a moderately ropy and sour milk product of slightly flowing consistency which contains not more than 0.3-0.5% of alcohol. This product is used in Scandinavian countries in Finland. It is produced mainly by fermenting fresh milk with a strain of *S.lactis var. hollandicus* and yeasts such as *Saccharomyces taette.*

Manufacture of Taette

Fresh cow's milk. Inoculation with leaves of butterwort (1%). Addition of starter *(Saccharomyces major taette, L.taette, Bacillus acidactislogus)*. Maturation (2-3 days at less than 10°C) in wooden cellars 'Taette'.

Cheese

The word cheese comes from Latin caseus, from which the modern word casein is also derived. The earliest source is from the proto-Indo-European root *kwat-, which means "to ferment, become sour". Cheese is a dairy product derived from milk that is produced in a wide range of flavours, textures, and forms by coagulation of the milk protein casein. It comprises proteins and fat from milk, usually the milk of cows, buffalo, goats, or sheep. During production, the milk is usually acidified, and adding the enzyme rennet causes coagulation. The solids are separated and pressed into final form. Some cheeses have molds on the rind, the outer layer, or throughout (Figure 5 and Table 4).

Cheese production

Most cheeses melt at cooking temperature. Cultures for cheese making are called Lactic Acid Bacteria (LAB) because their primary source of energy is the lactose in milk and their primary metabolic product is lactic acid. There is a wide variety of bacterial cultures available that provide distinct flavor and textural characteristics to cheeses. Starter cultures are used early in the cheese making process to assist with coagulation by lowering the pH prior to rennet addition. The metabolism of the starter cultures contribute desirable flavor compounds, and help prevent the growth of spoilage organisms and pathogens. Typical starter bacteria include Lactococcus lactis subsp. *lactis* or *cremoris, Streptococcus salivarius* subsp. *thermophilus, Lactobacillus delbruckii* subsp. *bulgaricus*, and *Lactobacillus helveticus*.

General Manufacturing Procedure

The temperatures, times, and target pH for different steps, the sequence of processing steps, the use of salting or brining, block formation, and aging vary considerably between cheese types.

General Cheese Processing Steps

- Standardize Milk
- Pasteurize/Heat Treat Milk
- Cool Milk
- Inoculate with Starter & Non-Starter Bacteria and Ripen
- Add Rennet and Form Curd
- Cut Curd and Heat
- Drain Whey
- Texture Curd
- Dry Salt or Brine
- Form Cheese into Blocks
- Store and Age
- Package

Standardize Milk: Milk is often standardized before cheese making to optimize the protein to fat ratio to make a good quality cheese with a high yield.

Pasteurize/Heat Treat Milk: Depending on the desired cheese, the milk may be pasteurized or mildly heat-treated to reduce the number of spoilage organisms and improve the environment for the starter cultures to grow. Some varieties of milk are made from raw milk so they are not pasteurized or heat-treated. Raw milk cheeses must be aged for at least 60 days to reduce the possibility of exposure to disease causing microorganisms (pathogens) that may be present in the milk.

Cool Milk: Milk is cooled after pasteurization or heat treatment to 90°F (32°C) to bring it to the temperature needed for the starter bacteria to grow. If raw milk is used the milk must be heated to 90°F (32°C).

Inoculate with Starter & Non-Starter Bacteria and Ripen: The starter cultures and any non-starter adjunct bacteria are added to the milk and held at 90°F (32°C) for 30 minutes to ripen. The ripening step allows the bacteria to grow and begin fermentation, which lowers the pH and develops the flavor of the cheese.

Add Rennet and Form Curd: The rennet is the enzyme that acts on the milk proteins to form the curd. After the rennet is added, the curd is not disturbed for approximately 30 minutes so a firm coagulum forms.

Cut Curd and Heat: The curd is allowed to ferment until it reaches pH 6.4. The curd is then cut with cheese knives into small pieces and heated to 100°F (38°C). The heating step helps to separate the whey from the curd.

Drain Whey: The whey is drained from the vat and the curd forms a mat.

