Processing of Horticultural Crops

2. Processing of Horticultural Crops (HPT 101) 3 (1+2)

Importance and scope of fruit and vegetable preservation industry in India, food pipe line, losses in post-harvest operations, unit operations in food processing. Principles and guidelines for the location of processing units. Principles and methods of preservation by heat pasteurization, canning, bottling etc. Methods of preparation of juices, squashes, syrups, cordials and fermented beverages. Jam, jelly and marmalade. Preservation by sugar and chemicals, candies, crystallized fruits, preserves chemical preservatives, preservation with salt and vinegar, pickling, chutneys and sauces, tomato and mushrooms, freezing preservation etc. Processing of plantation crops, products, spoilage in processed foods, quality control of processed products, Govt. policy on import and export of processed fruits. Food laws.

Practical: *Equipment used in food processing units. Physico-chemical analysis of fruits and vegetables. Canning of fruits and vegetables, preparation of squash, RTS, cordial, syrup, jam, jelly, marmalade, candies, preserves, chutneys, sauces, pickles (hot and sweet). Dehydration of fruits and vegetables – tomato product dehydration, refrigeration and freezing, cut-out analysis of processed foods. Processing of plantation crops. Visit to processing units.*

Lecture 1 - Importance and Scope of fruit and vegetable preservation in India

Lecture 1 : Importance and Scope of fruit and Vegetable Preservation in India

Objective: This chapter gives an overview of fruit and vegetable production, status of fruit and vegetable processing in the country, objectives and importance of preservation, important constraints in expansion of industry and scope for further growth in this sector.

Introduction

Introduction

Fruits and vegetables are important supplement to the nutritional requirements in the human diet as they provide the essential minerals, vitamins and fiber required for maintaining health. India is the second largest producer of fruits and vegetables in world after China. Huge quantity of produce is wasted due to inadequate facilities for preservation as only 1.5 to 2% of the total produce is processed in the country. Fruit and vegetable preservation is thus one of the major pillars of food industry. The food preservation and processing industry has now become a necessity rather than being a luxury.

Food is the prime necessity of life and can be classified in different groups according to their nutritional value and function in the body.

1. **Energy giving food:** Any food which provides energy is classified as energy giving food. One gram of carbohydrate imparts 4 calorie while 1 g of fat provides 9 calorie of energy, e.g., cereals, roots, tubers, dried fruits, sugar, fat etc.
2. **Body building food:** Foods which are rich in protein are body building foods, e.g., milk, meat, fish, egg are rich in protein of high biological value. Secondly pulses, oil, seeds and nuts etc are rich in proteins. Though, these proteins contain many essential amino acids for synthesis of body tissues yet may not possess all essential amino acids required for the human body.
3. **Protective food:** Foods rich in protein, vitamin and minerals are called protective foods, e.g., milk, egg, green leafy vegetables and fruits. Protective foods are of two types.

- High biological value foods: Foods rich in protein, minerals and vitamin. (e.g., milk) are protective foods of high biological values.
- Low biological value foods: This group includes foods rich in minerals and vitamins but deficient in proteins (e.g., fruit and vegetables, green leafy vegetables). Thus, fruit and vegetables are characterized as the protective foods of low biological value. They are rich source of carbohydrates, dietary fibre, mineral, vitamins, flavonoids etc.

Status of fruits and vegetables in India
Fruits and vegetables are the important category of horticulture crops grown in our country.

- Out of total cropped area of 184 million hectare, horticulture crops cover about 20.7 million hectares (about 11.25% of the total gross cropped area).
- Horticultural crops contribute about 18-20% of the gross value of India's agricultural output.
- India is the largest producer of mango, banana and lime.
- The country produces 41% of world mangoes, 23% banana, 24% cashew nut and accounts for 12% of world fruit production (MOFPI, 2009).
- India is the world's second largest fruit and vegetable producing country accounting for 79.97 million tonnes of fruit and 129.1 million tonnes of vegetables (FAO, 2009).
- Besides, about 5.66 million tonnes of loose flowers, spices, mushroom and aromatic plants are also produced.
- The export of fresh fruit and vegetables from India in 2006-07 was estimated at 9.84 lakh tonnes and valued at Rs 2411.70 crores.
- Mango, grapes, apple, onion, potato, green vegetables like okra, bitter gourd and green chilies are the major items of export.
- India also exported 9.53 lakh tonnes of processed foods comprising of mango pulp, juices, concentrates, dried and processed vegetables, pickle and chutney, alcoholic and non-alcoholic beverages worth Rs 2,757.74 crores (APEDA, 2007) (Table-1.1).

1. Fruits: Owing to wide diversity of agro-climatic conditions, almost all types of fruits are grown in the country.

- Temperate fruits: Apple, pear, peach, plum, apricot, cherries, almond, walnut and other nuts).
- Subtropical fruits: Mango, guava, papaya and citrus etc.
- Tropical fruits: Banana, pineapple, sapota, litchi and grapes etc.
- Arid fruits: Pomegranate, fig, phalsa, ber and aonla etc.
- Plantation crops: Coconut, cashewnut, and arecanut etc.

Table 1.1: Status of horticultural crops, post harvest management and processing in India

2. Vegetables: More than 40 kinds of vegetables are produced in our country. India comprises the prime position in cauliflower, second in onion and third in cabbage in the world. The country produces 36% green peas, 30% cauliflower and 10% onion and thus, accounts for 13% of total vegetable production in the world (MOFPI, 2009).

3. Status of fruit and vegetables processing industry in India
The food processing industry in India accounts for 14% of the total industrial output with 6.3% contribution in the national GDP. The food processing industry plays an important role in the

Indian economy and is establishing as one of the largest sector in terms of production as well as returns. The installed capacity of processing fruit and vegetable in our country from more than 6600 FPO licensed units is about 3.85 million tonnes which is less than 2% of total fruit and vegetable production against 60-83% in many horticultural advanced countries like 60-70% in USA, 70% in Brazil, 78% in Philippines, 80% Saudi Arabia and 83% in Malaysia. Further, the actual production of processed products from these units stood at only 1.33 million tonnes (Table-1.2) which accounts for less than 35% capacity utilization of the installed processing units.

Table 1.2: Quantity of processed fruit and vegetable products in India

Status		**Position in India**
Area[1], m ha	Fruits	9.5
	Vegetables	7.9
	Others	3.3
	Total	**20.7**
Production[1], m tones	Fruits	79.97
	Vegetables	129.1
	Flowers, Spices and Aromatic plants	5.66
	Total	**214.73**
Export	Fresh Fruits/vegetables [2]	9.84 lakh tonnes
	Value[2]	Rs. 2411.70 Crores
	Processed Products[3]	9.53 lakh tonnes
	Value[3]	Rs. 2757.74 Crores
Infrastructure	Cold Store units[4], number	5101
	Storage Capacity[4], m tonnes	21.7
	Processing capacity, m tonnes	3.85
	Actual Production of processed products, m tonnes	1.33
	Capacity utilization, %	Less than 35

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Categorization of different processing units

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The categorization of different processing units in the country indicate that 70% of the total units comprised of home/cottage/small scale sectors having capacity to process up to 250 tonnes/annum, while 30% of the units consisted of large scale sector with a capacity to process about 30 tonnes/hr. However, large scale sector contribute 70% of the total production of processed products in India. Region wise distribution of units in country is comprised of Western 41%, South 28%, North 22% and about 9% in Eastern region. With respect to public and private sectors, about 95% of the total units fall under the private sector and only 0f 5% in different states in India up to the year 2008 (5166 units) is given in Table 1.3. Major products which are prepared in these units includes pulps, juices, concentrates, dried and processed vegetables, pickle, chutney, alcoholic and non-alcholic beverages. The proportion of different products accounts for fruit juices and pulp (27%), ready to serve (RTS) beverages (13%), pickles (12%), jams and jellies (10%), synthetic syrup (8%), squashes (4%), tomato products (4%), canned products (4%) and other products (18%).

During 2007, India exported 9.53 lakh tonnes of processed foods (Table-1.4) comprising of mango pulp, juices, concentrates, dried and processed vegetables, pickle and chutney, alcoholic and non-alcoholic beverages worth Rs 2,757.74 crores (APEDA 2007). As such export value of processed products was higher then that of export value of fresh fruits and vegetables (2411.7 crores) during the same year. Thus there is a good scope for processing of fruit and vegetables in to different products to reduce wastage and earn foreign exchange.

Table 1.3 State-wise categorization of FPO licensed fruit & vegetable processing units in India.

Sr.no	State	Large Scale	Small Scale		Cottage Scale	Home Scale B	Re-labeler	Total
			B	A				
1	Andhra Pradesh	117	19	18	44	54	44	296
2	Arunachal Pradesh	-	-	-	1	1	-	2
3	Assam	7	3	2	7	26	1	46
4	Bihar	6	6	3	7	14	7	43
5	Chandigarh	1	1	3	1	3	1	10
6	Chhattisgarh	1	-	2	-	2	1	6
7	Delhi	6	10	11	36	56	90	209
8	Goa	1	2	2	11	22	4	42
9	Gujarat	77	36	27	63	51	51	305

10	**Haryana**	19	12	29	43	38	25	166
11	**Himachal Pradesh**	15	13	21	31	29	7	116
12	**Jammu & Kashmir**	4	6	12	27	21	7	77
13	Jharkhand	1	5	7	5	6	4	28
14	Karnataka	68	41	36	53	58	72	328
15	Kerala	21	38	42	112	174	58	445
16	Madhya Pradesh	20	13	9	34	30	7	113
17	Maharashtra	123	75	73	236	382	159	1048
18	Manipur	3	3	-	8	1	1	16
19	Meghalaya	-	1	2	4	3	-	10
20	Mizoram	1	1	-	-	1	-	3
23	**Punjab**	24	18	32	65	73	18	230
24	**Rajasthan**	5	12	12	26	43	8	106
25	Sikkim	1	-	-	1	2	-	4
26	Tamil Nadu	113	25	17	109	204	76	544
27	Tripura	3	1	-	-	2	1	7
28	**Uttar Pradesh**	31	25	46	129	212	42	485
29	**Uttaranchal**	17	12	9	29	56	6	129
30	West Bengal	23	20	23	69	128	45	308
31	Andaman Nicobar Island	-	-	1	1	-	-	2
32	Dadar & Nagar Haweli	1	1	1	1	3	-	7

[illegible]

S.No.	Item	2006-07	
		Quantity (,000 MT)	Value (Rs. Crores)
1.	Dried and preserved vegetables	125.7	429.94
2.	Mango Pulp	166.8	509.69
3.	Pickle & Chutney	158.5	250.62
4.	Alcoholic & Non-alcoholic beverages	59.6	338.56
5.	Other processed fruits & vegetables	311.8	754.46
6.	[illegible]	[illegible]	[illegible]

Objectives of fruit and vegetable processing

1. To reduce wastage and losses: Fruit and vegetable industry is the backbone of horticulture industry as it takes care of all possible waste that occurs in spite of improvement in the distribution and marketing of fresh produce.
2. To handle glut: Produce during glut season utilized for making different processed products, thus fruit processing helps in reducing wastage and handling excess produce during glut season.
3. To stabilize farm prices and income: It stabilizes farm price by utilizing the excess produce in value addition to provide additional income to the farmers.
4. To utilize marketable surplus: Processing utilizes marketable surplus as well as cull and deformed produce, to ensure remunerative returns to the growers.
5. To generate employment: Processing of fruits and vegetables being a labour intensive helps to generate both direct and indirect employment for the masses.
6. To add variety to the diet: Value addition/processing make the food more attractive and palatable.
7. To ensure nutritional security.
8. To earn foreign exchange through export of processed fruit and vegetable products.

