
UNIT 11 FRUIT AND VEGETABLE-BASED FERMENTATIONS AND THEIR COMMERCIAL PRODUCTS

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11.0 OBJECTIVES

After studying this unit, you should be able to:

- infer the commercial importance of fruit and vegetable based fermentations;
- state the significance of lactic acid fermentation in fruits and vegetables; and
- describe the state of art of sauerkraut, cucumber, kimchi, sinki and fermented pickles production.

11.1 INTRODUCTION

The importance of food fermentation has been highlighted earlier. It is evident that fermented foods are an intricate part of the diet of people in all parts of the world. These are always used as condiments accompanying the main dish. These foods are prepared from plant and animal sources. Fermentation primarily to preserve these commodities and also add flavour and change the texture in order to suit palatability and acceptability. Another important purpose is adding variety to the monotonous diet. Since it has been practiced since time immemorial, it is a house-hold art throughout the world. In recent years, a number of technological and biotechnological developments are taking place and several products are produced on commercial scale.

In early days, people used to collect vegetables and tried to preserve by adding salt. Chinese used to take acid-fermented vegetables during the 3rd century. Korean developed *Kimchi* made from acid fermented cabbage, radish etc., Fermented cabbage is popular in the Western World. Africans evolved the process for acid fermentation of maize, sorghum and tapioca. Even though nothing was known about the technology or microbiology and also about the nutritional quality of the products, the advantages of acid fermented

vegetables, fruits, cereals and milk were well known to people during those days.

During the early twentieth century, it became known that microorganisms are responsible for physico-chemical textural and flavour and taste changes in fermented products. In recent years, some of the fermented foods have been scientifically investigated and based on the microbiological and biochemical information, technologies have been developed for commercial production. Since microorganisms are the key to these fermented food production, these fermented foods can be grouped for convenience as follows:

- i) Acid fermentation preserving fruits, vegetables, milk, cereals, fish and meat etc., and enhancing organoleptic and nutritional quality.
- ii) Protein rich vegetarian foods from legumes and seeds (Tempeh, Oncom etc.).
- iii) Alkaline fermentation from beans (Kinema and African fermented foods).
- iv) Alcoholic foods and beverages (Ethanol is a major product).
- v) Sauces, pastes etc.

Microorganisms grow on the substrate and based on the chemical nature of the substrate, they bring about changes. Two types of acids are predominantly produced viz. lactic acid and acetic acid by microorganisms and thus a variety of products from agricultural commodities are produced especially from milk, cereals, and fruits and vegetables. The other important group of fermented foods is the protein enrichment and modification mainly from soybeans, peanuts and other legumes and pulses. Among beverages, alcoholic fermented beverages e.g., wine, beer top the list all over the world.

In recent years, vegetarian foods are considered to be ideal for human health. Among these lactic acid producing bacteria fermented foods are the best as these organisms tend to help in avoiding cardiovascular and heart diseases, cancer and several other gastrointestinal problems. The advantages of acid food fermentation are:

- i) They avoid spoilage of foods and mould and bacterial toxins production.
- ii) They preserve the food and assure the food safety.
- iii) They modify the flavour of the original ingredients and improve the nutritional value.

Since canned and frozen foods are beyond the reach of majority of people especially in rural areas, acid fermentation of agricultural commodities remains one of the most simplest and inexpensive method. However, in India acid fermentation of vegetables and fruits are not common as compared to European, Oriental and African countries. The raw materials containing high sugar content favour usually ethanol generation and its conversion to acetic acid. The fruits and vegetables having low level of sugar, allow lactic acid producing bacteria to proliferate which lowers the pH around 4.0 due to lactic acid production.

11.2 LACTIC ACID FERMENTED FRUITS AND VEGETABLES

Fermented vegetables are common ingredient of European diet. Sauerkraut, olives and cucumbers are often fermented. The method of vegetable fermentation has been standardized over the centuries both for natural (spontaneous) or addition of starter cultures. The lactic acid producing bacteria grow on the substrate (vegetables) and convert sugar into acids (lactic and acetic). The gradual disappearance of carbohydrate (carbon content) leads to the production of lactic acid which ensures food stability. The pH about 4 of the fermented products inhibits the growth of spoilage microflora and pathogenic organisms.

Salt is added in good quantity which promotes the growth of lactic acid producing bacteria and checks proliferation of contaminating and spoilage microorganisms.