Texture Curd: The curd mats are cut into sections and piled on top of each other and flipped periodically. This step is called cheddaring. Cheddaring helps to expel more whey, allows the fermentation to continue until a pH of 5.1 to 5.5 is reached, and allows the mats to "knit" together and form a tighter matted structure. The curd mats are then milled (cut) into smaller pieces.

Dry Salt or Brine: For cheddar cheese, the smaller, milled curd pieces are put back in the vat and salted by sprinkling dry salt on the curd and mixing in the salt. In some cheese varieties, such as mozzarella, the curd is formed into loaves and then the loaves are placed in a brine (salt water solution).

Form Cheese into Blocks: The salted curd pieces are placed in cheese hoops and pressed into blocks to form the cheese.

Store and Age: The cheese is stored in coolers until the desired age is reached. Depending on the variety, cheese can be aged from several months to several years.

Package: Cheese may be cut and packaged into blocks or it may be waxed.

Microflora of Different Cheese

Cheese Starter Composition

Cheddar *S. lactis, S. cremoris, S. diacetylactis*

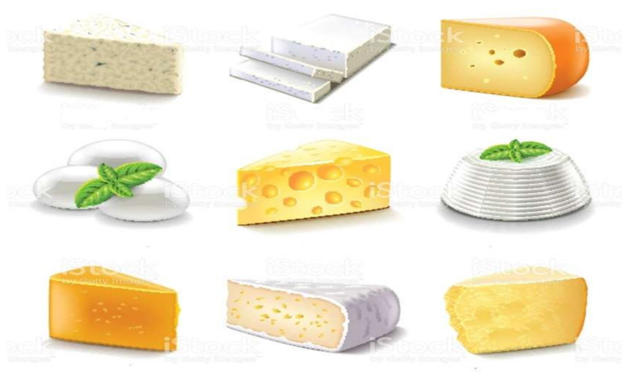

Figure 5: Different types of cheese.

Types of Cheese	Moisture %	Fat %	Protein %	Calcium %	Vitamins			Energy Content (Kcal/100g)
					Vit A (µg/100g)	Thiamin (µg/100g)	Riboflavin (mg/100g)	
Hard (Cheddar)	35.0	33.0	26.0	0.83	380	50	0.50	400
Semi-hard (Edam)	43.0	24.0	26.0	0.76	250	60	0.35	320
Blue-veined (Roquefort)	40.0	31.0	21.0	0.32	300	30	0.70	360
Soft (Camembert)	51.0	23.0	19.0	0.39	240	50	0.45	280
Unripened (Cottage)	79.0	0.4	16.9	0.09	3	30	0,28	82

Table 4: Composition of different types of cheese.

Gouda *S. lactis, S. cremoris, S. diacetylactis, Leuconostoc spp.*

Cottage *S. lactis, S. cremoris, Leuconostoc spp.*

Swiss *S. thermophilus, L. helveticus, Propionibacterium shermanii*

Brick *S. lactis, S. cremoris, S.thermophilus, Brevibacterium linens*

Mozzarella *S.thermophilus or S. faecalis & L. bulgaricus*

Blue (Roquefort) *S. lactis, Penicillium roqueforti*

Camembert *S. lactis, Penicillium camemberti*

Fermented Vegetables

In the early years of human civilization vegetable fermentation originated and, even now, is widely used by many cultures. Through natural processes almost all vegetables can be fermented because vegetables harbor many types of lactic acid bacteria and natural flora. Worldwide, domestically most of the vegetable fermentation is done. The vegetable fermentation process can result in nutritious foods that have increased shelf life, 1 year or more, without refrigeration. Examples of some fermented products and vegetables used currently fermentation are sauerkraut and kimchi, (from cabbage), olives, cucumbers, carrots, celery, beans, peas, corn, okra, tomatoes, cauliflower, peppers, onions, citron, beets, turnips, radishes, chard, Brussels sprouts, and their blends.