Major constraints in expansion of food industry

1. Variation in fresh produce quality involving frequent changes in production schedules.
2. Low productivity and high cost of raw material: Low production percent area in our country in comparison to horticulturally advanced countries is one of the major factors leading to high cost of raw material (Table-1.5).
3. Lower quality of raw material (low in soluble solids) in our country leads to requirement of comparatively more raw material for production of equivalent quantity of finished products, thus resulting in higher cost of production (Table 1.5).
4. Non availability of cost effective technologies for processing and packaging of fresh and processed products.
5. Lack of infrastructure for post harvest management, cool chain and cold storages.
6. Non-availability of trained man-power.
7. Low domestic demand of processed fruit and vegetable products due to high cost.
8. Irregular in supply and non-uniform quality of processed products due to variation in raw material quality and use of batch processes.
9. High cost of packaging material, higher taxes and excise duties.
10. Low capacity utilization in food industries.
11. Financial and fiscal constraints.
12. Infra-structural constraints in processing.
13. Inadequate farmer-processor linkage; leading to dependence on intermediataries.
14. Lack of strategies for market promotion.
15. Lack of strategies for utilization of processing industries waste (pomace, peel, core, stones/seed) for value addition.
16. Lack of R&D in food processing sector and its linkage with the food industry.

Fruit/vegetable	Productivity, tones/ha

	India	Abroad
Apple	8	30
Pine apple	10	80
Cauliflower	8	25
Onion	10	30
Potato	12	70
Tomato	15	60
Finished products		
Orange juice concentrate (65^0B)	14	10 (Brazil)
Pineapple juice concentrate (65.14^0B)	16	8 (Philippines, Hawaii)
Tomato Paste (20^0B)	7	4 (Italy)

Table 1.5: Comparison of productivity (tonnes/ha) of import fruits and quantity of raw material required to prepare finished processed product (tonnes/ha) India and Abroad

Prospects for growth of processing industry

In spite of large number of constraints, the prospects for growth of processing industry are very high due to following factors:

1. Increased urbanization.
2. Changing life style and food habits.
3. Increase in purchasing power of the population.
4. Change in consumption pattern.
5. Increased awareness of population about health promoting foods.
6. Increased demand for functional foods, organic foods, convenience foods and diet foods.
7. Expansion of organized food retail.
8. Increase in population of working women having less time for spending in the kitchen. Thus need for processed convenience foods.

Government Initiatives

In order to reduce post harvest losses and expand the food processing industry, the Ministry of Food Processing Industries, government of India, has taken the following initiatives to provide a policy support for the industry.

- Formulation of the National Food Processing Policy
- Complete de-licensing, excluding for alcoholic beverages
- Food processing sector declared as Priority Sector for lending in 1999.
- 100% FDI on automatic route
- Excise duty waived on fruits and vegetables processing from 2000–01
- Income tax holiday for fruits and vegetables processing from 2004–05
- Customs duty reduced on freezer van from 20% to 10% from 2005–06
- Enactment of Food Safety and Standards Act, 2006 which includes all acts and rules pertaining to food such as Fruit Products order (FPO), Prevention of Food Adulteration (PFA) Act, 1954.

SWOT Analysis of food–processing industries in India

I. Strengths

- Abundant availability of raw material
- Priority sector status for agro-processing given by the central Government
- Vast network of manufacturing facilities all over the country
- Vast domestic market

II. Weaknesses

- Low availability of adequate infrastructural facilities
- Lack of adequate quality control and testing methods as per international standards
- Inefficient supply chain due to a large number of intermediaries
- Higher requirement of working capital.
- Inadequately developed linkages between Research organizations and industry.
- Seasonality of raw material

III. Opportunities

- Large crop and material base offering a vast potential for agro processing activities
- Setting of Agri-export zone (AEZ) and food parks for providing added incentive to develop green field projects
- Rising income levels and changing consumption patterns
- Favourable demographic profile and changing lifestyles
- Integration of development in contemporary technologies such as electronics, material science, bio-technology etc. offer vast scope for rapid improvement and progress
- Opening of global markets

IV. Threats

- Affordability and cultural preferences of fresh food
- High inventory carrying cost
- High taxation
- High packaging cost

Thus, keeping in view the availability of diverse raw material (fruit and vegetable), change in life style, rising income, increased urbanization and positive government support, their exists a good potential for expansion of fruit and vegetable processing industry in the country. Establishment of fruit processing units in rural sector shall help in reducing the post harvest losses, develop wide variety of value added products, and utilize by-products of food industry to improve the economic lot of growers, processors and nutritional status of Indian population.

Lecture 2- Food Pipeline: Losses on Post harvest System

Objective: This chapter deals with different stages under which agricultural commodities undergoes different steps right from harvest till consumption. Ideal value chain for horticultural commodities which should be adopted to reduce post harvest losses and ensuring profitable return is also discussed. Important areas of research and development under post harvest management and value addition of horticultural commodities are suggested at the end of the chapter.

Introduction

Food Pipe Line refers to a post harvest system which deals with ensuring the delivery of a crop from the time and place of harvest to the time and place of consumption, with minimum loss, maximum efficiency and returns to all concerned including grower, processors and consumer. The term 'system' represents a dynamic, complex aggregate of locally interconnected functions or operations within a particular sphere of activity. While, the term pipeline refers to the functional succession of various operations but tends to ignore their complex interactions.

Stages of post harvest system

The food commodities broadly undergo different stages/operations of post harvest systems right from harvest till consumption.

1. Harvesting
2. Threshing (food grains, pulses and oilseeds)
3. Drying (food grains, pulses and oilseeds)
4. Transportation and distribution
5. Storage
6. Processing

a) Primary processing (washing/cleaning, sorting, grading, dehulling, pounding, grinding, packaging, soaking, winnowing, drying, sieving, whitening and milling)

b) Secondary Processing (mixing, cooking, drying, frying, moulding, cutting, extrusion product preparation)

7. Product evaluation (quality control, product standardization, standard recipes)
8. Packaging (weighing, labeling, packing/sealing)
9. Marketing (publicity, selling, distribution)
10. Use (recipes elaboration, method of consumption, traditional dishes and new dishes)
11. Consumer preferences (Product-evaluation, consumer education)

Food Pipe line

While undergoing various unit operations of post harvest systems, the quality of produce is affected by action of various biotic and abiotic factors (Fig 2.1).

Fig. 2.1: Food pipe line of agricultural and horticultural crops

Post harvest losses in horticulture crops

- The level of post harvest loss in food grains and perishables are estimated as 10-15% and 25-33% respectively.
- Losses in the value chain: weight loss, bruises, peeling and blanching losses, over ripening, spoilage due to micro-organisms, enzymes, insects and rodents.
- Losses during processing: peeling, trimming, coring, pitting, washing, blanching and heat processing.
- Pilferage during transportation, storage and marketing.
- Losses in food grains: broken grains, excessive trimming, spillage, bruising and leakage.
- Losses due to spoilage caused by moulds, bacteria, rodents, birds, sprouting.
- Polishing and quality losses during marketing.

Unit operations during Post harvest handling

Harvesting: Time of harvesting is determined by the degree of maturity.

- For cereal and pulses, a distinction is made between maturity of stalks (straw), seed pods and seeds with respect to storage and preservation.
- In fruit and vegetables, the maturity indices such as size, development of colour, days from full bloom to harvest (DFFB), degree of ripeness, tenderness in vegetables, starch iodine ratings etc are taken into consideration.
- Harvesting before maturity, increases the risk of loss through moulds and decay.

Pre-Harvest drying: Pre-harvest drying is generally practiced only in case of cereals and pulses. Extended pre harvest drying ensures good preservation.

Sorting, grading and packaging: These operations are used for fruit and vegetables.

- Sorting is done to remove diseased, bruised, rotten, bird eaten fruit or vegetable.
- To select only uniform and healthy produce.
- Grading of produce is then done on the basis of size and colour before packaging.
- Packaging in appropriate containers is done after wrapping individual fruits.

Transport: Collection and initial transportation of the produce depends on the place and condition of grading, packaging and storage space.

- Great care is needed in transporting the produce from orchard to grading and packing house and then to the distant market.
- Storage in godown and cold stores should be done carefully to prevent bruising.
- Over loading and rough handling should be avoided.
- During stacking in the trucks, proper aeration should be provided to the produce.
- Gentle handling is required during loading and unloading of the fresh produce.

Post-harvest drying: Post harvest drying is practiced in case of agricultural crops. The duration of drying of grains depend upon weather and atmosphere conditions during drying in open conditions.

- Drying for a longer time also causes loss thus drying for longer period should be avoided.
- If the grain is not dry enough, it is spoiled by moulds and may rot during storage.
- Moreover, if the grain is too dry, it becomes brittle and can crack after threshing, during hulling and milling.