Fruits and Vegetables suitable for Lactic Fermentation

- Cabbage, cauliflower, broccolys, mustard
- Carrots, turnips, beetroots, radish
- Cucumber, Olives, tomatoes, peppers, green-beans and green peas
- Onion and garlic
- Apples, pears, green mangoes, banana, lemon, lime

11.3 SAUERKRAUT (CABBAGE) FERMENTATION

Sauerkraut or Sauerkohl is a German term which means '*Sour Cabbage*'. Sauerkraut is extensively used in the North America (Canada and U.S.A.), Germany, Holland, France, U.K. and other European countries. Cabbage ('*Brassica oleracea*') normally grown in cold climate is found to be suitable for the fermentation purpose.

i) Processing

Fresh cabbage is taken, cleaned, trimmed and shredded into 2-5mm size and finally filled into wooden vats or cement tanks. Salt is added at the rate 2.25% and mixed thoroughly. The top portion of the vat or tank is covered with plastic and enough weight is applied in order to make it compact and allow anaerobic conditions prevail for fermentation. When weight is applied, the salt dissolves in the sap which is expressed by the pressure and by osmosis it comes out from the cells. The leaves respire for sometime and oxygen is utilized and thus anaerobic conditions are created. The leaves shrink in size due to water removal. A spontaneous lactic acid fermentation follows. Fermentation is done for about 30 days or more until 1% lactic acid is formed. The Sauerkraut is removed from the vat and packed in cans, glass or plastic containers. In cans the fermented product is pasteurized at 74°C for 3 minutes. Sodium benzoate or potassium metabisulphite is added when product is packed unpasteurized. It is stored at $\pm 5^{\circ}\text{C}$.

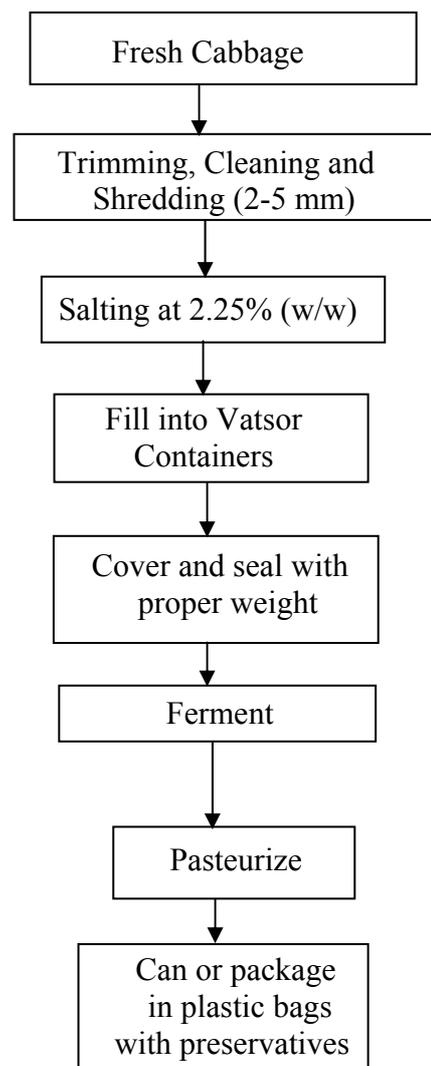


Figure 11.1: Sauerkraut (Cabbage) Fermentation

ii) Microorganisms Involved in Fermentation

Initially the shredded and processed cabbage leaves contain very high number of aerobic bacteria with low counts of lactic acid bacteria. During fermentation, the number of lactic acid bacteria increases suppressing the growth of undesirable organisms and a distinctive flavour of sauerkraut develops with about 1% of lactic acid content. The microorganisms follow usually the following pattern in succession: *Streptococcus faecalis*, *Leuconostoc mesenteroides*, *Lactobacillus brevis*, *Pediococcus cerevisiae*, *Lactobacillus plantarum*. Initially heterofermentative nominate the numbers which is taken over by the homofermentative type of microorganisms. Sometimes a previous batch brine is added as a starter culture to facilitate quick fermentation.

iii) Spoilage

Sometimes fermented products are very badly spoiled by contaminating bacteria causing off flavours and colour and undesirable texture. Temperature, salt concentration and sanitary conditions are important to control the desired fermentation. Lower temperature around 7-10°C

favours slow growth of bacteria and thus allows good fermentation. In traditional system, fermentation is allowed for 6 months.