Sauerkraut

Sauerkraut originating in the 4th century BC. is one of the most common forms of preserved cabbage. Sauerkraut is eaten frequently in Germany, but also in other European and Asian countries and the United States [11]. Sauerkraut is produced from a combination of shredded cabbage and 2.3%-3.0% salt, which is left to undergo spontaneous fermentation, generally involving *Leuconostoc* spp., *Lactobacillus* spp., and *Pediococcus* spp. The low pH of the final product results in a preserved cabbage [12].

Country: Germany

Major Ingredients: Cabbage, Salt

Usage: Salad, Side Dish

Product Description: Fermented shredded cabbage. The product has a sour taste with a clean acid flavor.

Microorganisms: *L. mesenteroides, Lactobacillus brevis, Pediococcus cerevisiae* and *Lb. plantarum,*

Starter Culture: Natural Microflora, commercial starter cultures are available. Sometimes backslopping.

Salting

The level of salting is critical to obtaining a satisfactory product, it must be within the range 2-3% w/w and is normally about 2.25%. Too little salt (<2%) and the product softens unacceptably, too much salt (>3%) and the correct microbial sequence is not obtained.

The salt serves a number of purposes**:**

i. It extracts moisture from the shredded cabbage by osmosis to form the brine in which the fermentation will take place;

ii. It helps to inhibit some of the natural microflora of the cabbage such as pseudomonads which would otherwise cause spoilage and helps to select for the lactic acid bacteria;

iii. It helps maintain the crisp texture of the cabbage by withdrawing water and inhibiting endogenous pectolytic enzymes which cause the product to soften;

iv. Finally, salt contributes to the flavour of the product.

Fermentation

The starter for sauerkraut production is usually the normal mixed flora of cabbage. The raw material has a large number of undesirable organisms and a small population of lactic acid bacteria (<1%). Among the lactic acid bacteria, most are *Lactococcus spp*. and *Leuconostoc spp*., and a small fraction is Lactobacillus spp. and *Pediococcus spp*. The presence of 2.25% salt, large amounts of fermentable sugars (sucrose, hexoses, pentoses), an absence of oxygen, and a low fermentation temperature facilitate *Leuconostoc spp*., primarily *Leu. mesenteroides*, to grow rapidly.

Fermentation

WThe growth of *Leuconostoc mesenteroides* slows down when the acidity reaches approximately 1% (as lactic acid). Then Lab. brevis starts growing rapidly until acid production reaches approximately 1.5%. Then *Ped. pentosaceus* takes over and increases the acidity to approximately 1.8%. Finally, Lab. plantarum starts growing and brings the acid level to approximately 2%.

Biochemistry

Leuconostoc spp. metabolize sucrose, hexoses, and some pentoses in the raw material to lactate, acetate, ethanol, CO_2, and diacetyl. Lab. brevis (obligatory heterofermentative, such as *Leuconostoc spp.*) ferments sucrose, hexoses, and pentoses to products similar to those by *Leuconostoc spp*. *Ped. pentosaceus* metabolizes hexoses to form mainly lactic acid and some pentoses to lactic acid, acetate, and ethanol. *Lab. plantarum* also produces products from sucrose, hexoses, and pentoses similar to those by *Ped. pentosaceus*. The characteristic flavor of sauerkraut is the result of the combined effects of lactate, acetate, ethanol, CO_2, and diacetyl in proper amounts.

Kimchi

Kimchi, is a term used for a group of salted and fermented vegetables which originates from Korea. It consists of Chinese cabbage and/or radishes, and various flavoring ingredients (e.g., chili, pepper, garlic, onion, ginger), seasonings (e.g., salt, soybean sauce, sesame seed), and other additional foods (e.g., carrot, apple, pear, shrimps) [13]. To produce kimchi, the cabbage is brined and drained, then the rest of the seasonings, spices and food products are added and mixed with the cabbage, and finally, fermentation takes place. The fermentation occurs spontaneously by the microorganisms naturally found on the cabbage and foods included in the mixture, although starter cultures may be used for commercial production of kimchi [13]. The kimchi mix contains a variety of different bacterial species within the Leuconostoc, Lactobacillus, Pseudomonas, Pantoea and Weissella genera prior to fermentation [14]. However, once fermentation has started, the bacterial diversity decreases and the bacterial community is rapidly dominated by the genus Leuconostoc within only three days of fermentation [14]. Within this genus, Leuconostoc citreum is the most abundant species prior to fermentation, but it is present in only a minor proportion after three days of fermentation, at which time point Leuconostoc gasicomitatum and Leuconostoc gelidum become dominant [14].