Winnowing: The broken grains can be removed with the husks during winnowing and are also more susceptible to certain insects (beetles and weevils). Besides, excessive drying leads to loss in weight.

Threshing: If crop is threshed before it is dry enough, this operation will be incomplete. Further, if grain is threshed when it is too damp and immediately heaped up or stored in storage room or bags, it will be much more susceptible to attack from micro-organism, thus limiting its preservation.

Storage: Long term storage space should be adequate, effective and hygienic. In closed structures like granaries, warehouses, cold stores, CA stores, hermatic bins etc, the control of cleanliness, temperature and humidity is particularly important. Damage caused by pests (insects, rodents and moulds) can lead to loss of food value in quality as well as quantity.

Processing: In food grains excessive hulling or threshing can also result in grain losses, for examples hulling of rice can suffer cracks and lesions. The grains not only become unfit for consumption but also become vulnerable to insects such as the rice moth (Corcyra cephalonica). In fruit and vegetables both quantitative and qualitative losses occur during different operations of processing include peeling, trimming, washing and blanching, heat processing, filling and packaging.

Marketing: Marketing is the last operation of post harvest system. Although, produce can be marketed at different points in the agro-food chain particularly from the growing place (orchard), stores, wholesale markets and retail markets. In fresh fruit and vegetables, excessive delays in marketing of the produce at wholesale markets during gluts leads to losses in quantity as well as quality. Thus, the duration between harvesting, storage and marketing should be as short as possible.

Post harvest losses: With respect to agricultural commodities, the loss is defined as a measurable reduction in foodstuffs which may affect either quantity, quality or both. Post harvest losses arise from the fact that freshly harvested agricultural produce is a living entity that breathes and undergoes changes during post harvest handing.

- Loss in form of damage, is the visible sign of deterioration and can only be partial e.g., chewed grain, birds eaten fruit/vegetable etc.
- Damage restricts the use of the product, while loss makes it use impossible.

- Food loss refers to total modification or decrease of food in quantity or quality and makes it unfit for human consumption.

Types of losses
1. Quantitative loss 2. Qualitative loss 3. Direct and indirect loss

1. **Quantitative loss:** It refers to a loss in terms of physical substance i.e. reduction in weight and volume which can be assessed and measured.
2. **Qualitative loss:** It refers to the food and reproductive value of the products. Broadly it includes loss in quality, nutrients, vitamins, appearance, seed viability and commercial loss.
3. **Direct and indirect loss:** Direct losses occur when the disappearance of food stuff is caused by leakage, pilferage or consumption by pests (insects, rodents, birds), loss in weight whereas indirect losses occur when a reduction in quality leads to the consumer's refusal to purchase.

Post harvest losses in horticultural crops
The value chain in post-harvest management of horticultural crops mainly comprise of pre-harvest factors, harvesting, market preparation (pre-cooling, sorting, grading, packaging and on-farm storage), transportation, storage, value addition/processing and by-product waste management (Table 2.1). Factors responsible for post harvest losses in the value chain are discussed as under:

Table 2.1: Ideal value chain for post harvest handling of horticultural crops

Issue	Unit operation	Remarks
Harvesting	Improved cultivars	▪ Cultivars with better attributes, shelf life and suitable for processing
	Cultural practices	▪ Pre-harvest cultural practices like nutrition, irrigation, water sprays helps in uniform colour and size development
	Pre harvest treatments	▪ Pre harvest treatments to increase colour, firmness and improve storage quality.
	Maturity indices for intended use	• Maturity indices for fresh market, short and long distance marketing, storage and processing
	Time of harvesting	• Harvesting during cool hours (evening and early morning) improve storage life
	Harvesting methods and tools (manual/mechanical)	• Mechanical harvesting is suitable for bulk handling
Market preparation	Pre-cooling	• Pre cooling to remove field heat and improve storage quality
	Ripening	• Ripening chamber for mango, banana, papaya etc for uniform ripening and alternative for banned calcium carbide
	Sorting/ trimming	• Sorting/trimming to separate undesirable part and

		to select healthy and uniform produce
	Grading	• Grading with respect to size, colour and quality
	Post harvest treatment	
	• Washing/cleaning	• Washing of fruit/vegetable to remove any dust, dirt or debris on the surface, soil in case of tuber crops.
	• Polishing, waxing, pest or fungus treatments	• Helps to impart shine to the produce, slows down respiration and checks spoilage
	• Coating, SO_2 fumigation ethylene scrubber	• Treatments helps to extend shelf-life by checking respiration, ripening and spoilage
	• Curing	• Extends storage life in onion and potato, etc
	Packaging/wrapping	
	Polyethylene cushioning, wrapping in polypropylene, waxed paper etc	▪ Cushioning/wrapping reduces bruising impact during transportation and also extends storage quality
	Packaging boxes	• Corrugated fibre board box (CFB), wooden box, plastic lined CFB • Reusable plastic crates for processable produce.
	On farm storage	• Storage at the farm and packing house.
Transport	Time of transport	▪ Immediately after harvesting, loading during night (cool hours)
	Loading/stacking	• Load gently to avoid bruising and impact
	Transport with or without refrigeration	• Refrigerated transport is preferred for perishables
Storage	Cold storage, CA storage,	▪ Preferred for better storage quality of perishables
	Zero Energy Cool Chamber	• Suitable for short term storage near farm/orchard
	Handling at destination	• Unload produce at sanitized place to avoid losses
Value addition /Processing	Utilize market surplus	• Processing for manufacture of value added products
	Semi finished products manufacturing	• Raw slices, pulps and juices at growing area/production catchments to reduce losses during transportation and their utilization for finished product manufacturing.
	Drying	• Solar tunnel drier or solar cum gas fired drier for continuous drying and safe storage of dried products to prevent insect damage and spoilage
	Osmotic drying	• Popularization for commercial adoption for selected fruits • Development of method for left over syrup utilization protocol •

	Carbonated juice & beverages	Fruit juice based carbonated beverages from citrus, apple, grapes etc to replace aerated waters
	High flavonoids rich products	• Development of method to utilize peel rich in polyphenols in product manufacture
	Pickling	• Mechanization for adoption at production catchments
	Minimally processed fruits/vegetables	• Development, refinement and popularization of the technology
	Finished products like jam, jelly, candies/preserve, puree, sauce, ketchup, canned and bottled products etc	• Mechanization for commercial adoption at production catchments
	Juices and Beverages	• Juice, squash, ready to serve (RTS) drinks, nectar, appetizers etc
	Concentrated juices/pulps	• Development of protocol and equipment for juice concentration for cottage scale entrepreneurs
	Extruded products	• Development of processes for fruit and vegetable based extruded products
	Fermented products	• Utilization of marketable surplus for preparation of fruit based low alcoholic beverages
By-product and waste utilization	Industrial alcohol, pectin, dietary fibre, oil, starch, candies, vinegar, biocolour, bio-flavonoides	• Utilization of food industries waste and crop residue like pomace, peel, seed/pit and waste for value addition and checking environmental pollution

1. Pre-harvest practices

a. Varietal improvement: Good returns can only be obtained from a good quality raw material and selection of varieties is most essential. In horticultural crops, there is range of genetic variation in composition, quality and post-harvest life potential.

- Selection of carrot and tomato cultivars with comparatively high carotenoid and vitamin A contents.
- Onion and tomato cultivars with high TSS and longer shelf-life.
- Potato cultivars with low sugars.
- Watermelon cultivars with higher sugar content and firmer flesh.
- Spur type apple cultivars with better colour and firmness.
- Grape cultivar with high sugar content.
- Ginger with less fibre.
- Pineapple cultivars with higher content of ascorbic acid, carotenoids and sugars.

Thus, there is a need for development of cultivars for specific traits having longer shelf life and suitability for processing.

b. Cultural practices: Proper nutrition, irrigation prior to harvest and other cultural operations in the field affect the quality of harvested produce.

c. Pre-harvest treatments: Pre-harvest treatments like cultural practices, nutrition, irrigation and chemical sprays of fruit and vegetable in the field affect the post-harvest shelf-life of the commodity. Chemical sprays of fungicides, calcium chloride, bio-pesticides etc used as pre-harvest treatments have been utilized to reduce the post-harvest losses in different fruits.

2. Harvesting

1. Maturity indices: Maturity at harvesting is the most important determinant of storage life and final fruit quality. Fruit picked either pre-mature or too late, are more susceptible to post-harvest physiological disorders and diseases than those picked at proper stage of maturity. Maturity indices developed for mangoes (Dashehari, Chausa, Langra and Mallika), guava, date palm, apple, aonla, Nagpur mandarin, acid lime, sweet oranges, pomegranate, grapes, ber, litchi, capsicum and stone fruits can be used to harvest fruits at optimum maturity. Many leafy vegetables and immature fruit vegetables like cucumber, green beans, peas and okra attains optimum eating quality prior to reaching maturity, but are often harvested late and consequently result in low quality produce.

2. Method of harvesting: The methods of harvesting (manual or mechanical) significantly affect the post-harvest quality of fruits and vegetables. Mechanical injuries (bruising, surface abrasions and cuts) during harvesting can accelerate loss of water and vitamin C resulting in increased susceptibility to decay causing pathogens. Most fresh fruits and vegetables in India are harvested by hand. However, commodities meant for processing like tomatoes and potatoes can be mechanically harvested. Different fruits require different methods of harvesting.

- Mangoes are manually harvested with the use of bamboo poles to which a net is attached and are lowered to the ground in a basket.

Different mechanical harvesters developed for harvesting of fruits are:

- Mango harvester.
- Bael fruit picking platform.
- Strawberry harvester cum holding tool.
- Sapota harvester.
- Semi-mechanized hydraulically operated oil palm harvesting device.
- Ber and jamun fruit harvester along with fruit saver device.

Harvesters of different sizes with respect to economic feasibility and affordability of farmers are required to be developed in view of difficult hilly terrains in most of the fruit growing areas.

Unit operations during Post harvest handling (Contd..)

3. Market preparation

a. Pre-cooling: Immediate cooling of the produce to its optimum storage temperature for removal of field heat is the most effective and well established tool for extending storage life of fresh horticultural perishables. It is now considered as the most accepted treatment but rarely used in actual practice in India.

