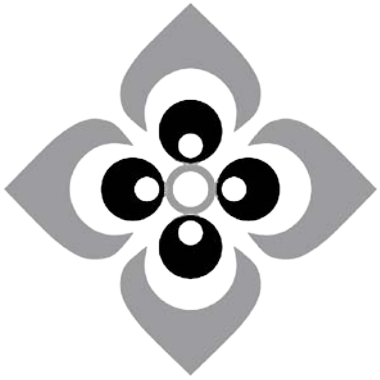

Consortium for Educational Communication

Module
on
Processing Of Leafy, Root And Tuberous Vegetables

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INTRODUCTION

The principle used in preservation of vegetables is to eliminate complete or to prevent the activities of the organisms capable for destroying the product. The best food preservation methods for fresh vegetables depend on their degree of ripeness. Here one needs to understand difference between maturity and ripening. Maturity means the produce will ripen and become ready to eat after picking it. Ripeness occurs when the color, flavor, and texture is fully developed. Once it is fully ripe, fresh produce begins the inevitable and declining spoilage process. To prepare fresh vegetables for preserving, always wash in plenty of running water, remove non-edible parts such as stems and seeds, peel or trim as desired, and cut into slices or cubes. The various processing methods of vegetable include fermenting in salting, dehydration, freezing, pickling in vinegar, canning in brine, cooking, etc.

VEGETABLE CLASSIFICATION

Quite a large number of vegetable crops are grown in the country either on a commercial scale or limited to backyards of homesteads. A few crops have similarity while others have dissimilarity in their climatic and soil requirements, parts, used, method of cultivation etc. While describing individual vegetables, there is possibility of repetition in many aspects. In order to avoid repetition, it is essential to classify or group into different classes/groups. Different methods of classification followed in vegetables are described below:

Botanical classification

Botanical classification is based on taxonomical relationship among different vegetables. Plant kingdom is divided into four viz. *Thallophyta, Bryophyta, Pteriodophyta and Spermatophyta.* All vegetables belong to division Angiospermae of Spermatophyta. It is further divided into two classes viz., *Monocotyledoneae and dicotyledoneae*.

The family wise distribution of vegetables under the classes is as follows:

Classification based on hardiness

This classification is based on ability to withstand frost and low temperature and it will be useful to know season of cultivation of a crop. Here the vegetable crops are classified into hardy, semi hardy and tender. Hardy vegetables tolerate frost and

low temperature and are basically winter or cool season or temperate vegetables. Warm season or subtropical or tropical vegetables are considered as tender since they cannot withstand frost. Temperate vegetables, in general, can be stored for long periods under low temperature. Tropical vegetables are bulky and more perishable compared to temperate vegetables.

Table No 1: Classification of vegetables on the basis of hardness

Hardy	Semi hardy	Tender
Asparagus	Carrot	Amaranth
Crucifers	Celery	Okra
Garlic	Beet root	Brinjal
Leek	Globe artichoke	Chilli
Onion	Lettuce	Cluster bean
Parsley	Palak	Cucurbits
Peas	Parsnip	Tomato
Radish	Potato	Colocasia
Rhubarb		Amorphophallus
Spinach		Yams
		Sweet potato

Classification based on parts used

In this system, crops are classified based on their parts used for vegetable purpose.

1. Tubers:

A tuber is a large underground stem that stores nutrients. Tubers have

carbohydrates and vitamins. Potatoes are tubers.

2. Root Vegetables:

Roots store a plant's food supplies and send nutrients and moisture to the rest of the plant. Carrots, beets, turnips, and parsnips are examples. Roots and tubers are plants yielding starchy roots, tubers, rhizomes, corms and stems. They are used mainly for human food (as such or in processed form), for animal feed and for manufacturing

starch, alcohol and fermented beverages including beer.

3. Bulb Vegetables:

A bulb is made up of layers of fleshy leaves surrounding a portion of stem.

They have intense flavour. Onion and garlic are examples.

4. Stem or Stalk:

Minerals and vitamins are transported through the stem or stalk to other parts of the plant. Celery and asparagus are common stalk vegetables.

5. Leaves:

Leaf vegetables are a good source of vitamins and minerals. The darkest

green leaves have the most vitamin A. Spinach, lettuce, and brussels sprouts are examples.

6. Flowers:

Broccoli and cauliflower are examples. They include the flower of the plant and the stems. They are high in vitamins and mineral.

7. Fruits:

The fruit is the part of the plant that holds the seeds. Tomatoes, eggplant,

pumpkins and squash are fruits of the plant.

8. Seed Vegetables:

Seeds are high in carbohydrates and protein as well as vitamins and minerals. Corn, peas, and beans are examples.