Region: Korea

Major Ingredients: Chinese cabbage, Asian radish, Red pepper, Ginger, Garlic, Salt

Usage: Salad, Side Dish

Product Description: Fermented shredded cabbage. The product has a sour taste with a clean acid flavor.

Microorganisms: *L. mesenteroides*, *Lactobacillus brevis*, *Pediococcus cerevisiae* and *Lb. plantarum,*

Starter Culture: Natural Microflora, commercial starter cultures are available.

Biochemistry and fermentation aspects of Kimchi are similar to sauerkraut. The best taste is claimed after 3 days at 20°C when the acidity is 0.6% and the pH around 4.2. *Leuconostoc mesenteroides* is the principal organism responsible for the fermentation. Dominance of *Lactobacillus plantarum* is regarded as a defect which results in an excessively sour product (Table 5).

Sauerkraut	Parameter	Kimchi
2%	Acid content	0.6%
2-3%	Salt Content	3-3.5%
Min 7 days	Fermentation Time	3-4 days
Only Cabbage and Salt	Ingredients	Contains added ingredients for flavor
Finely Shredded	Cabbage	Large Chunks

Table 5: Difference between Kimchi and Sauerkraut.

Olives

Region: Mediterranean

Major Ingredients: Olives, Brine

Usage: Salad, Side Dish

Microorganisms: *L. mesenteroides*, *Lactobacillus brevis*, *Pediococcus cerevisiae* and *Lb. plantarum*.

Starter Culture: Natural Microflora, commercial starter cultures are available.

Fermentation

The initial pH of the fermentation can be above 7 depending on how much washing was done after the NaOH treatment. As a consequence, the initial microflora during fermentation can include a variety of gram-positive bacilli (*Bacillus* species) and gram-negative enteric bacteria (*Enterobacter, Citrobacter, Klebsiella*, and *Escherichia*). As organic acids accumulate and the pH decreases below 6, the LAB, principally Lb. plantarum, dominate the fermentation to the exclusion of the other gram-positive and gram-negative microbes. Yeast species may also be present (*Candida, Pichia, Saccharomyces,* and others) and contribute desirable flavor characteristics to the brined olives.

Pickles

Region: North America, Germany

Major Ingredients: Cucumber, Spices,

Usage: Salad, Side dishes

Microorganisms: *Lactobacillus brevis*, *Pediococcus cerevisiae* and *Lb. plantarum*,

Starter Culture: Natural Microflora, commercial starter cultures are available.

Meat Fermentation

Meat fermentation is a complex biological phenomenon accelerated by the desirable action of certain microorganisms in the presence of a great variety of competing or synergistically acting species mainly acquired from meat. In general the qualitative characteristics of naturally fermented sausages are known to be largely dependent on the quality of the ingredients and raw material since different genera and species and even strains have been shown to significantly affect the sensory traits of fermented sausages (Figure 6).