- Protocols optimized for pre-cooling of mango, apple, banana and stone fruits etc need to be refined further for commercial adoption.
- Packing the produce with crushed or flaked ice to provide rapid cooling along with high RH.
- Keeping produce under shade can also be used in farmers' fields.

b. Ripening: Considerable information exists on the physical and chemical changes that occur during fruit ripening, particularly with respect to polysaccharide hydrolysis and role of ethylene etc.

- Artificial ripening of banana with 500 ppm etheral dip or spray and keeping at 18-20oC has been found to impart uniform ripening in Cavendish group of banana. The treatment appears to be good substitute for smoking or carbide treatment presently practiced by many wholesalers in artificial ripening of mango and banana.
- Ripening in sapota is hastened by the application of etheral, 2, 3, 5-TP and maleic hydrazide.
- Ripening chambers are needed to develop for checking the use of banned chemicals like calcium carbide.
- Very few large scale enterprises use ripening chambers for uniform ripening of banana yet such facilities are beyond the reach of small growers.

c. Sorting/grading: Mostly, manual grading of fruits on the basis of size is done in India. Growers generally employ trained packers who also grade the fruit on the basis of their experience.

- Few mechanical graders developed in the country like expanding belt type grader, mechanized sorting, washing, wax coating and size grading unit for Nagpur mandarin, mosambi and kagzi lime.
- Mechanical grader for black pepper and raw cashewnut.
- Onion halving and spherical fruit grader.
- Mango fruit grader and sapota fruit grader.
- All these graders need to be popularized among the farmers after taking into account their affordability.
- Development of complete packaging line with size grader, de-saping unit, hot water treatment unit, washing, sponging, waxing, dehydration and packaging for mango can be used to reduce losses and to ensure good returns.

d. Post-harvest treatment: Post harvest treatments are applied to fruits before packaging and storage to improve colour, appearance, firmness and to extend the shelf-life. Various post harvest treatments includes:

- SO_2 fumigation of litchi fruits followed by citric acid dip, surface drying and packaging in CFB box for retention of peel colour.
- $CaCl_2$ dip in apple and stone fruits.
- Degreening of citrus fruits.
- Gamma radiation (60-90 Gy) of cured onions to check sprouting.
- Vapour heat treatment, fumigation, bio-pesticide for control of fruit flies in fruits like mango, papaya etc.

e. On-farm storage: On-farm storage is required during gluts and in remote and inaccessible areas in the country. Low cost evaporative cool chambers like zero energy cool chamber, evaporative cooled structures and household evaporative coolers can be used to keep the produce in a good condition for short periods.

f. Packaging: Packaging is an integral element in the marketing of fresh horticultural produce as it provides an essential link between producer and consumer.

- Fruits and vegetables are generally packed in the field without any pre-treatment.
- Some are even transported without any packaging like tomatoes.
- Due to large volumes of non-edible portions of vegetables such as cauliflower, peas etc are transported to wholesale markets from the field.
- Removal of these non-edible portions prior to marketing would reduce both transportation costs and environmental pollution.
- Traditional forms of packaging such as bamboo baskets, wooden baskets and gunny bags for packing of many fruits like citrus, mango, cull apples and vegetables like beans, peas, onion, garlic, okra, potato, etc are widely used.
- Corrugated fibre board boxes are also used for packaging apples, oranges, grapes, stone fruits, sapota etc to reduce load on the forests.

4. Transportation

Almost all horticultural produce are transported in non-refrigerated trucks to distant markets leading to loss in quantity as well as quality. Temperature management during transportation of fresh fruits and vegetables over long distances is critical. Some of the important points needed to be kept in mind during transportation are:

- Loads need to be stacked to enable proper air circulation, in order to facilitate the removal of heat from the produce as well as to dissipate the incoming heat from the atmosphere.
- Simple intervention like immediate transportation of produce after packaging and loading.
- Movement during cool hours preferably during night.
- Optimum stacking provisions for proper aeration in the truck.
- Cushioning to check vibrations impact etc for safe transportation.
- Transportation in refrigerated vehicle can also be used to reduce post harvest losses of highly perishable produce.

5. Storage

Storage losses of fruits and vegetables are high due to large variation in temperature and humidity between growing fields to the place of marketing in case of distant marketing. The lowest temperature that does not cause chilling injury is the idle storage temperature for fresh fruits and vegetables. Optimum refrigerated storage requirement for different fruits have been worked out as 1.7-3.3oC for apples, 12.8oC for banana, 0-1.7oC for grapes, 8.3-10oC for guava, mango & pineapple and 5.5-7.2oC for oranges. When combined with low temperature, controlled or modified atmospheres appreciably retards respiratory activity and delays softening, senescence and changes in quality of stored product.

6. Processing

a. Primary processing: Simple primary processing operations like sorting, trimming, grading, washing, surface drying and packaging can be used to prepare fruit and vegetables for immediate marketing. The available equipment and technologies for various unit operations of primary processing include farm level fruit and vegetable washing machine, basket centrifuge, shrink packaging of fruit and vegetable and hydro cooler-cum-washer for fruits and vegetables, vegetable dryer, tamarind dehuller and deseeder, pomegranate aril remover cumin cleaner-cum-grader, turmeric washing and polishing machine etc.

b. Secondary processing

i) Drying: Drying is the oldest and cheapest method of preservation of horticultural produce. Significant information is available on the use of solar drier for drying of fruits, vegetables, plantation crops and spices. However, medicinal and aromatic plants can be dried in solar drier, poly tunnel solar drier or mechanical drier. Pre-treatments of fruits like peeling, slicing, blanching, sulphuring, etc, are used for preparing fruit and vegetables for drying.

ii) Osmotic dehydration: Osmotic dehydration consisting of partial removal of water by dipping in sugar syrup prior to washing in a mechanical dehydrator is now a standard accepted practice for preparation of intermediate moisture products with acceptable sensory qualities. Some fruits not otherwise fit for drying owing to inherent high acid and astringent taste can also be dried by using this technique. Fruits suitable for osmotic dehydration include pineapple slices, mango slices, banana slices, sapota, apricot, apple and grapes etc.

iii) Processing of lesser utilized fruits: Large quantities of lesser utilized horticultural crops like bael, aonla, jack fruit, aloe vera etc cannot be consumed in fresh form without processing. They are known for many therapeutic/medicinal and nutritive properties. Processing of such crops can play an important role in satisfying the demand for nutritious, delicately flavoured and attractive natural foods of high therapeutic value.

- Bael fruit having hard shell and mucilaginous texture is popularly consumed as a dessert fruit in India.
- Kokum and hill lemon are not acceptable in the fresh form owing to their high acidity, while fresh aonla has a strong astringent taste.
- The products prepared from such fruits include unripe mango drink,(mango pana) high fiber and anti-oxidant rich.
- Cashew apple powder fortified with 2% cereal flour.
- Bael products like ripe bael drink, squash, RTS, (ready to serve) drink jam and jelly, bael dry powder.

- Aonla preserve, candy, shreds, chayawanprash, squash, dehydrated powder, aonla beverages, toffees etc.
- Aloe vera gel and beverages.

iv) Value addition: The fruit and vegetables which can not be sold in the fresh market can be utilized for preparation of different value added products. The value added products include juice, concentrate, fruit based carbonated juices, canning, pulp extraction, pickling, chutney and sauce making, preserves and candies, beverages like squashes, ready to serve (RTS) drinks and appetizer etc from different fruits and vegetables.

v) Fermented products: Production of alcoholic drinks like cider, wine, vermouth, vinegar etc is now an accepted practice for utilization of different fruits.

- Manufacture of champagne (sparkling wine), still wine and brandy from grapes is commercially practiced in the country.
- Other fermented beverages include cider, wine and vermouth from apple, plum, apricot, wild apricot, peach, strawberry, banana etc.

vi) By product waste utilization: Fruit processing plants generate large volume of by-products in the form of pomace, seeds, stones/pits skin, peel which is thrown as a waste. Though such left over produce still contain good proportion of nutrients which can be utilized to prepare large number of value added products for industrial uses.

- Pomace can be used for extraction of pectin, dietary fibre and industrial alcohol.
- Oil extracted from fruit stones/seed left after processing of stone fruits pulp can be used for cooking of foods, pharmaceutical and cosmetic purposes.
- Vinegar extracted from mango peel.
- High fiber containing biscuits from aonla and apple pomace.
- Peel oil, pectin powder, peel candy and animal feed are some of the citrus peel products.
- Oil and fiber from oil palm.

Areas for Research and Development

- Selection and development of improved cultivars for better post-harvest quality.
- Development and adoption of integrated pre and post-harvest treatment protocol (irrigation, water and chemical spray, ethylene management, 1-MCP, fumigation, vapour heat treatment) for different fruit and vegetables.
- Development of protocol for harvesting of produce (maturity indices, time of harvest, method and machineries) for use in different orchard situations.
- Optimization of method for artificial ripening of fruits.
- Development of cost effective mechanical graders (based on size and colour) cum polisher of different size and capacities for different horticultural commodities.
- Optimization of methods for pre-cooling and cool chain handling of horticultural perishables.

- Modification in existing transport vehicle using evaporative cooled system for safe transport of perishables.
- Development and adoption of shrink wrapping/packaging, cushioning and modified atmosphere packaging technology for selected produce.
- Refinement and commercial adoption of evaporative cooled chambers for use in growing areas, retail and whole sale outlets.
- Standardization of post-harvest treatment like irradiation, vapour heat, biopesticides, fumigation etc control of pest and diseases in fresh and stored products.
- Development and integration of protocol for primary processing and market preparation (sorting, grading, washing, surface drying and packaging) of selected fruits, vegetables, medicinal and aromatic plants.
- Standardization of process and equipment for drying of horticultural produce in poly tunnel solar dryer using different modifications like solar, electrical and fuel for uninterrupted drying.
- Establishment of processing units for manufacturing semi-finished products (pulps, slices, raw juices) for their later use in processing industry.
- Development of process and machinery for minimal processing of organically processed products, juice concentrates extruded products, fruit wines, brewed vinegar, flavonoid rich products and health foods from horticultural produce.
- Standardization and adoption of technology for manufacture of pectin, fibre, industrial alcohol, starch, natural colourants and oil extraction from food industries waste (peel, pomace and seed kernels).
- Development of HACCP protocol for fresh and processed horticultural produce.
- Estimation, monitoring and control strategies for pesticide residue, heavy metal and toxins in fresh and processed products for food safety.