Role in nutrition:

The majority of vitamins and micronutrients essential for the human life can be supplied by vegetable consumption. Some vegetables provide volatile, essential oils, which have health maintaining effects: in the representatives of Cruciferous crops (cabbages, turnips and radishes) there are essential oils, which contain sulphur,

and are partly nitrogenous (mustard oil compounds). These are important as natural therapeutics, since they display anti-microbial, cholagogue, thyreostatic effects and reduce blood pressure. Essential oils containing sulphur (di- and polysulphides) and not containing nitrogen are present in garlic and onions, leeks and chives, are strongly anti-microbial. Carrots, parsnips, celery and parsley provide oils mainly of the terpene series, which contain neither sulphur, nor nitrogen. Vegetables have been found to help prevent a host of diseases if their consumption meets the requirement of the organism for vitamins, minerals, fibre and other nutrients, including antioxidants.

Processing of vegetables:

Because of the varied growing and harvesting seasons of different vegetables at different locations, the availability of fresh vegetables differs greatly in different parts of the world. Processing can transform vegetables from perishable produce into stable foods with long shelf life and thereby aid in the global transportation and distribution of many varieties of vegetables. The goal of processing is to deter microbial spoilage and natural physiological deterioration of the plant cells. Generally, the techniques include blanching, dehydrating, canning, freezing, fermenting and pickling, and irradiating.

1. **Blanching**

After vegetables have been washed clean, they must undergo blanching (heating) in hot water at 88° C (190° F) for two to five minutes or with steam in a conveyor at 100° C (212° F) for one-half to one minute. Blanching inactivates natural enzymes that would cause discoloration and off-flavours and aromas. It also serves to reduce the number of microorganisms and to render vegetables limp for easy packing into containers. For some vegetables, such as spinach, snap beans, and collards, the blanching step also serves to remove harsh flavours. After blanching the vegetables must go through rapid cooling in either cold water or cold air for better quality retention. The vegetables are then ready for the various food-processing methods described below.

2. **Drying**

Drying is probably the oldest method of preserving foods. The removal of water from vegetables is accomplished primarily by applying heat, whether it be through the radiant energy **of the sun or through air heated by electrical energy. A major**

advantage of removing water is a reduction in volume and weight, which aids in storage and transportation of the dried products. Modern drying techniques are very sophisticated. Many machines are available to perform tunnel drying, vacuum drying, drum drying, spray drying, and freeze-drying. Although freeze-drying produces a food of outstanding quality, the cost is high, and it has not been used widely in vegetable products. Drying inhibits the growth of bacteria, yeasts, and mold through the removal of water. One of the most familiar dehydrated products is instant potatoes. Almost all the mashed potato dishes served in restaurants and institutions are rehydrated instant potatoes. In restaurants and institutions dehydrated potato granules are used, while dehydrated flakes are preferred for home cooking. Potato granules have high bulk density and are easy to handle in large quantity

(A) **Dried sweet-sour sweet potato**

Dried sweet-sour sweet potato was originally named Delicious-SP and it is a product that has the sweet and sour taste of dried fruits. The most acceptable product was made with boiled sweet potato slices 0.3 mm thick which were soaked in 60° Brix syrup containing 0.8 - 1.0% citric acid and dried at 65°C. Dried sweet sour sweet potato contains 13,033 I.U. of vitamin A per 100 g which is higher than both dried mango and dried apricot.

(B) **Cassava Chips:**

Cassava chips are unfermented, dry products of cassava. Roots are chipped into smaller sizes for fast drying that also helps the process of detoxification. Cassava can be dried naturally in the sun or artificially in an oven to produce cassava chips that vary in size, usually not exceeding 5cm in length and about 2 ± 1mm thick. They are used mostly in animal feed production but have potential for human consumption although this has not been fully explored. In some West African countries, chips are utilized in the production of flour and starch.

(C) **Sun Drying of Cassava**

Chips Sun drying is the simplest method of drying and traditionally cassava is sun dried in the open air, either on the ground or on a raised platform (Atikson et al; 1983). The practice involves spreading out freshly sliced cassava roots on drying areas or concrete floors of various dimensions with the chips being turned over at

intervals with the use of a shovel or rake. The time of drying and chips quality are affected by the chips shape and size. Interrupted sun drying affects the quality of the finished chips. Sun drying has been reported to be more effective in the elimination of cyanide than oven drying as it allows more contact time between linamarase and the cyanoglycosides and also retains water, essential for linamarase action, for a longer time in the tubers.

3. Frying

Frying is the cooking of food in oil or another fat. Chemically, oils and fats are the same, differing only in melting point, and the distinction is only made when needed. Foods can be fried in a variety of fats, including lard, vegetable oil, rapeseed oil and olive oil. In commerce, many fats are called oils by custom, e.g. palm oil and coconut oil, which are solid at room temperature. A variety of foods may be fried, including the potato chip, bread, eggs and foods made from eggs, such as omelettes or pancakes.