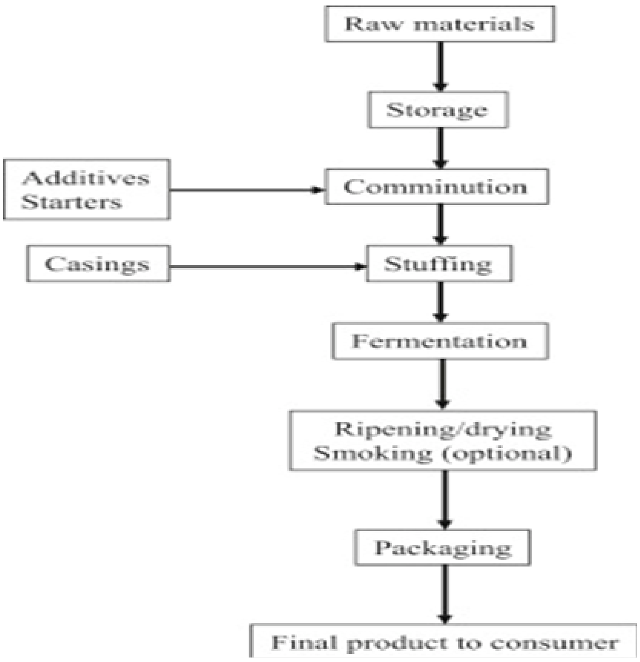

Figure 6: Steps for the production of Sausage.

A sausage is fermented if its pH is below 5.6 and the lactic acid content above 0.2%. Its texture is no longer crumble. Its aroma is typical. Lactic acid bacteria predominate. *Enterobacteriaceae* counts are low.

Nutritional Role of Meat in Human Diet

Essential component of the human diet to ensure optimal growth and development. As a concentrated source of a wide range of nutrients. Protein of high biological value. Micronutrient such as iron, zinc, vitaminB12 significantly contribute to the nutritional value of meat. Meat is extremely susceptible to microbial spoilage. Meat as a substrate are optimal for the growth of bacteria. Water activity and pH are 0.96 to 0.97 and 5.6 to 5.8, respectively nutrients and growth factors are abundantly available. Storage and preservation of meat is necessary for the suppression of microbial growth or the elimination of microorganisms and prevention of recontamination.

Reduction Traditional Methods which Comprise

1. Water activity (drying, salting) and/ or pH (fermentation, acidification)
2. Smoking, storage at refrigeration or freezing temperatures,
3. Use of curing aids (nitrite and nitrate).

Meat may also contain bacterial food pathogens. Meat has to be of high quality with regard to hygiene and microbial counts (Figure 7).

Variables in Sausage Production

Variables include: The particle size of the comminuted meat and fatty tissue (1 and 30 mm). The selection of additives (curing salt, nitrate, ascorbic acid, sodium glutamate and glucono-∂-lactone -source

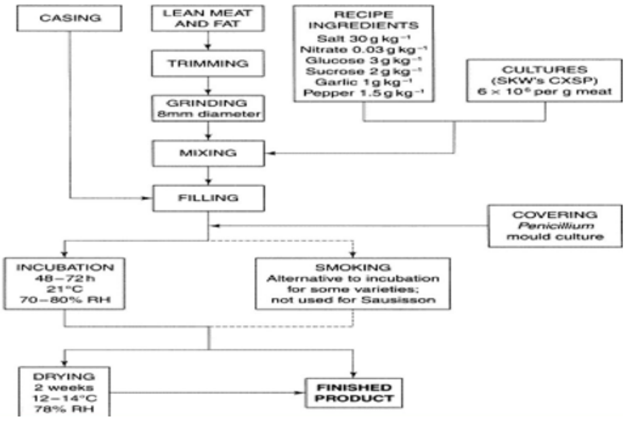

Figure 7: Flow Diagram for the Manufacture of Fermented Sausage.

glucose. The temperature /humidity (below 2to 3°C, the temperature is raised usually to >20°C and >28°C, but maximum higher temperatures (32 to 38°C). The diameter of the sausages. The nature of the casings smoking. Heating after fermentation. Supporting the development of mold growth on the surface or establishing a special tight surface film (e. g. coating with a titanium dioxide film). Dipping in antifungal preparations (sorbic acid or pimaricin) pH-4.8 to 5.4.

Species Employed in Meat Starter Cultures

Bacteria: Lactic Acid Bacteria such as *Lactobacillus acidophilus*, Lb. *alimentarius*, Lb. *curvatus,* Lb. *plantarum* etc, *Lactococcus lactis*, *Pediococcus acidilactici*, *P. pentosaceus*

Actinobacteria: *Kocuria varians*, *Streptomyces griseus, Bifidobacterium* spp.