Lecture 3- General Principles and methods of food preservation

Objective: In this chapter, the basic principles of food preservation are discussed. Classification of foods on basis of level of perishability in the foods, various methods of food preservation on the basis of these principles has also been discussed in detail. The uses of low temperature, high temperature, use of radiations etc are the important methods elaborated in this chapter.

Introduction

Food preservation can be defined as the science which deals with the process of prevention of decay or spoilage of food thus allowing it to be stored in a safe condition for future use. All foods gradually undergo deterioration or spoilage from the time they are harvested or manufactured. Some commodities spoil rapidly, while others can keep for longer but limited periods.

The basic purposes of food preservation are:
1. Extension of shelf-life of foods thus increasing the supply.
2. Ensuring the availability of seasonal foods throughout the year.
3. Adding variety to the diet.
4. Saving time by reducing preparation time and energy.
5. Stabilizing firm prices and prices of food.
6. Improving the nutritional qualities.

The food spoilage might be due to growth and activity of micro-organisms, insects or rodents, action of enzymes. Chemical reactions and physical changes take place during processing by burning, drying, freezing etc. Depending upon the easiness of spoilage and the level of perishability the foods have been classified into three categories:

1. Non-perishable or relatively stable
2. Semi-perishable or protectable
3. Perishable

1. Non-perishable or relatively stable: The foods that do not spoil easily and can stored for several months unless handled carelessly. They have low moisture content and are not easily susceptible to spoilage by micro-organisms. They include mature food grain, cereals, pulses, nuts, sugar, dry beans etc.

2. Semi-perishable or protectable: These foods can be kept for about a week to a month's time and remain unspoiled for fairly long period with proper care. They contain comparatively much less level of moisture content and also contain certain natural inhibitors to spoilage such as roots, vegetables and eggs. These include potatoes, flours, roasted oil seeds, biscuits, onions, dried fruits and other dehydrated foods. Some other examples of prepared foods are pasteurized milk, smoked fish and pickled vegetables.

3. Perishable foods: the perishable foods are those which deteriorate/spoil quickly after harvesting and cannot be kept for more than a day or two without affecting their quality. These food stuffs have a higher degree of moisture content and are highly susceptible to spoilage. The typical examples of such foods include most fruit and vegetables, milk, meat, fish and poultry

Principles of food preservation

Keeping in view the various causes of deterioration of foods, various methods of food preservation (Table 3.1) have been devised on the basis of following principles:-

1. Prevention or delay of microbial decomposition of food

- By keeping out micro-organisms (asepsis)
- By removal of micro-organisms (filtration)
- By hindering the growth or activity of micro-organisms (use of low temperature, drying, creating anaerobic conditions or using chemicals).
- By killing the micro-organisms (using heat or irradiation).

2. Prevention or delay of self decomposition of food

- By destruction or inactivation of food enzymes (blanching or boiling)
- By prevention or delay of purely chemical reactions (use of antioxidants to prevent oxidation).

3. Prevention of damage by insects, animals, mechanical causes etc (use of fumigants, cushioning, packaging etc).

1. Prevention or delay of microbial decomposition

i) By keeping out micro-organisms (Asepsis): Asepsis refers to keeping out the micro-organisms from the food by making use of either natural covering or providing artificial covering around the food. Natural barrier in foods include outer shell of the nuts (almond, walnut, pecan nut) skin/peel of fruit and vegetables (banana, mango, citrus, ash gourd etc), shells on eggs, skin or fat in meat, husk of ear corn etc. Similarly packaging prevents entry of micro-organisms in the food.
For example peach or mushroom sealed in tin can, clean vessels under hygienic surroundings helps in preventing spoilage of milk during collection and processing by keeping out the micro-organisms.

ii) By removal of micro-organisms (Filtration): Filtration of liquid foods through bacteria proof filters is a common method for complete removal of micro-organisms from the foods. Liquid foods are passed through the filters made of suitable material like asbestos pad, diatomaceous earth, unglazed porcelain etc and allowed to percolate through either with or without nano-filtration etc works on this principle. Centrifugation, sedimentation, trimming and washing etc can also be used but are not very effective.

iii) By hindering the growth and activity of micro-organisms

a. By using low temperature: Microbial growth and enzyme activity is retarded in foods by storing them at low temperatures. The food commodities can be stored under cellar storage (15oC) like root crops, potato, onion refrigerator or chilling temperatures (0-50C) like most fruits and vegetables, meat, poultry, fresh milk and milk products and under freezing temperature (-18oC to -40oC) like frozen peas, mushrooms etc.
b. By drying of food commodity: Removal of water from the food to a level at which micro-organisms fails to grow is an important method of preservation. Moisture can be removed by the application of heat as in sun drying and in mechanical drying or by binding the moisture with addition of sugar (as in jams, jellies) or salt (high salt in raw mangoes) and making it unavailable to the micro-organisms. Examples include osmotic dehydration, dried grapes (raisins), apricots, onion, cauliflower etc.
c. By creating anaerobic conditions: Anaerobic condition can be created by removal or evacuation of air/oxygen from the package, replacement of air by carbon dioxide or inert gas like nitrogen.

- Lack of oxygen prevents growth of any surviving bacteria and their spores under such conditions.
- Production of carbon dioxide during fermentation and its accumulation at the surface makes the conditions anaerobic to prevent the growth of aerobes.
- Carbonation of drinks and storing fresh food under controlled atmospheres serves the same purpose.
- Canned food in which the food is sealed after removal of air (exhausting) illustrates this principle.
- Anaerobic bacteria and their spores present however, need to be killed to prevent the food from being spoiled.
- A layer of oil on top of any food prevents growth of microbes like moulds and yeasts by preventing exposure to air.

d. By use of chemicals: Appropriate quantity of certain chemicals added to the food can hinder the undesirable spoilage in the food by

- Interfering with the cell membrane of the micro-organisms, their enzyme activity or their genetic mechanism
- By acting as an anti-oxidant.
    - The optimum quantity of preservative as per approved regulation need to be used as higher concentrations can be a health hazard.
- Chemical preservatives are benzoic acid and its sodium salt, sorbic acid, potassium meta-bi-sulphite, calcium propionates etc.
- Common antioxidants to check off flavour (rancidity) in edible oils include butyl hydroxy anisole (BHA), butyl hydroxy toluene (BHT), tertiary butyl hydroxy quinone (TBHQ), lecithin etc.
- Addition of organic acids like citric, acetic and lactic acid in the food inhibits the growth of many organisms.

iv) By killing the micro-organisms
a) Use of heat: Coagulation of proteins and inactivation of their metabolic enzymes by

application of heat leads to destruction of micro-organisms present in foods. Exposure of food to high temperature also inactivates the enzymes present in the food. Foods can be heated either at temperature below 100oC (pasteurization) at 100oC (boiling) or at temperature above 1000C (sterilization).

i) Pasteurization (heating below 100oC): It is a mild heat treatment given to the food to kill most pathogenic micro-organisms and is used in the food where drastic heat treatment cause undesirable changes in the food. It is usually supplemented by other methods to prolong shelf life. Pasteurization is most commonly used in treatment of milk and other dairy products either as low temperature long time (LTLT) or high temperature short time (HTST) process.

- Heat treatment of milk at 62.2oC for 30 minutes refers to LTLT process.
- Heating at 72oC for 15 seconds is termed as HTST process.
- Grape wine is pasteurized at 82-85oC for 1 minute and beer is pasteurized at 600C.
- Pasteurization of juices depends upon their acidity and method of packing whether in bulk or in bottle or can.
- Bottled grape juice is pasteurized at 76.70C for 30 minutes while in bulk the juice is heated to 80-85oC for few seconds by flash treatment.
- Carbonated juice is heated at 65.6oC for 30 minutes in bottles and vinegar in bulk is held at 60-65oC for 30 minutes.

ii) Boiling (heating at 100oC): Cooking of food including vegetables, meat etc by boiling with water involves a temperature around 1000C. Boiling of food at 100oC kills all the vegetative cells and spores of yeast and moulds and vegetative cells of bacteria.

- Many foods can be preserved by boiling (e.g. milk).
- Canning of acid fruit and vegetables (tomatoes, pineapple, peaches cherries etc) is carried by boiling at about 100oC.
- Various terms used for heating of food are baking (in bread), simmering (incipient or gentle boiling), roasting (in meat) frying (shallow or deep fat frying) and warming up (small increase in temperature up to 100oC).

iii) Heating above 1000C: Heating by steam under pressure is used to obtain temperature above 1000C by using steam sterilizer or retort. The temperature in the retort increases with increase in steam pressure. The temperature in retort at mean sea level is 100oC; with 5psi pressure at 1090C; with 10psi pressure at 115.5oC and with 1 kg/cm2 (100 Pa) pressure at 121.5oC.

- For canning of mushrooms and other non-acid vegetables the processing temperature of 121.10C at 15 psi pressure are used.
- For sterilization of milk and other liquid foods like juices, ultra high temperature (UHT) process is used.
- In UHT process, the food is heated to very high temperature (1500C) for only few seconds by use of steam injection or steam infusion followed by flash evaporation of the condensed steam and rapid cooling. The process is also used for bulk processing of many foods.

b) Use of radiation: Irradiation consists of exposing the food to either electromagnetic or ionizing radiations to destroy the micro-organisms present in the food. Examples of irradiation include use of ultraviolet lamps in sterilizing slicing knives in bakeries. Gamma (?) radiation from cobalt -60 or cesium 137 source have been used for irradiation of many fruits like papaya, mango and onion, spices, fish etc. They are also used for inhibition of sprouting in onion and potatoes.

2. Prevention or delay of self decomposition of food
i) By destruction or inactivation of food enzymes (blanching or boiling): Blanching is a mild heat treatment given to vegetables before canning, freezing or drying to prevent self decomposition of food by destroying enzymes. Blanching is carried out by dipping the food commodity either in boiling water or by exposing than to steam for few minutes followed by immediate cooling.

ii) By prevention or delay of purely chemical reactions (use of antioxidants to prevent oxidation): Foods containing oils and fat turn rancid and become unfit for consumption due to oxidation. Addition of appropriate quantity of antioxidants like butyl hydroxy anisole (BHA), butyl hydroxyl toluene (BHT), tertiary butyl hydroxy quinone (TBHQ), lecithin etc prevents oxidation and preserves the food.

iii) Prevention of damage by insects, animals, rodents and mechanical causes: Use of fumigants in dried fruits, cereals etc checks the damage caused by insects and rodents. Wrapping of fruits, providing cushioning trays, using light pack and good packaging material checks the damage to fresh food commodities during handling and transportation.