Check Your Progress Exercise 1

- Note:** a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. List some of fruits and vegetables used commonly for fermentation and the mode of lactic acid production by the lactic acid producing bacteria.

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2. Define the word sauerkraut.

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3. Explain, how sauerkraut is prepared.

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4. Cite some microorganisms involved in cabbage (kraut) fermentation.

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5. What are the causes of spoilage of sauerkraut?

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11.4 CUCUMBERS FERMENTATION

Cucumbers (*Cucumis sativus*) are grown throughout the world. It is reported to have been originated in India. A number of varieties of cucumbers are cultivated in fields or greenhouses for table or pickling purposes.

i) Processing

Cucumbers are washed after selecting them and placed in a covered tank containing a salted and acidified brine. The brine is normally acidified (vinegar or acetic acid) to pH 4.5. The salt concentration of the brine is maintained between 5-8%. Too little salt less than 5% favours the growth of enterobacteriaceae bacteria. Higher levels of salt allows growth of yeasts. After the initiation of fermentation, almost everyday the brine is buffered with sodium acetate. During fermentation, contamination with yeasts is observed and therefore, to avoid bloater formation, the brine is purged with nitrogen or air. Potassium sorbate (0.035%) is also added to check the growth of yeasts and moulds preferably if fermentation is done at smaller scale. Fermentation if it is carried out at 15-20°C, it takes normally 3 weeks to 1 month.

ii) Microorganisms involved in the fermentation

Streptococcus faecalis, *Streptococcus lactis*, *Leuconostoc mesenteroides*, *Pediococcus pentosaceus*, *Lactobacillus brevis*, *Lactobacillus plantarum*, *Lactobacillus bavaricus* are usually noticed during the fermentation. Controlled fermentation and pure culture fermentation have been studied but not commercially exploited. Glucose and fructose are converted to lactic acid, acetic acid, ethanol, mannitol and carbon dioxide. About 1.1% lactic acid is present after the fermentation. Textural properties after fermentation is important. A firm and crisp texture is desired. A clean flavour is also desired.

iii) Spoilage

Bloater formation is observed due to the growth of gas forming microorganisms e.g. yeasts, bacteria and other contaminating organisms. Bleaching of the green colour of cucumbers takes place due to exposure of fruits to sunlight. Offensive flavours are produced due to the formation of butyric and propionic acids.

11.5 KIMCHI FERMENTATION

Kimchi is a major condiment of Korean diet. It is a popular dish served at every meal along with cooked rice. Kimchi is a fermented product, gaining popularity in the United States of America and other countries. It is made from cabbage and other vegetables like radish, mustard greens, cucumbers, green onions, Chinese leeks, turnips and green peppers, spinach, pumpkins and egg plants.

i) Processing

Good quality cabbages are selected, cleaned and cut into smaller pieces. The cut cabbage is placed in a brine solution containing 5-7% salt concentration for 12 hours. The brined vegetables are rinsed and drained. Seasoning ingredients are thoroughly mixed and filled in earthen jars or glass jars. The jars are buried (80-90% of container depth) underground. These are covered on the top with bundles of rice straw to protect from sunlight and rain. This technique is followed in the rural areas. In urban areas the mouth of the jar is covered with a cloth piece and kept in shaded places. Low temperature is considered to be ideal for slow fermentation. Usually less than 15°C temperature is optimum for good quality Kimchi.

ii) Microorganisms involved in the fermentation

The microorganisms involved in Kimchi fermentation are *Leuconostoc mesenteroides*, *Streptococcus faecalis*, *Lactobacillus brevis*, *Lactobacillus plantarum*, *Pediococcus cerevisiae*. The aerobic bacteria found are species of *Achromabacter*, *Flavobacterium* and *Pseudomonas*. The main bacterium responsible for Kimchi fermentation is *Leuconostoc mesenteroides*. The fermentation is initiated by *Leuconostoc mesenteroides* and terminated by *Lactobacillus plantarum* / *Lactobacillus brevis*.

The organic acids produced during fermentation contribute to the final flavour of Kimchi. The organic acids normally noticed in Kimchi are citric, fumaric, oxalic, malonic, malic and succinic acids. Freshly fermented, good quality Kimchi should have distinct red or green colour with pleasant flavour and taste.

iii) Spoilage

Softening is the major problem in Kimchi fermentation. Yeasty and off flavours also effect the quality of the fermented product.