Staphylococci: *Staphylococcus xylosus, S. carnosus ssp.*

Halomonadaceae: *Halomonas elongata*

Fungi: *Penicillium nalgiovense, P. chrysogenum, P. camemberti*

Yeasts: *Debaryomyces hansenii, Candida famata*

Sausages as Possible Probiotics

Contain the probiotic bacterial strain which effective in the intestines. Probiotic bacteria supports survival and metabolic activity in the intestinal tract. Probiotic food should have been performed to substantiate any health claim. *Lactobacilli* and *bifidobacteria* (probiotic strains) had been used for sausage production. *Lactobacillus paracasei* are used for the production of moist type of fermented sausage. Large reduction of pH- <5.0, extended ripening- >1 month. Drying, or excessive heating in these condition all strains of bacteria damaged or killed.

Fermented Soy Products (Temph, Natto, Miso)

The first known fermented soy products originated in China and Japan, including fermented black soybean and red fermented tofu [15]. There are many fermented soybean products from different parts of Asia, including tempeh, natto, miso, sufu, douche, soy sauce and doenjang.

Temph

Tempeh is a traditional Indonesian food produced by fermenting boiled and dehulled soybeans with a starter culture of *Rhizopus oligoporus* fungal species at room temperature for 35-37 hours [15,16]. This produces a soft white cake with a chewy texture and mushroom-like flavour. The microbial composition of tempeh varies according to variations in production [17]. Tempeh contains lactic acid bacteria [18,19], *Enterococcus faecium* [19], and Rhizopus filamentous fungi. Fermentation of soybeans has been shown to reduce concentrations of protease inhibitors, phytic acid and phenols [20], antinutritional factors that are high in raw soybeans, which may relate to phytases expressed by Rhizopus species in tempeh [21]. Fermented soy products have been proposed to have beneficial effects on health, including purported "anti-carcinogenic", "anti-diabetic", "antioxidant", "anti-inflammatory" and "anti-hyperlipidaemic" effects, although much of the existing evidence is limited to in vitro and animal studies [15]. Tempeh has been associated in vitro with greater free-radical and superoxide scavenging ability than unfermented soybeans [22], which may relate to changes in polyphenol content and digestibility in soybeans following fermentation [23,24].

Natto

In the manufacture of natto, boiled soybeans are wrapped in rice straw and fermented for 1 or 2 days. The package becomes slimy on the outside. *Bacillus natto*, probably identical with *Bacillus subtilis*, grows in natto, releasing trypsin like enzymes that are supposed to be important in the ripening process. Natto is a traditional Japanese fermented soybean, of which Itohiki-Natto is the most commonly consumed [16]. Natto is produced through fermentation of cooked yellow soybeans with *Bacillus subtilis* var. natto. This produces a viscous food with a distinct flavour and strong odour [25]. Natto characteristics vary according to soybean steaming time, relative humidity, fermentation time and temperature [16]. The fermentation of Natto produces a number of bioactive factors, including nattokinase, bacillopeptidase F, vitamin K_2 and dipicolinic acid [16]. Furthermore, the quantity of the isoflavone genistein, with purported associations with metabolic and inflammatory disorders and carcinogenesis [26], is greater in Natto compared to unfermented soy products [27].

Miso

Miso is a traditional Japanese paste of fermented soybean used to make miso soup. Miso is produced by fermenting soybeans with 'Koji', produced from a mould *Aspergillus oryzae*, although *Saccharomyces cerevisiae* and lactic acid bacteria may additionally be used. As with other fermented soy foods, miso production varies greatly in terms of ingredients, temperature and fermentation time, salt concentration and the strain of *A. oryzae* used. The koji for miso is a culture of Aspergillus oryzae grown at about 35°C on a steamed polished rice mash in shallow trays until the grains are completely covered but the mold has not sporulated. The koji is mixed with a mash of crushed, steamed soybeans, salt is added and the fermentation is allowed to proceed for a week at 28°C and then for two months at 35°C, after which the mixture is ripened for several weeks at room temperature. Involved in the main fermentation are the enzymes of the koji, yeasts (saccharomyces rouxii and Zygosaccharomyces spp), lactic acid bacteria and bacilli. The final product is ground into a paste to be used in combination with other foods.