Table 3.1: Methods of food preservation on the basis of food preservation principles.

Physical method

Method
a)By removal of heat (Preservation by low temperature)

Refrigeration, Freezing preservation, dehydro-freezing, carbonation
b. By addition of heat (preservation by high temperature

Pasteurization (LTLT, HTST), sterilization, UHT Processing, microwave.

c. By removal of water

Drying (open sun, solar/poly tunnel solar), Dehydration (mechanical drying), Evaporation/concentration, Freeze concentration, reverse osmosis, freeze drying, foam mat drying and puff drying

d. By Irradiation

UV rays and gamma radiations

e. By non-thermal methods

High pressure processing, pulsed electric fields

Chemical methods

a. By addition of acid (acetic or lactic)

Pickling (vegetable, olive, cucumber, fish, meat)
b. By addition of salt/brine

Salted mango/vegetable slices, salted and cured fish and meat
- i. Dry salting
- ii. Brining

c. By addition of sugar along with heating

Confectionary products like jams, jellies, preserves, candies, marmalades etc.
d. By addition of chemical preservatives.
- i) Use of class II preservatives like Potassium meta-bi- sulphite, sodium benzoate, sorbic acid in food products.
- ii) Use of permitted and harmless substances of microbial origin like tyrosine, resin, niacin as in dairy products.

iii. By fermentation
- i. Alcoholic fermentation (wine, beer)
- ii. Acetic acid fermentation (vinegar)
- iii. Lactic acid fermentation (curd, cheese, pickling of vegetables).

iv. By combination method
- i. Combination of one or more methods for synergistic preservation.
- ii. Pasteurization combined with low temperature preservation.
- iii. Canning: heating combined with packing in sealed container.
- iv. Hurdle technology like low pH, salting, addition of acid, use of sugar, humectant and heating.

Lecture 4 - Unit Operations in Food Processing

Objective: Large number of unit operations /steps is involved in preparation of products from fruit and vegetables. They are broadly categorized as raw material preparation for processing (receiving, sorting, grading, washing, peeling, blanching, slicing, cutting, dicing etc), processing (canning, drying, product manufacture like jam, jelly, preserve, candies, pickling, sauce making, etc) and post harvest handling including packaging and storage. The brief detail about each unit operation is discussed in this chapter.

Types of Unit Operations

1. RAW MATERIAL HANDLING

Material handling include varied operations as hand or mechanical harvesting on the farm, transportation in trucks or refrigerated vehicles of perishable produce to the market or to the processing plant or to store/godowns. For conveying, wide variety of mechanical conveyors is used depending upon the type of material. Common conveyors used in the processing plant include screw conveyor, bucket conveyor, belt conveyor and vibratory conveyor. Throughout these operations care is taken to maintain sanitary conditions, minimizing bruises and product loss, maintaining raw material quality like physical appearance, vitamin contents, minimizing microbial growth and minimizing other detrimental changes to the product quality during handling etc. It also includes other unit operations like receiving, cleaning/washing, sorting, grading, peeling, halving, slicing, blanching etc for preparation of fruit and vegetables for processing.

Raw material selection/receiving

- Fruits and vegetables should be ripe but firm, evenly matured, free from blemishes, insect damage and malformation.
- Harvesting at proper maturity is an important step in selection of raw material.
- Most of the fruits are harvested at soft ripe stage.
- Vegetables except peas, beans etc are harvested at mature stage to enable them to withstand cooking during sterilization.
- Some vegetables like green beans, greens peas, ladies finger should be tender and free from soil, dirt etc.

2. WASHING/CLEANING

Cleaning is the unit operation in which contaminating materials are removed from the food and separated to leave the surface of the food in a suitable condition for further processing. Cleaning can be performed by using:

- Wet procedures: Soaking, spraying, floatation, washing and ultrasonic cleaning.
- Dry procedures: Separation by air, magnetic attraction of metal contaminants or by physical methods depending upon the product and nature of the dirt.
- Fruit and vegetables are generally washed with water to remove dust, dirt and adhering surface micro-flora.
- Fruits like peach, apricot etc that are lye peeled are not washed before peeling.
- Washing after peeling removes vitamins and minerals and should be discouraged.

- Different methods of washing include soaking or agitating in water, washing with cold or hot water sprays etc.
- Mechanical washers involve agitating or tumbling the commodity on moving belts or revolving screens while they are immersed in water or subjected to water sprays.
- Washing by using high pressure sprays is most satisfactory.
- Detergents are frequently used in the wash or rinse water.
- Vegetables may be soaked in dilute solution of potassium permanganate or chlorine (25-50 ppm) for disinfection.

3. SEPARATING

It involve separating a solid from a solid like peeling of potatoes, separating a solid from a liquid as in filtration or a liquid from solid as in pressing of juice from a fruit. It might involve the separation of a liquid from a liquid as in centrifugation of oil from water. It might also involve removing gas from a solid or liquid as in vacuum removal or air from canned food during canning. Common separating methods used in fruit and vegetable processing are discussed as under:

- Sorting: Sorting is the separation of foods into different categories on the basis of a measurable physical property. Sorting and grading ensures the removal of inferior or damaged commodity. For sorting, inspection belt can be used, in addition to trained personnel who detect poor quality produce unsuitable for canning. Automatic colour sorters can be used for sorting to reduce labour cost.
- Grading: After preliminary sorting, the fruit and vegetables are graded to obtain uniform quality with respect to size, colour etc. Grading can be done either manually or with the help of mechanical graders. Different types of mechanical graders include screen grader, roller grader, rope or cable grader, conveyor grader etc.
- Peeling, coring and pitting: These are the primary unit operations for preparing fruit and vegetables for processing.
    - Peeling of fruit and vegetables is carried out to remove unwanted or inedible material and to improve the appearance of the final product.
    - The main consideration for peeling is to minimize cost by removing as little of the underlying food as possible and reducing energy, labour and material cost to a minimum.
    - The peeled surface should be clean and undamaged.
    - Depending upon the commodity, peeling and coring methods can be selected such as 1) hand or knife peeling 2) machine/abrasive peeling 3) flash steam peeling 4) lye (caustic) peeling 5) flame peeling.
    - Cores and pits in fruits like apple, peach, apricot etc are removed by hand or by machine (de-corer).

4. DISINTEGRATING

It covers wide range of operations that are used to sub-divide large masses of foods into smaller units or particles. It may involve cutting, slicing, chopping, grating, pressing to extract juice, pulping, homogenizing etc.

- Slicing, chopping, cutting and dicing: Fruit and vegetables are sliced to a desirable size either manually or by using semi or automatic slicing/chopping or dicing machines. These unit operations are collectively called as size reduction. These unit operations increase the rate of drying, heating, cooling and improve the efficiency and rate of extraction of liquid components like fruit juices.
- Juice extraction: For juice extraction, the fruits and vegetables like apple, pear, carrot, aonla etc are grated in fruit grater to reduce their particle size. The grated mass is then pressed through basket press/hydraulic press to extract juice.
- Homogenization: Homogenization of milk causes disintegration of fat globules in milk or cream from large to minute globules. The smaller fat globules then remain evenly distributed throughout the milk or cream with less tendency to coalesce and separate from the water phase of the milk. Disintegration of fat globules is done by forcing the milk or cream under high pressure through a valve with very small openings. Similarly, fruit juices are homogenized to prevent sedimentation during storage.
- Pulping: For extraction of pulp, the fruits like apple, pear, apricot, guava, plums, tomato etc after preliminary treatment (crushing with or without heating), are passed through the pulper. With the action of blades/flights in the pulper, the fine pulp is forced through the openings of the screen/sieve which is collected at one end, while, seeds, skin and core is forced through other end of the pulper. Depending upon the type of fruit, various types of pulper like baby pulper, tomato pulper, mango pulper etc can be used.

5. PUMPING

This unit operation is used for moving liquids from one processing step to another. Single screw type and gear type pump are used for this purpose.

6. MIXING

There are different types of mixers depending upon the type of material to be mixed. They may be used for mixing solids with solids, liquid with liquids, liquids with solids, gases with liquids etc.

- For simple mixing of dry ingredients, a conical blender may be used.
- A ribbon blender with rotating mixing elements is used to mix sugar with other dry components to produce fluffy dry mix.
- Propeller type agitator mounted within stainless steel vat is used for mixing solids into liquids to dissolve them as in case of salt and sugar solution.

7. HEATING

Heating of foods is carried out to destroy the micro-organisms, to preserve the food as in case of pasteurized milk and canned peas and to make them more tender and palatable as in cooking operations. Foods are heated by conduction, convection, radiation or their combination. Most of the foods are sensitive to heat and prolonged heat may cause burnt flavour, dark colour or nutrition loss. It is therefore desirable to heat such foods rapidly and cool immediately. Foods may be heated or cooked by using hot water toasters, direct steam, direct contact to flame or microwave cookers.

a. Blanching: Treatment of fruit and vegetables by dipping in boiling water or steam for short periods followed by immediate cooling is called blanching. The basic objectives of blanching are:

- Inactivation of enzymes, to cleanse the product initially to decrease the microbial load.
- To preheat the product before processing.
- To soften the tissue for facilitating compact packing in the cans.
- To expel intercellular gases in the raw fruit.
- To prevent excessive pressure built up in the container.
- To allow improved heat transfer during heat processing.
- To ensure development of vacuum in the can and
- To reduce internal can corrosion.

b. Pasteurization: Pasteurization is a relatively mild heat treatment in which the food is heated below 1000C to destroy selected vegetative microbial pathogens or to inactivate enzymes.