(A) Potato chips

Fully grown and ripe potatoes are thoroughly washed before peeling them. Then these potatoes are trimmed and put in brine water for 30-35 minutes to prevent browning. They are afterwards cut in the required sizes on slicing machine. These slices are blanched in boiling water and are then placed on drying trays which are then put in the drying machine. Temperature of dryer is maintained in the range of 140 to 150 F. After drying, they are fried in edible oil to make them crisp and brown and then they are packed in polythene bags. The chips could be salty or spicy. Some other flavours which are locally popular can also be tried. The process flow chart is as under:

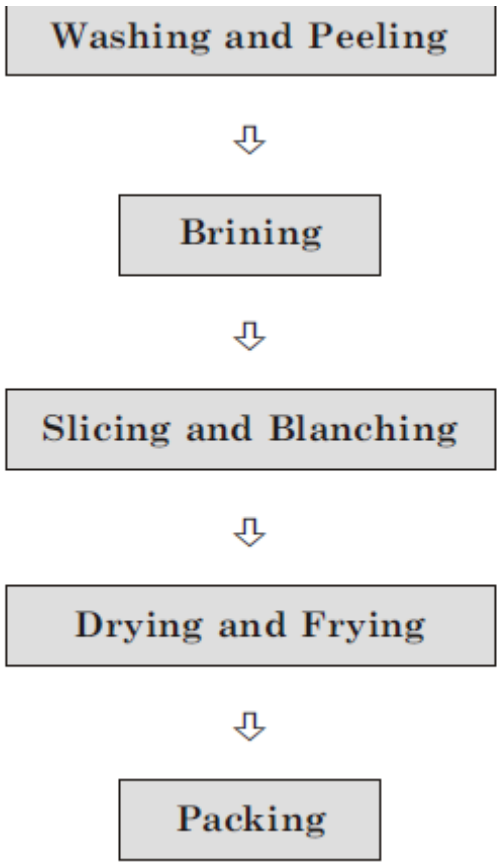

Fig No 1: Flowchart of Potato Frying

4. Freezing Process

Freezing, or solidification, is a phase transition in which a liquid turns into a solid when its temperature is lowered below its freezing point. For most substances, the melting and freezing points are the same temperature; however, certain substances possess differing solid–liquid transition temperatures. Most liquids freeze by crystallization, formation of crystalline solid from the uniform liquid. This is a first-order thermodynamic phase transition, which means that, as long as solid and liquid coexist, the temperature of the whole system remains very nearly equal to the melting point due to slow removal of heat when in contact with air, which is a poor heat conductor. Because of the latent heat of fusion, the freezing is greatly slowed down and the temperature will not drop anymore once the freezing starts but will continue dropping once it finishes. Crystallization consists of two major events, nucleation and crystal growth. Nucleation is the step wherein the molecules start to gather into clusters, on the nanometer scale, arranging in a defined and periodic manner that defines the crystal structure. The crystal growth is the subsequent growth of the nuclei that succeed in achieving the critical

cluster size. Freezing is a common method of food preservation that slows both food decay and the growth of micro-organisms. Besides the effect of lower temperatures on reaction rates, freezing makes water less available for bacterial growth.

Frozen vegetables are vegetables that had their temperature reduced and maintained to below their freezing point for the purpose of storage and transportation until they are ready to be eaten. They may be commercially packaged or frozen at home. A wide range of frozen vegetables are sold in supermarkets. Examples of frozen vegetables which can be found in super markets include spinach, broccoli, cauliflower, peas, corn, yam either packaged as a single ingredient or as mixtures. The processing of some frozen vegetables is discussed as below:

(A) **Frozen Asparagus:**

Frozen asparagus consists of sound and succulent fresh shoots of the asparagus plant (*Asparagus officianalis*).The product is prepared by sorting, trimming, washing and blanching as necessary to assure a clean and wholesome product. It is then frozen and stored at temperatures necessary for preservation.

(B) **Frozen Lima Beans:**

Frozen lima beans are the frozen product prepared from the clean, sound, succulent seed of the lima bean plant without soaking, by shelling, washing, blanching, and properly draining. They are then frozen in accordance with good commercial practice and maintained at temperatures necessary for the preservation of the product. Most vegetables frozen commercially are intended for direct consumer use or for further processing into soups, prepared meals, or specialty items. Advances in packaging materials and techniques have led to bulk frozen products being stored in large retortable pouches. Many restaurants and institutions prefer bulk frozen soups packaged in these pouches because of their quality and convenience.

(C) **Frozen beans, speckled beans (Lima)**

Frozen speckled butter (lima) beans are the frozen product prepared from the clean, sound, freshly-vined (but not seed-dry) seed of the speckled butter (lima) bean plant (*Phaseolus limensis*). The skins of the seed are pigmented and the external colors range from variegated speckling of green, pink, red, and/or lavender to purple. The

product is prepared by shelling the pods; by washing, blanching, and properly draining the seeds that have been sorted and blended or otherwise prepared in accordance with good commercial practice. They are frozen in accordance with good commercial practice and maintained at temperatures necessary for the preservation of the product.