A microbial analysis of miso at different time points following the start of fermentation revealed *Bacillus subtilis*, *Bacillus amyloliquefaciens*, *Staphylococcus gallinarum* and *Staphylococcus kloosii* to be present during fermentation, with only the *Bacillus* species remaining in the final product [28]. A range of miso samples have also been shown to contain *Lactococcus* sp. GM005, which produces a bacteriocin with strong antibacterial activity that inhibits the growth of a range of bacteria, including *Bacillus subtilis*, *Pediococcus acidilactici* and *Lactobacillus plantarum* [29,30].

Conclusion

Fermentation is a metabolic process in which microorganisms such as bacteria, yeast or fungi convert organic compounds usually carbohydrates such as sugars and starch into alcohol or acids. For example yeasts converts sugar into alcohol, lactic acid bacteria turn sugars and starch into lactic acid and acetobacter bacteria turn alcohol into acetic acid (vinegar). Many people eat fermented foods to get a supply of live "good" bacteria. Example include sauerkraut, kimchi, kombucha tea and other pickled vegetables. Fermentation is a key to sustainable and healthy food production. Fermented foods are nutritious, shelf-stable and have a number of health benefits. The demand for fermented food is expected to continue to grow in the years to come and the food industry is responding to this demand by developing new fermented food products and by expanding the distribution of existing fermented food products. The future of fermented foods is bright and these foods will play an increasingly important role in our diets in the years to come. Fermented foods can help to improve gut health by increasing the levels of beneficial bacteria in the gut, boost immune system by providing the body with essential nutrients, and protect against cancer by helping to prevent the growth of harmful bacteria, they can help to reduce inflammation and they can help to promote weight loss.

References

1. Ray B (1992) Food Biopreservatives of Microbial Origin. CRC Press, USA.
2. Platt GC (1994) Fermented foods-a world perspective. Food Research International 7: 253-257.
3. Newberry M, Phan-Thien N, Larroque O, Tanner R, Larsen N (2002) Dynamic and elongation rheology of yeasted bread doughs. Cereal Chem 79: 874-879.
4. Mondal A, Datta AK (2008) Bread baking-A review. J Food Eng 86: 465-474.
5. Katina K, Heiniö RL, Autio K, Poutanen K (2006) Optimization of sourdough process for improved sensory profile and texture of wheat bread. LWT Food Sci Technol 39: 1189-1202.
6. Venturi F, Sanmartin C, Taglieri I, Nari A, Andrich G, et al. (2016) Effect of the baking process on artisanal sourdough bread-making: A technological and sensory evaluation. Agrochimica 60: 222-234.
7. Lopitz-Otsoa F, Rementeria A, Elguezabal N, Garaizar J (2006) Kefir: A symbiotic yeasts-bacteria community with alleged healthy capabilities. Rev Iberoam Micol 23: 67-74.
8. Prado MR, Blandón LM, Vandenberghe LPS, Rodrigues C, Castro GR, et al. (2015) Milk kefir: Composition, microbial cultures, biological activities, and related products. Front. Microbiol 6: 422.
9. Yüksekdağ Z, Beyatli Y, Aslim B (2004) Determination of some characteristics coccoid forms of lactic acid bacteria isolated from Turkish kefirs with natural probiotic. LWT 37: 663-667.

10. Zanirati DF, Abatemarco M, Sandes SHDC, Nicoli JR, Nunes AC, et al. (2015) Selection of lactic acid bacteria from Brazilian kefir grains for potential use as starter orprobiotic cultures. Anaerobe 32: 70-76.

11. Raak C, Ostermann T, Boehm K, Molsberger F (2014) Regular consumption of sauerkraut and its effect on human health: A bibliometric analysis. Glob Adv Health Med 3: 12.