- The pasteurization of liquid foods (fruit juices, milk, milk products, liquid egg etc) is carried out in continuous heat exchanger. The product temperature is quickly raised to the pasteurization levels in the first heat exchanger, held for the required length of time in the holding tubes, and quickly cooked in a second heat exchanger.
- For viscous fluids, a swept surface heat exchanges (SSHE) is used to promote faster heat transfer and to prevent surface fouling problems.
- In package pasteurization is similar to conventional thermal processing of foods, but is caused at lower temperatures.
- The extent of heat treatment required to stabilize a food is determined by the D value of the most heat resistant micro-organism or enzyme present in the food.
- Milk pasteurization is based on D60 and a12 logarithmic cycle reduction in the numbers of Coxiella burnetti while liquid whole egg is treated to produce a 9 D reduction in numbers of Salmonella seftenberg. Since colour, flavour and vitamins are also characterized by D values, therefore HTST (High temperature short time) process is used for retention of nutritional and sensory quality.
- In milk processing, the low temperature long time (LTLT) process operating at 630C for 30 minutes (holder process) cause greater changes to flavour and loss to vitamins than HTST processing at 71.80C for 15 seconds.
- Flash pasteurization uses higher temperature and shorter times (HTST) for example 880 C for 1 s, 94 0 C for 0.1 sec or 100 0 C for 0.01 sec. for milk and is known as Higher heat shorter time processing.
- For milk pasteurization, inactivation of alkaline phosphatase is used as indicator of pasteurization.
- Liquid egg pasteurization is based of measurement of a- amylase activity.

c. Processing: Heat processing consists of heating cans to a predetermined time and temperature combination of heating to eliminate all possibilities of microbial spoilage.

- Over cooking should be avoided as it spoils the texture, flavour and appearance of the product.
- In continuous non-agitating cookers, the cans travel in boiling water in crates carried by over-head conveyors on a continuous moving belt.
- In continuous agitating cookers, the sealed cans moving on the belt are rotated by a special mechanical device to agitate the contents of the cans. This helps in reducing the processing time.
- Generally all fruits and acid vegetables can be processed satisfactorily in boiling water (100oC) and non acidic vegetables (except tomato and rhubarb) are processed at higher temperatures of about 115-121oC under pressure.

d. Sterilization: Sterilization is a more severe heat treatment given to a food to destroy both spoilage and pathogenic micro-organisms, after packaging the food in a hermetically sealed container. The thermal processing criterion for acid and medium acid foods (pH<4.5) is the destruction of heat resistant vegetative micro-organisms or enzymes.

- The low acid foods such as mushrooms, potatoes, peas and other vegetables are processed at elevated temperatures (115-1210C).
- Acid foods like peaches, pears, pineapple and other fruits are processed at 1000C or lower for adequate inactivation of enzymes.

Types of Unit Operations (Contd..)

8. COOLING

Cooling is the subtraction of heat energy which is added during processing. The cooling may be done to the degree where food is chilled to refrigerated temperature. The milk is cooled by passing them in thin layers through heat exchangers or through coolers (cold water or refrigerants are pumped). Fruits such as apple slice, berries, and cherries are frozen. Thawing will be done by the unit operations of heating or disintegrating.

- Air blast freezers automatically freeze peas, beans and other vegetables, mushrooms individually.
- Freezing of canned or packaged foods may be done by direct immersion in refrigerants.

9. EVAPORATION

Evaporation in the food industry is used principally to concentrate foods by removal of water. All liquids boil at lower temperature under reduced pressure and are the key to modern evaporation. Vacuum evaporators and multi stage evaporators can easily remove water.

10. DRYING

Drying involves the removal of water with minimum damage to the food. Evaporators will concentrate the food 2-3 folds or more while driers take the foods very close to total dryness that is to 97-98% solids. Driers are used to prepare well known products like milk powder and instant coffee. Subdivision of a liquid is the basic principle behind the widely used spray driers. The liquid is atomized by a spray nozzle and at the same time the hot air is passed, which results into drying. Sun and solar drying, atmospheric dehydration including stationary or batch processes (kiln, tower, and cabinet driers) and continuous processes (tunnel, continuous belt, belt-trough, fluidized-bed, explosion puffing, foam-mat, spray, drum, and microwave-heated driers) are used. Vacuum shelf, vacuum belt, vacuum drum and freeze driers are the type of driers that can be used for drying and dehydration of products. Prior to drying, the fruits are pretreated in sulphur fumigation chambers by burning sulphur or are dipped in a solution of potassium metabisulphite.

11. FORMING

It is an important unit operation in the breakfast cereals and snack food industries. The characteristic shapes of the popular breakfast cereals are the result of pressure extrusion through dies, together with adherence operating conditions like pressure, temperature, dough consistency and other variables. The special kind of forming is known as extrusion cooking. Further examples of forming are shaping of butter, bars, pressing of cheese curd into various shapes, bread dough shapes and shaping of sausages.

12. PACKAGING

The packaging of food is necessarily required to protect the food from microbial contamination, dirt, dust, light, moisture and the losses. The foods are packaged in metal cans, glass, plastic bottles, paper and metallic films, pouches etc. Now a days the packaging of food products has emerged as an important industry and automatic packaging units are in great demand. The containers for packaging are automatically formed, filled and sealed by passing through machines. Such packages are easy to open and dispose off. The newer packaging systems have some advantages like saving of space in food plants, during transportation and marketing. Thus, for preparation of any furnished product, different unit operations are used. Depending upon the availability of facilities, the processing can be carried out as a batch process, semi-continuous process or as an automatic continuous process.

Lecture 5 - Principles and Guidelines for the establishment of processing units

Objective: This chapter deals with importance of plant layout, selection of site for building, categories of processing unit, appropriate combination of fruit and vegetable for manufacture of different products in view of demand.

Introduction

Introduction
For setting up fruit processing plant following cost and non cost factors affecting location of the plant are taken into consideration.

- Cost factors include raw material cost, transportations cost, cost of land, building and machinery, utilities cost, taxes and insurance costs.
- Non-cost factors consists of wages, salaries and incentives, market potential, community attitude, cost regulation, quality of life (school, living, recreation for workers etc) and environmental impact.

The main objective for selection of site for processing unit is to minimize the sum of all costs. To minimize the cost, one should think not only the today's costs, but of long term costs as well.
Plant layout
The advantages of good plant layout are:-

1. Saving in floor space
2. Increased output
3. Fewer production delays
4. Reduced material handling
5. Greater utilization of machine and man power
6. Easier and better supervision
7. Less congestion and confusion
8. Better appearance and more sanitary condition of work areas
9. Reduced risk to health and safety of employees

1. Selection of Site for fruit processing unit
The location of unit is a dominant factor in viability (success or failure) of any processing industry. The following factors are considered in the selection of site for processing unit.

- Easy availability of raw material: Fruit and vegetables should be available in adequate quantity in the locality as they are highly perishable and deteriorate in long distance transportation. Other raw material like fuel, sugar, salt, chemicals etc and miscellaneous hand tools such as nuts, bolts, minor machinery parts etc should also be easily available in the locality.
- The site should be well connected with road.
- Proper transport facilities for movement of raw material and finished products.

- Area should have adequate supply of potable water and electricity (preferably three phase connection).
- Environment should be clean and free from debris, dirt, dust etc.
- The processing industry should preferably be well away from other industries to avoid soot, smoke and disagreeable odour.
- Provision for disposal of processing waste.
- Adequate availability of labour.
- The selected site should have scope for future expansion.

2. Building for processing plant: Following points should be kept in mind for establishment of building for the processing plant.

- It may be single storied or multi storied building. Single storeyed building is sufficient for small unit working for short periods during the year. However, for larger processing plants running throughout the year, multistoried construction is desired. It facilities the movement of raw material and finished products.
- Firm flooring to withstand constant use of water and movement of heavy machinery.
- Slope in flooring (2cm per meter) for proper drainage.
- All doors, windows and ventilators should be provided with fine wire gauge to prevent entry of flies, wasps and other insects.
- The roof of the building should be high and well ventilated to provide outlet for vapours and steam.
- The windows should have large glass panels for sky light and artificial lighting.
- Provision for dressing and toilet rooms separately for male and female workers.

3. Types of plant layout

The layout of a processing plant can be selected on the basis of either product layout or process layout (Fig 5.1). Product layout deals with either single fruit or single product such as apple processing in to juice or jam processing line in which only apple product can be handled.

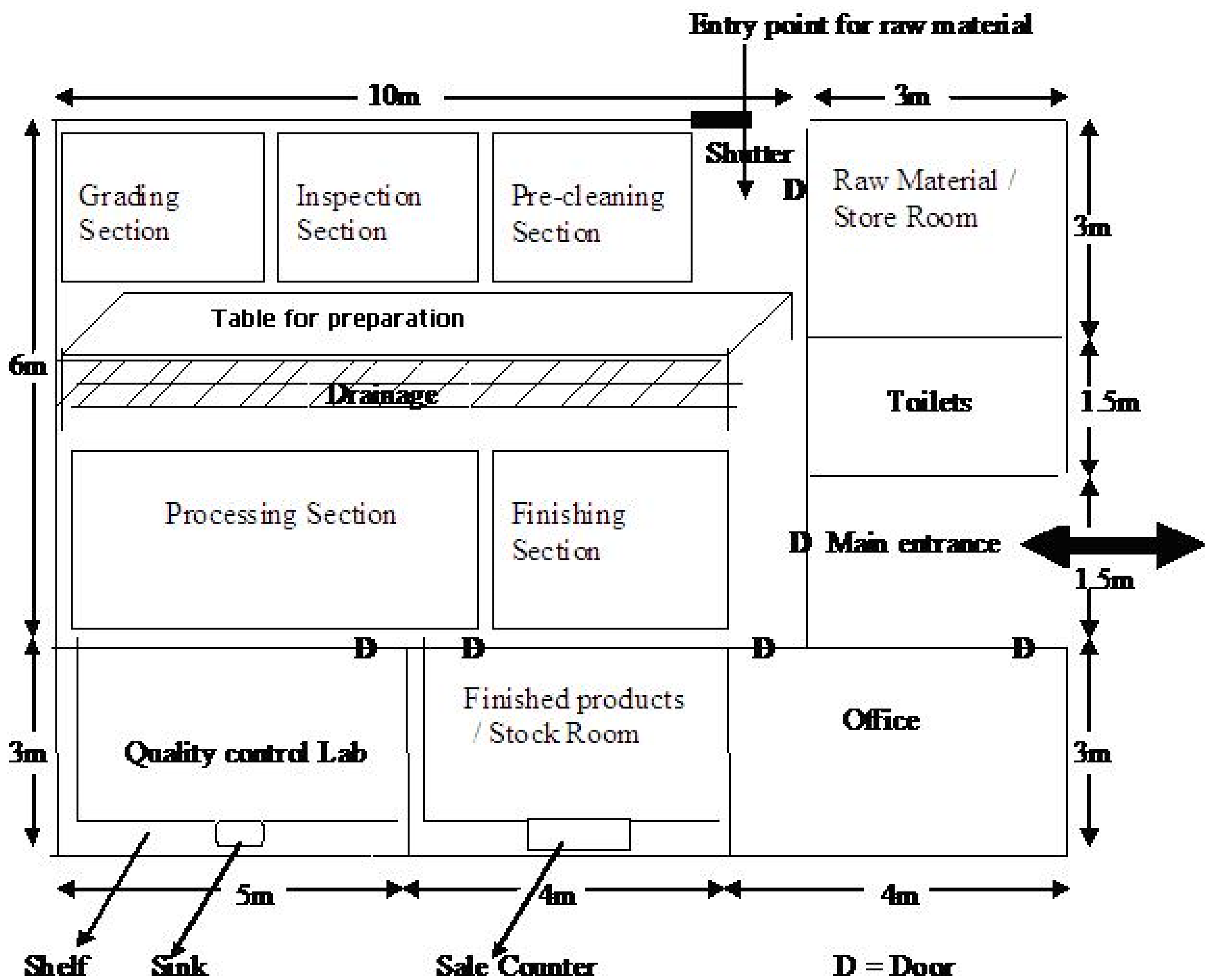
- In product layout, all types of jam, pickle, juice or ketchup can be handled irrespective of fruit.
- In process layout, the machinery dealing with different unit operation is placed separately. For example for extraction of juice, the fruit is washed in washing line, grate in grating machine, pressed in hydraulic press and then juice is filled in filling line and processed in processing line.