(D) **Frozen corn on the cob**

Frozen corn on the cob is the product prepared from sound, properly matured, fresh, sweet corn ears by removing husk and silk, by sorting, trimming, and washing to assure a clean and wholesome product. The ears are blanched, then frozen and stored at temperatures necessary for the preservation of the product.

5. Canning Process

Canning is defined as the preservation of foods in the sealed containers and usually implies heat treatment as the principal factor in prevention of spoilage. The canning industry uses thermal processing to ensure microbial safety and shelf life extension of food products. Retorting is a process that relies on the transfer of heat to guarantee the safety of canned food. In this process, cans are filled with the food product and then sealed hermetically before retorting. Wet heat and pressure are applied within the retort to sterilize both the container and food product. This heat sterilization is essential in canning, especially for low-acid foods, which have a pH greater than 4.6 and a water activity greater than 0.85, such as papaya, bananas, melons, corn, green beans, and peas. These foods provide appropriate conditions for some spore-forming microorganisms and anaerobic microorganisms, such as *Bacillus coagulans* and *Clostridium botulinum*, to grow. Therefore low acid food requires more severe heat treatment, such as 121.1^{0}C for 25 min for canning small carrots (FAO, 1995), than acid or acidified food (pH below 4.6 and water activity below 0.85), which can be canned at 100^{0}C. Many fruits are acid and have a pH below 4.6, such as apricots, grapefruit, pineapples, tomatoes, and peaches. A thermal process at temperatures at or below 100^{0}C is used to destroy vegetative cells of spoilage microorganisms and inactivate enzymes. Hot-filling, a process of heating the juice with a heat exchanger to a fill temperature of 88-95^{0}C, then filling the juice into a container, is also sufficient for acidic beverages, such as cherry, cranberry, and apple juice. Fruits and vegetables selected for canning pass through several processes before they are turned out as finished products. Various steps involved in canning process are given below:

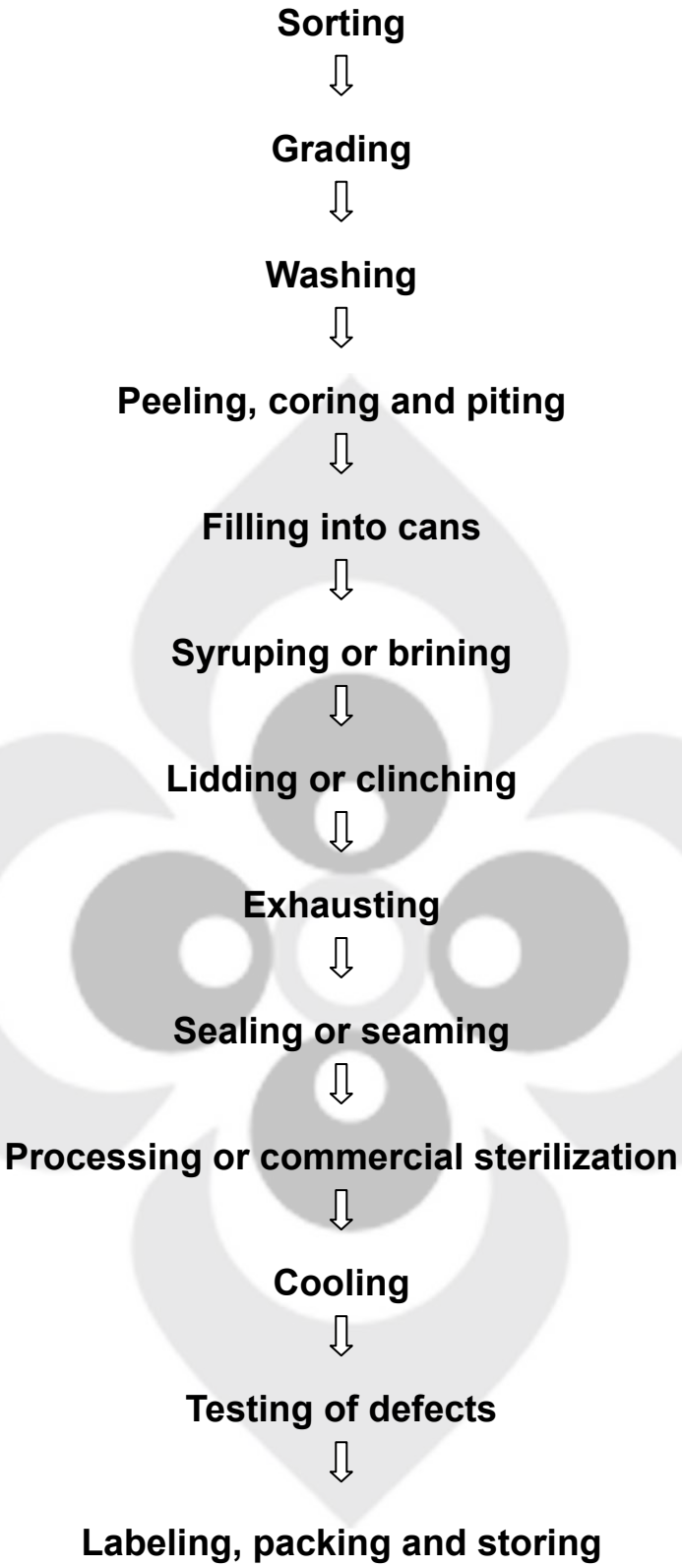

Fig No2. Flow chart for canning of vegetables

Canning of Vegetables

Most of the vegetables contain more starch while their acidity is generally much lower than of fruits. Vegetables are grown in or near the ground therefore, they contain more of heat resistant soil microorganisms and thus, require more cooking or processing than fruits to develop their more desirable flavour and texture and also for sterilization of material. Vegetables often contain disagreeable flavours or organic compounds which should be removed before canning, therefore they are usually blanched before being filled into cans. The vegetables may be canned in brinein their natural form or in curried style using spices, fat etc. as the covering liquid. Some of the examples of canned vegetables is discussed as below:

(A) Canning of Beans

Green beans or French beans are prefered for canning. Desirable characters for processing include long, straight, tender pods of medium size, thick walled and small seeded, free from fibre and strings at optimum maturity, bright green colour after blanching. Beans are cut into slices of about 2.5 cm in length. The pieces are blanched for 2-3 minute in boiling, water, drained and filled into plain cans. They are covered with 2% brine. The filled cans are exhausted, closed and processed under pressure . Lima and wax beans are also canned in a similar manner.

(B) Cauliflower Canning

Cauliflower is rather difficult to can due to their greying and loss of firm texture after heat processing. The heads are broken or cut into pieces of about ¾" across and thoroughly washed. The pieces are blanched for 3-4 minutes in 0.75% citric acid solution. Pieces are then washed, filled into cans and covered with boiling 1.5% brine. The cans are exhausted, processed and cooled rapidly.

(C) Tomato Canning

Tomato products can be hot filled or processed in a retort as needed to minimize spoilage. Because tomatoes are a high-acid food with a pH of 4.0–4.5, they do not have to be sterilized. However, most tomato products undergo a retort process to ensure an adequate shelf life of 24–30 months. The continuous rotary retort is most commonly used for tomato products. This retort provides agitation of the product

and can handle large quantities in a continuous process. Because tomatoes are a high-acid food, a continuous rotary retort set at 104 ^{0}C for 30–40 min is common. Exact processing conditions depend on the product being packed, the size of the can, and the type and brand of retort used. The key is for the internal temperature of the tomatoes to reach at least 88^{0}C.

(D) **Potato Canning**

Since potatoes are a low-acid food, the required processing temperature is 115.6–121.1^{0}C for 27–50 min, depending on the temperature, type of retort, and can size. Some commercial retorts include static retort, continuous retort, and hydrostatic pressure sterilization. Before canning, potatoes should be half-cooked using steam or boiling water to inactivate the enzymes and prevent discoloration.

(E) **Mushroom Canning**

Fresh mushrooms are washed in cold water and then blanched in boiling water for around 3- 4 minutes. To inhibit enzymatic activity, blanching is necessary. It also inactivates micro-organisms and removes the air from the raw materials to achieve a satisfactory and uniform pack. Mushrooms are blanched in boiling water for 2-3 minutes followed by immediate cooling in cold water. The blanched mushrooms are filled into cans with declared drain weight i.e. 440gms in A-2.5 can. After filling the cans with mushrooms strained hot brine solution of 2% common salt, 1% sugar and 0.05% citric acid is added upto the brim of the can. Brining adds flavour to the product, reduces processing time and enhances the shelf life of canned mushrooms. After brining, cans are exhausted to remove any entrapped air and other accumulated gases from the product to ensure a longer shelf life. Exhausting can also be performed by placing the filled cans in boiling water till temperature of the centre of can reaches 85 - 90^0 C for 1-2 minutes. Immediately after exhausting, cans are sealed with the help of a double seamer to get hermetically sealed container. This is accomplished by processing the hermetically sealed cans at a pressure of 15 lbs PSI for a specified period of time depending upon the size of can and altitude of processing place. Cooling of cans is done immediately after sterilization in cold running water to room temperature in order to give an abrupt shock to the micro-organisms to get rid of their adverse activities. The cooled cans are stored in a cool dry place and smeared with grease to remove any adhering moisture from the can body to avoid rusting

6. Pickling Vegetables

Pickling is one of the oldest methods of food preservation. Pickle is an edible product preserved and flavoured in a solution of common salt and vinegar. Spices and oil are also added. Pickles are relished by people throughout the world. They add to the palatability of a meal, aid in digestion and are good appetizers too. Pickles are prepared from fruits and vegetables like cauliflower, cabbage, onion, beans, cucumber, bittergourd, amla, lemon. The Chinese were fermenting vegetables as early as by the third century BC. By the first century, the Romans were pickling. Pickled products also appeared early in America, and the pickle barrel was common during the colonial days. Pickles even became part of our folklore, as children learned to recite the "Peter Piper picked a peck of pickled peppers" tongue twister. By the early 1920s, the U.S. Department of Agriculture (USDA) had published instructions on making pickles at home. Many of these procedures are still used today.