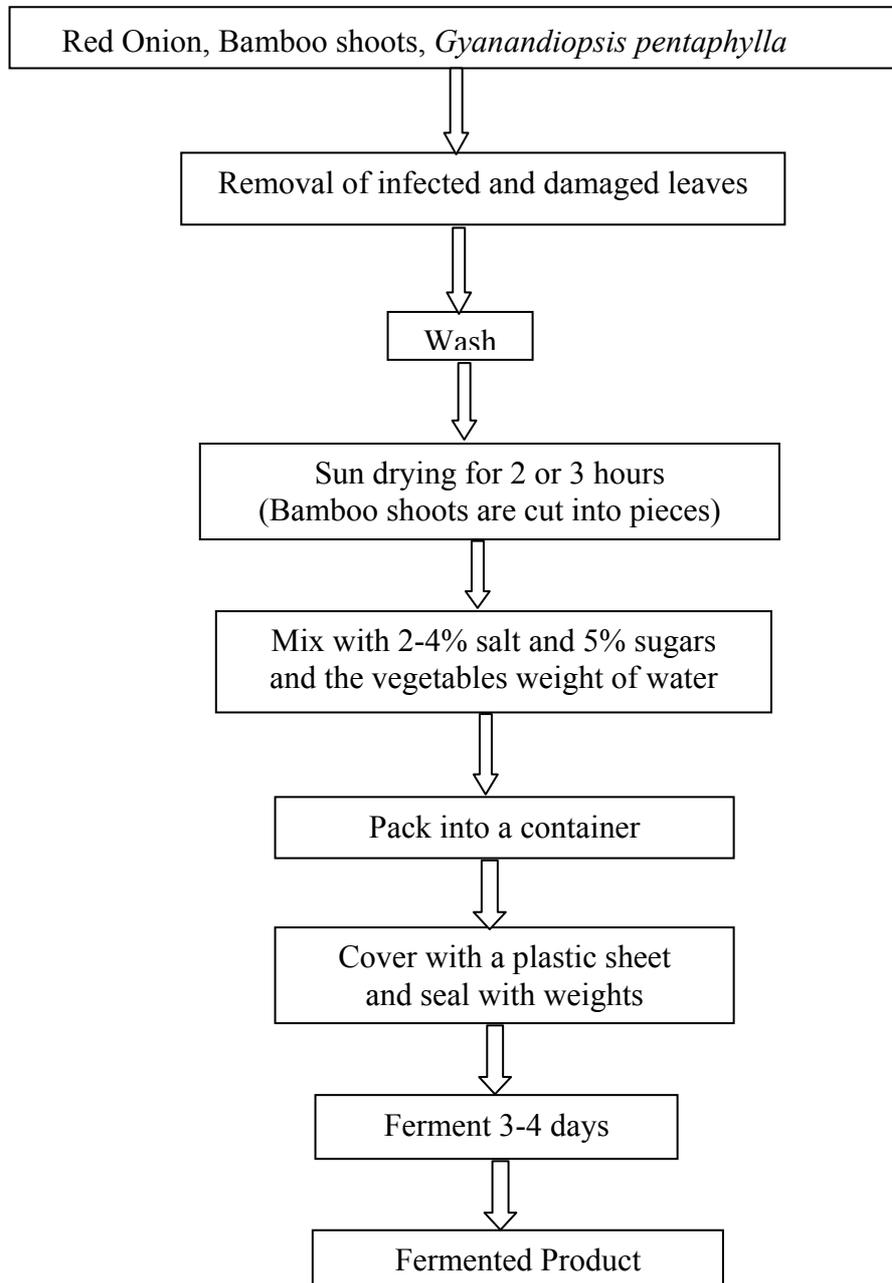
11.6 INDIAN SINKI FERMENTATION

Sinki is consumed as a pickle in the Himalayan belt of India, Nepal and Bhutan. It is prepared from the tap root of radish. Fresh radish roots are washed and placed outside for sun drying for 1 or 2 days. These are shredded and washed again and packed tightly into an earthen ware or glass jars, sealed and left for fermentation. Fermentation is carried out for 15-30 days at room temperature around 30°C. Initially *Lactobacillus fermentatum* grows followed by *Lactobacillus brevis* and *Lactobacillus plantarum*. The pH drops to 3.3 and acidity rises to 1.28%. When fermentation is over, the fermented radish is sundried for 3-5 days. It is fried with salt, tomato and green chilli. The fried mixture is then boiled in rice water and served hot as soup along with the main meal.