12. Swain MR, Anandharaj M, Ray RC, Rani RP (2014) Fermented fruits and vegetables of Asia: A potential source of probiotics. Biotechnol Res Int 2014: 250424.

13. Patra JK, Das G, Paramithiotis S, Shin HS (2016) Kimchi and other widely consumed traditional fermented foods of Korea: A review. Front Microbiol 7: 1493.

14. Jeong SH, Jung JY, Lee SH, Jin HM, Jeon CO (2013) Microbial succession and metabolite changes during fermentation of dongchimi, traditional Korean watery kimchi. Int J Food Microbiol 164: 46-53.

15. Jayachandran M, Xu B (2019) An insight into the health benefits of fermented soy products. Food Chem 271: 362-371.

16. Cao ZH, Green-Johnson JM, Buckley ND, Lin QY (2019) Bioactivity of soy-based fermented foods: A review. Biotechnol Adv 37: 223-238.

17. Nout M, Kiers J (2005) Tempe fermentation, innovation and functionality: Update into the third millenium. J Appl Microbiol 98: 789-805.

18. Rezac S, Kok CR, Heermann M, Hutkins R (2018) Fermented foods as a dietary source of live organisms. Front Microbiol 9: 1785.

19. Moreno M, Tee L, De Vuyst L, Leisner J, Ley C, et al. (2002) Microbial analysis of Malaysian tempeh, and characterization of two bacteriocins produced by isolates of Enterococcus faecium. J Appl Microbiol 92: 147-157.

20. Abu-Salem FM, Mohamed R, Gibriel A, Rasmy NMH (2014) Levels of Some Antinutritional Factors in Tempeh Produced From Some Legumes and Jojobas Seeds. Int Sch Sci Res Innov 8: 296-301.

21. Sutardi, Buckle KA (1988) Characterization of extra- and intracellular phytases from Rhizopus oligosporus used in tempeh production. Int J Food Microbiol 1988 6: 67-79.

22. Chang CT, Hsu CK, Chou ST, Chen YC, Huang FS, et al. (2009) Effect of fermentation time on the antioxidant activities of tempeh prepared from fermented soybean using Rhizopus oligosporus. Int J Food Sci Technol 44: 799-806.

23. Kuligowski M, Pawłowska K, Jasińska-Kuligowska I, Nowak J (2017) Isoflavone composition, polyphenols content and antioxidative activity of soybean seeds during tempeh fermentation. CyTA-J Food 15: 27-33.

24. Ahmad A, Ramasamy K, Majeed AB, Mani V (2015) Enhancement of beta-secretase inhibition and antioxidant activities of tempeh, a fermented soybean cake through enrichment of bioactive aglycones. Pharm Biol 53: 758-766.

25. Kada S, Yabusaki M, Kaga T, Ashida H, Yoshida KI (2008) Identification of two major ammonia-releasing reactions involved in secondary natto fermentation. Biosci Biotechnol Biochem 72: 1869-1876.

26. Mukund V, Mukund D, Sharma V, Mannarapu M, Alam A (2017) Genistein: Its role in metabolic diseases and cancer. Crit Rev Oncol 119: 13-22.

27. Fukutake M, Takahashi M, Ishida K, Kawamura H, Sugimura T, et al. (1996) Quantification of genistein and genistin in soybeans and soybean products. Food Chem. Toxicol 34: 457-461.

28. Onda T, Yanagida F, Tsuji M, Shinohara T, Yokotsuka K (2003) Production and purification of a bacteriocin peptide produced by Lactococcus sp. strain GM005, isolated from Miso-paste. Int J Food Microbiol 87: 153-159.

29. Onda T, Yanagida F, Tsuji M, Shinohara T, Yokotsuka K (2003) Time series analysis of aerobic bacterial flora during Miso fermentation. Lett Appl Microbiol 37: 162-168.

30. Onda T, Yanagida F, Uchimura T, Tsuji M, Ogino S, et al. (2002) Widespread distribution of the bacteriocin-producing lactic acid cocci in Miso-paste products. J Appl Microbiol 92: 695-705.