Preservation by Pickling

Microorganisms are always on vegetables. Proper home canning prevents the growth of the microorganisms that cause spoilage and illness. When the acidity of a canned food is high, harmful bacteria such as Clostridium *botulinum* cannot grow. That is why pickling (adding acid) prevents spoilage. There are two types of pickles:

1. Brined (fermented) pickles require several weeks of "curing" at room temperature. During this period, colors and flavors change. Acid is produced as lactic acid bacteria grow.

2. Quick (unfermented) pickles are made in 1 or 2 days by adding acid in the form of vinegar. It is critical to add enough vinegar to pickling vegetables to prevent bacterial growth.

Pickles are usually made from a mixture of vegetables and fruit. They are eaten as a savoury, spicy accompaniment to a meal. Pickles are preserved by a combination of increased acidity (reduced pH), added salt, reduced moisture and added spices. Pickles can be prepared using one of two main methods:

(a) lactic acid fermentation of vegetables, either with or without the addition of salt

(b) Preservation of vegetables in acetic acid (vinegar). The products made by

these two methods are very different -each one has its own distinctive taste and texture. Vegetables such as cucumber, cabbage, olive and onion are fermented by lactic acid bacteria which can grow in low concentrations of salt. The bacteria ferment sugars in the food to form lactic acid, which then prevents the growth of food poisoning bacteria and moulds. The amount of salt added controls the type and rate of the fermentation. If 2-5% salt is used, the fermentation is carried out by a series of bacteria that produce lactic acid. The pickle is preserved by the high level of acidity. If higher levels of salt are used (up to 16%) the product is preserved by the high salt concentration rather than by fermentation and is known as a salt-stock pickle. Fruit and vegetables can be semi-processed and stored for many months by preserving in a high salt solution. They can be further processed into pickle later in the season. Sometimes sugar is added to increase the rate of fermentation or to make the product sweeter. Pickles prepared by fermentation are not heated, therefore strict attention must be paid to cleanliness and hygiene. The concentration of salt, pH of the mixture and temperature of fermentation must all be controlled to ensure a good fermentation and to prevent the growth of undesirable bacteria. Vegetables pickled in acetic acid (vinegar) have salt and sugar added. They are not fermented and therefore have a different texture flavour.

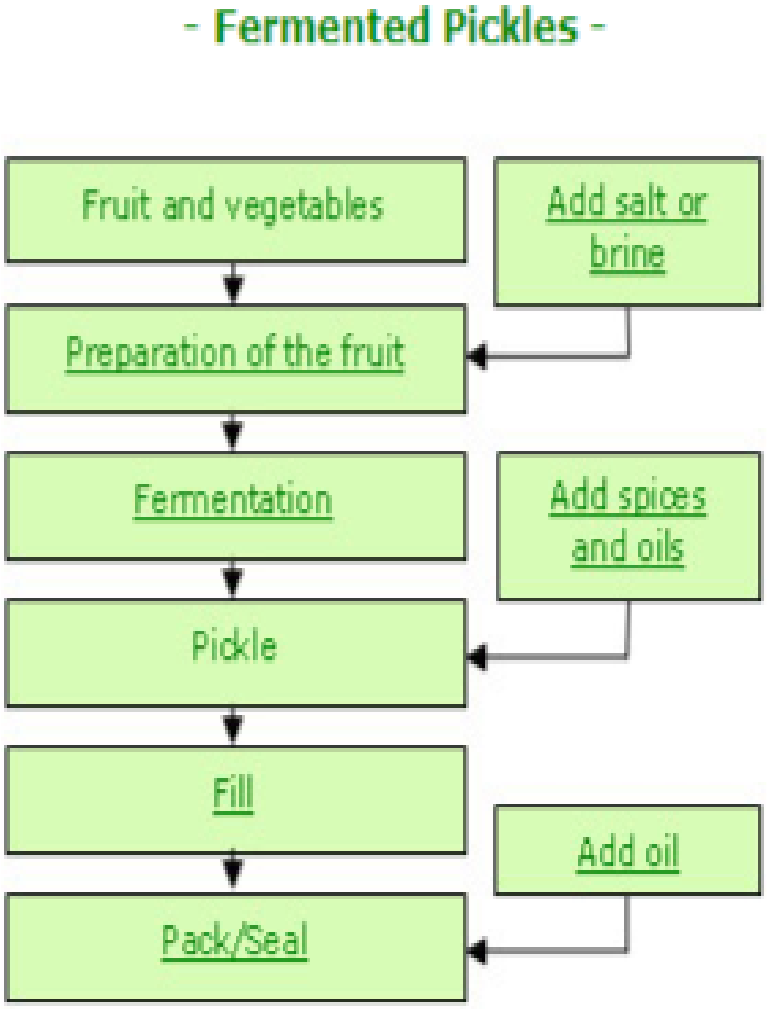

Fig No 3: Flowchart of Vegetable Pickling

Types of Pickles:

Dill pickles:

(1) Fermented dill pickles

(2) Unfermented dill pickles

(3) Pickles made from salt rocks

Sour pickles

(1) Sour pickles including plain sour and slice or hot sour

(2) Mixed sour including spiced or hot mixed and mixed chutney

Sweet pickles

(1) Plain sweet including standard gherkins, slice, chips or wafer

(2) Mixed sweet pickles, plain, mustard.

Methods and recipes of different pickles:

Vinegar pickles are important in foreign countries. These pickles are imported also and onion occupies number one positon in India. Mixed pickles followed by dill, walnut, beetroot, cabbage and all other kind of pickles made from different fruit and vegetables are also imported. The recipes of some pickles are given here.

(A) **Cabbage Pickle:**

For making cabbage pickle, fully mature solid heads are desirable. After the coarse outer leaves are removed, the head is cut first into two, then quarted and again it is cut across. Shreds are placed in a vessel and sprinkled with a thin layer of salt (1 kg salt for 40 kg shreds). After salting the shreds, a wooden board is placed over the whole mass and it is allowed to stand for 24 hrs. Next day, the brine is drained out and the shreds are covered with the spiced vinegar and allowed to stand for another 24 hrs. The shreds are packed into jars, covered with fresh vinegar and jars are sealed.

(B) **Sauerkraut:**

It is the clean, sound product of characteristic flavour, obtained by full fermentation, chiefly lactic of properly prepared and shredded cabbage in the presence of not less than 2% nor more than 3% of salt. It contains, upon completion of the fermentation not less than 1 $^{1/2}$ %of acid expressed as lactic acid.

(C) **Kimchi**

It is a group of fermented vegetable foods of Korea with cabbage or radish as the main ingredient. Cucumbers can also be added. Cabbages are cut and brined in 5 to 7% salt solution for 12hr or in 15% brine for 3 to 7hr. Thereafter, brined cabbage is rinsed and mixed with 10% seasoning ingredients i.e. garlic, green onions, peppers, ginger, mustard, parseley, sesame grains and fermented shrimp. This mixture is allowed to ferment in jars which takes a few days at a temperature of more than 20^0C or 1 month below 10^0C. Kimchi has a pH value of 4- 4.5 and lactic acid content of 0.4 to 0.8%. The main organisms responsible for fermentation of kimchi is *Leuconostoc mesenteroides*

and acidifying microorganism is *Lactobacillus plantarum.*

(D) **Mixed vegetable pickle**

Delicious pickles from carrot, turnip and cabbage can be prepared by using the following recipe. The method for preparing mixed vegetable pickle consists of washing and cutting of vegetables into pieces, blanching by wrapping in muslin cloth and dipping in boiling water for 5-8 minutes followed by immersing in cold water. Then, pieces are spread over a muslin cloth to remove the excessive moisture. Onion, ginger and garlic are fried in oil and jaggery is added when the material turns brown. Vegetable pieces and other ingredients as per the recipe are also added and mixture is heated for 10-15 minutes. Acetic acid or vinegar is added and mixture is heated for 2-3 minutes with continuous stirring and pickle gets ready to be packed in a clean jar.

7. Irradiation

Irradiation is a physical process like drying, freezing, thermal processing (canning and pasteurization) that can be used to disinfest, sterilize and preserve food. It is a cold process and can be used to pasteurize and sterlize foods without causing changes in freshness and texture of food unlike heat. The irradiation process involves passing of food through a radiation field allowing the food to absorb desired radiation energy. The food itself never comes in contact with radioactive material. Three types of ionizing radiation can be used for the treatment of food:

- Gamma rays from Co-60 or Ce-137 with respective energies of 1.33 and 0.67 million electron volts.
- X-rays generated from machine sources operated at a maximum energy of 5 Mev.
- Electrons generated from machine sources operated at a maximum energy of 10 Mev.

Irradiated Vegetables:

- Irradiation is used to reduce post harvest losses. It reduces populations of spoilage micro-organisms in the vegetables and can slow down the speed at which enzymes change the vegetable and therefore slow spoilage and inhibits sprouting in onions, potatoes, garlic, etc. Irradiation at very low levels (0.05- 0.15 KGy) inhibits

sprouting in tubers while cold stored potatoes on removal to ambient temperatures sprout profusely. Low dose of radiation when combined with hot water dip treatment (50-55^{0}C for 5-10 minutes) improve the shelf life as well as the fungal decay in tomatoes.