11.7 FERMENTED PICKLES

i) Pak-Sian-dong and Related Fermentations (Fermented bamboo shoots and fermented red onion)

These are the common pickles of Thailand. The fresh vegetable is washed thoroughly and spread on a mat in the air or sunlight in order to loose water and tissues to wilt. It is mixed with 2% salt, 4% sugar and the same quantity of water and kept in a tight container. It becomes ready for consumption in 3-4 days. Acidity normally reaches to 0.8% with pH around 3.9-4.0.



Microorganisms involved : *Leuconostoc mesenteroides*, *Pediococcus cerevisiae*,
Lactobacillus plantarum, *Lactobacillus brevis*,
Lactobacillus fermentii.

Figure 11.2: Pickles (fermented) of Thailand

ii) Malaysian Pickles

Home made pickles are common in most of these countries especially in rural areas. Fruits and vegetables which are relatively sour, are used for pickle preparation. Many types of fruits and vegetables are used depending upon the availability and seasonality. The common vegetables used are: gherkins, cucumbers, ginger, onion, leek, chilli, bamboo shoots, unripe

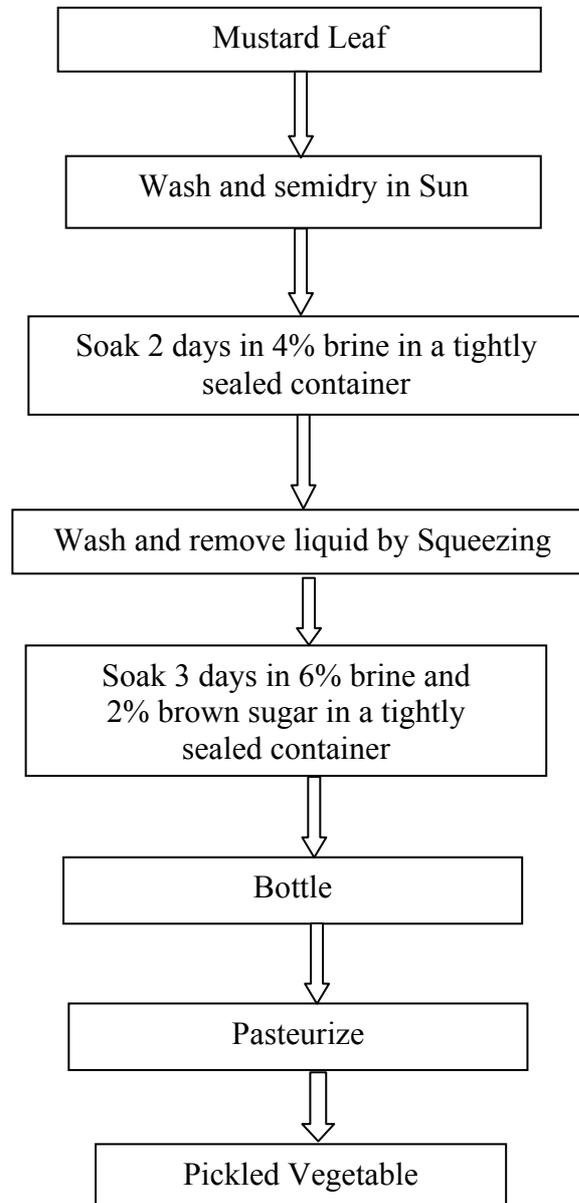


Figure 11.3: Malaysian pickled vegetable

mango, papaya, lime, lemon and nutmeg. In all these fermentations higher level of crystal salt or brine is used in curing the tissues. Sugar and other fermentable carbohydrates, dilute vinegar, and spices are also added. It appears to be a simple process but the quality differs from house to house. Pickles undergo a bacterial lactic acid fermentation. The same group of microorganisms are involved in the fermentation. Fermentation takes about 8 days depending upon the substrate.

In India, several varieties of pickles are prepared both for indigenous consumption and export purposes. We usually prefer non-fermented pickles preserved in edible oils. The quality and taste differ based on the ingredients used. Bamboo shoots pickles, brinjal and mixed vegetable pickles are common in North India. Some of these are exotic in nature prepared at house-hold level.

iii) Lactic Fermented Fruits in European Countries

Fruits are cleaned and blanched at 50-60°C to destroy undesirable bacteria. After the addition of *Lactobacillus acidophilus* or *Lactobacillus bifidus* the product undergoes to lactic acid fermentation. The fruit is shredded and pulverized and pasteurized and finally goes for marketing.

Check Your Progress Exercise 2



- Note:** a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Highlight the importance of cucumber fermentation and different steps involved in fermentation.

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2. Name the countries where Kimchi is prepared and used. List vegetables used in Kimchi fermentation.

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3. Explain about the Indian sinki fermentation and method of its preparation.

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4. Give a brief account of fermented bamboo shoots and fermented red onion.

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11.8 LET US SUM UP

Fermentation of different types of agricultural commodities has been practiced with an aim to preserve them and also add exotic flavour and change the texture. Fermented fruits and vegetables have been in use mostly as condiments in order to avoid monotonous diets. Lactic acid producing bacteria grow luxuriantly in favourable conditions on fruits and vegetables and produce good quantity of lactic acid and other acids and antimicrobial substances which lower down the pH and thus check the growth of spoilage and pathogenic microorganisms. It is a simplest method of preservation. Sauerkraut and cucumber fermentations are the typical examples. Kimchi of Korea, Sinki of Indian sub-continent, fermented bamboo shoots and red onion and Malaysian pickles are produced commercially and consumed by the people. Lactic fermented fruits are becoming popular in European countries.

11.9 KEYWORDS

- Sauerkraut** : Fermented cabbage.
- Kimchi** : Korean fermented product (cabbage).
- Sinki** : Indian fermented product from radish.
- Pak-Sian-dong** : Fermented bamboo shoots of Thailand



11.10 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:
 - Cabbage, cauliflower, broccoli, mustard, carrots, turnips, beetroots, radish, cucumber, olives, tomatoes, peppers, green beans, peas, onion, garlic, apple, pears, green mangoes, banana, lemon and lime.
 - Lactic acid producing bacteria grow on vegetables and fruits and convert sugars into acids (lactic and acetic).

2. Your answer should include the following points:
 - A German term meaning ‘Sour Cabbage’.

3. Your answer should include the following points:
 - Fresh cabbage → trimming, cleaning and shredding → salting → filling into vats → covering the vat and applying weight on the top → allowing fermentation → pasteurization → packing with preservatives.
4. Your answer should include the following points:
 - *Streptococcus faecalis*, *Leuconostoc mesenteroides*, *Lactobacillus brevis*, *Pediococcus cerevisiae*.
5. Your answer should include the following points:
 - Good sanitary conditions needed while processing cabbage for fermentation.
 - Low temperature and appropriate salt concentrations favour good fermentation and the final product.

Check Your Progress Exercise 2

1. Your answer should include the following points:
 - Widely cultivated in India in all the States irrespective of climatic changes Selection of fruits → washing → placing fruits in brine 5-8% (pH 4.5 adjusted with vinegar) → allowing natural fermentation at 15°C → purging nitrogen to avoid bloater formation → fermentation for one month.
 - *Streptococcus faecalis*, *Streptococcus lactis*, *Leuconostoc mesenteroides*, *Lactobacillus brevis*, *Lactobacillus plantarum*.
2. Your answer should include the following points:
 - A major condiment of Korean diet.
 - Vegetables like cabbage, radish, mustard (green), cucumbers, green onions, Chinese leeks, turnips, green peppers, pumpkins, etc.
3. Your answer should include the following points:
 - Radish roots → sundrying for 1-2 days → shredding → packing tightly in an earthen vessel → sealing of the mouth of vessel → allowing fermentation for 15-30 days → fermented radish sundried → used as a condiment for soup.
4. Your answer should include the following points:
 - Fermented vegetables of Thailand.
 - Fresh vegetables washed and spread on a mat and sundried.
 - After sundrying 2% salt and 4% sugar are added and mixed with the vegetables quantity of water and placed in a container.
 - Fermentation normally takes 3-4 days.

11.11 SOME USEFUL BOOKS

1. Flemming, H.P. (1982) Fermented Vegetables. In: Economic Microbiology; Fermented Foods. A.H. Rose, Academic Press Inc., New York.
2. Pederson, C.S. (1960) Sauerkraut. In: Advances in Food Research, E.M. Mrak and G.F.Steward, eds., Vol. 10, Academic Press, New York.
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