- Irradiation in the frozen state reduces the chlorophyll degradation in string beans.
- Blanched pumpkins irradiated with doses in the range of about 15- 25 KGy were stable at 22^{0}C with improved flavour and colour.

Other processed products

1. Preserves

Preserves are prepared by addition of sugar and salt, and concentrating them by evaporation to a point where microbial spoilage cannot occur. The principle of preserve making is based on the reduction of water activity and thus creating conditions for lowering down the enzyme activity and inhibition of growth of undesirable micro-organisms. For making amla preserve the fruits are washed and placed in freshly prepared 8% brine for a week, which reduces most of the astringency. The fruits are again washed and blanched in 2% alum solution until they become sufficiently soft. They are then passed through several stages of syruping.

2. Sauces and chutneys

Chutneys and sauces are both pleasant preserves of mainly fruits and vegetables, and are a good accompaniment of Indian as well as continental foods. Both improve the taste of food, stimulate the appetite and enhance digestion. Chutney is basically a mixture containing fruit or vegetable, spices, salt or sugar and vinegar. Sauces are usually made from a mixture containing spices and flavours, however, difference is that, all sauces are sieved and as a result, are thinner and of smoother consistency than chutneys.

3. Sweet potato Ketchup

Sweet potato ketchup consists of 32.3% (w/v) sweet potato, 42% water, 12.9% vinegar, 11.3% sugar, salt, 0.3% spices, and food colouring. The roots are washed, trimmed, chopped into chunks, and boiled. The boiled chunks are blended with water and

other ingredients and boiled to the desired consistency before bottling. Various sweet potato cultivars having cooked flesh colours which range from yellow to orange and a “moist” texture can be used for catsup making. Sweet potato ketchup had viscosity, pH, total soluble solids, and intermediate vitamin A content comparable to values found in banana ketchup. In consumer acceptability tests, sweet potato ketchup was ranked statistically equal to the leading brand of tomato and banana ketchup in terms of colour, consistency, flavor, and general acceptability (Truong et al., 1990). Sweet potato ketchup stored for four months at ambient temperature was given comparable sensory scores to that of freshly prepared samples.

4. Sweet potato jam

The sweet potato jam formula contains 20.7% (w/v) sweet potato, 45% sugar, 34% water, and 0% citric acid and this has proved most acceptable by the trained taste panel compared with other ratio. The initial steps in preparing sweet potato roots are similar to those for sweet potato ketchup. The cooked chunks are blended with water, sugar, citric acid, and optionally with 1.0%flavourings. The slurring is then cooked until total soluble solids of 68° Brix is obtained. Due to the high starch content of sweet potato roots as compared to fruits, the proportions of sweet potato and sugar are different from the standard formula of 45% fruit and 55% sugar in fruit jams.

5. Sweet potato leather

Steamed sweet potato chunks are blended with water, sugar, salt, citric acid, and optionally with artificial fruit flavours in processing sweet potato leather. The slurry is then thinly spread on plastic sheets and dried in a mechanical drier until the desired moisture content and texture of the product are obtained. A loading density of 4 kg slurry per m^2 produced the sweet potato leather which was rated with high sensory scores for thickness, texture, and general acceptability. The product also obtained scores of over 7.0 for colour, sweetness, and sourness on the 9-point hedonic scale. Addition of pectin at 0.05 to 0.15% w/w did not improve the texture of the product. Apparently the pectin content of sweet potato is sufficient to produce a leathery textured product.

6. Beverages

A drink or beverage is a liquid intended for human consumption. In addition to their basic function is thrist quenching property. Common types of drinks include plain water,

milk, juices, coffee, tea, and soft drinks. Vegetable juice is a juice drink made primarily of blended vegetables and also available in the form of powders. Vegetable juice is often mixed with fruits such as apples or grapes to improve flavor. It is often touted as a low-sugar alternative to fruit juice, although some commercial brands of vegetable juices use fruit juices as sweeteners, and may contain large amounts of sodium.

(A) **Sweet potato beverage**

The processing steps for sweet potato beverage involve washing, peeling, trimming to remove damaged parts, steaming, extracting, and formulating with 12% (w/v) sugar, 20% (w/v) citric acid, and 232 mg/L ascorbic acid as vitamin C fortification. The formulated beverage is bottled in 150 ml glass containers and pasteurized at temperature of 90 to 95°C. Various sweet potato varieties were evaluated for their suitability in processing into the beverage. In general, the orange coloured beverage is preferred to other coloured products. Addition of the juice or pulp of different fruits, e.g., guava, pineapple, or Philippine lemon, at concentrations of 0.6 to 2.4% (w/v) significantly improved aroma scores. Similar to jam, incorporation of artificial orange flavouring also enhanced the aroma of sweet potato beverage. More than 85% of consumer respondents rated “like” for the sweet potato beverage, and 96% liked guava-flavoured sweet potato beverage.