Depending upon the size of the unit, the layout can be selected.

4. Water supply and drainage

Water of potable nature should be abundant in supply. If water is not of desired quality there is a need for installing water softening plant.

- A large quantity of water is needed for cleaning of fruits and vegetables, making syrup and brine, washing floors and machinery etc.
- Water system should work at sufficiently high pressure so that supplies can be made to different places without any break.
- The water should not be alkaline or very hard, should be free of organic matter.
- Presence of iron and sulphur make the water unsuitable for making syrups and brines.
- Saline water affects the taste of the products and should be avoided.



4. **Categories of fruit processing units**
   According to Fruit Products Order (1955) of the Govt. of India, the fruit processing units are categorized as under depending upon the installed capacity and requirement of minimum area for processing (Table 5.1).

5. **Table 5.1: Categorization of fruit processing units and requirement of area.**

Sr.No	Category	Annual Production, tonnes	Minimum manufacturing area required, m^2
1.	Home scale(B)	25	25
2	Cottage scale	10-50	60
3.	Small Scale(A)	50-100	100
4.	Small Scale(B)	100-250	150
5.	Large Scale	>250	300
6.	Relabeller	-	-
7.			

Source: www.mofpi.nic.in

Advantages of good plant layout

6. Machinery and equipments: Requirement of machinery and equipments for a Fruit Processing unit depends upon the capacity of the unit and category to which it belongs. Depending upon the requirement of operation, the unit should have following machineries (Table 5.2).

Table 5.2: Machinery and equipment required for different categories of processing units on the basis of unit operations.

Sr.No	Unit Operation	Categories of Unit		
		Cottage scale	Small scale	Large scale
1.	Washing of Raw material and Bottles	· One rectangular tank with false bottom capacity 100 Lts. · One tank of 200 Lts capacity. · Bottle brush and buckets	· Rectangular tanks- 2 · One tank with water taps capacity 200 Lts. · Bottle washing machine · Bottle sterilizing tank · Trolleys for holding and conveying bottle	· 3 rectangular tanks. · 2 tanks with water tap, 450-500 Lts capacity. · Bottle washing machine · Bottle sterilizing tank · Trolleys for holding and conveying bottle.
2.	Preparation of Fruit and Vegetables	· Tables with aluminium or stainless steel (SS) top area 1.86 m^2. · Stainless steel (SS) peeling, slicing, trimming and coring knives. · Stainless steel (SS) pricking forks for preserves. · Vessels for blanching. · Polythene barrels tank with covers for curing. · Stainless steel (SS) trays 5 No's.	· Tables with aluminum or stainless steel top area. 4.65 m^2 · Stainless steel peeling, slicing, trimming and coring knives. · Stainless steel (SS) pricking forks for preserves. · Vessels for blanching · Polythene barrels tanks for curing with covers. · Stainless steel (SS) trays 10 No's.	· Tables with aluminum or stainless steel top area 10 m^2 · Peeling, coring, cutting equipment/ machinery. · Stainless steel (SS) pricking forks, pricking machine for preserves. · Blanching tank with steam. · Polythene barrels/ tanks for curing with covers. · Stainless steel (SS) trays at least 20 (No's)
3	Juice/pulp extraction	· Juice extractor/ basket press/ fruit grater · Stainless steel/ aluminium sieve · Tanks/barrels (45-50 Lts capacity) · Buckets	· Juice extractor/ Rosing machine for citrus fruits · Basket/Hydraulic press, Pulper · Tanks/barrels (200 Lts capacity) · Buckets	· Power driven juice extractor, fruit mill/ grater heavy duty · Hydraulic press, pulper heavy duty · Storage tanks heavy duty 250 lts capacity · Buckets
4.	Heating/Boiling	· Diesel Bhatti/LPG · Heating pan/vessels. · Ladles (SS/wooden) · Thermometer · Refractometer · Sensitive Balance	· Boiler · Steam jacketed kettle · Ladles(SS/wooden) · Thermometer · Refractometer · Sensitive Balance	· Boiler heavy duty. · Steam jacketed kettle. · Ladles(SS/wooden) · Thermometer · Refractometer · Sensitive Balance
5.	Filling/ Bottle Sealing	· Mugs/funnel · Crown corking machine · Rolled on (RO)/ Pilfer Proof (PP) cap sealing machine · Weighing balance	· Mugs/Funnel · Bottle filling machine, automatic crown corking machine · Rolled on (RO)/ Pilfer Proof (PP) cap sealing (Heavy duty · Weighing balance	· Bottle filling machine (vacuum operated) · Automatic crown corking(Heavy duty) · Rolled on (RO)/Pilfer Proof (PP) cap sealing (Heavy duty machine)
6.	Exhausting, Sealing and Processing	· Can reformer · Flanger · Coding machine · Double seamer · Sterilization tanks · Cooling tank pressure cooker/ retort for vegetable processing.	· Can reformer · Flanger · Coding machine · Exhaust box · Double seamer · Semi-automatic retort · Cooling tank · Incubator · Can sterilizer	· Can reformer · Flanger · Coding machine · Exhaust box · Double seamer · Can sterilizer · Retort · Cooling tank · Incubator

6. **Product selection:** Selection of products to be prepared depends upon the market potential and capacity of the processing unit. For the small scale and cottage scale unit manufacturing of single item is not appropriate for viability of the unit. Efforts should be made to regulate the production in such a way that the processing unit runs throughout the year for minimum 200 days of working. While for large scale processing plant handling of single commodity can be practiced since they have assured supply of raw material and assured market for the products. The varieties of products which can be prepared keeping in new the availability of raw material in a processing unit are given in Table 5.3 and 5.4.
7. **Table 5.3: List of different products prepared from fruits and vegetables.**

Products	Fruit and Vegetables
Juice/Beverage/ready to serve drinks	Apple, mango, litchi, kinnow, guava pineapple, grapes, bael juice, based carbonated drink
Squash /Appetizer/cordial	Plum, apricot, litchi, mango, lemon, lime, ginger, pineapple, guava, bael.
Jam/chutney/jelly	Apple, mixed fruit jam, mango, guava, mixed fruit chutney, dry fruit chutney, ginger, pineapple.
Canned products	Peach, pear, pineapple, mango slices/orange segments, mushroom, potato, peas, okra.
Preserve and candies	Aonla, bael, apple, carrot, and petha (ash gourd), ginger, citrus peel candy.(Ash guard)
Pickle	Mango, mushroom, galgal, kagzi lime, mixed vegetable pickle, garlic/ginger.
Sauce/ketchup	Tomato ketchup mixed vegetable sauce and continental sauce.
Dried products	Raisin, dried apricot, triphala, dried date palm.
Instant powder	Instant chutney powder, potato powder, mushroom powder.
Products from medicinal herbs	Brahmi syrup, Rhododendron squash
Alcoholic products	Apple cider, plum wine, fruit wines, peach wine, jack fruit wine, peach wine, jackfruit wine

Table 5.4: Consolidated list of fruit and vegetable products for year-round working of processing unit

S. No.	Period	Fruit/Vegetable	Products
1.	January-April	Citrus fruits like galgal (Hill lemon), kagji lime, oranges, kinnow, guava, papaya, anola, harar and bahera. Vegetables like carrot, cauliflower, turnip, tomato,	Squash, cordial, pickle, candy, marmalade, carbonated drinks. Jelly, toffee, dried products, canned products, Pickle, preserves (Murrabba), candy, candy, tuty-fruity jam drink ketchup, sauce, canned

		peas *etc*	puree, paste, brined vegetable slices.
2.	May-August	Mango, stone fruit like peach, apricot, plum, pineapple, litchi. Tomato, green chilies, olive and brahmi leaves.	Squash, nectar, mango bars/leather (*papad),*canned peach, canned pear, jam, dried apricot, pickle, tomato puree, ketchup, brahmi syrup, apple juice, pickle in oil and brined raw mango slices.
3.	September - December	Galgal, kagzi lime, apple, guava Garlic, ginger, tomato and mushroom	Pickle, candy, squash, cordial, canned mushroom, dried mushroom, chutney, juice, paste, squash, puree, dried ginger (sonth) and ketchup.

8. Viability of a processing unit: Following factors are taken into consideration for making the processing unit a viable enterprise.

- Establishing unit at proper location
- Start with a small capacity and venture into large scale production only after getting experience and good response for the product
- Purchase raw material in bulk as possible
- During harvesting season of fruit and vegetables prepare semi-finished products like pulps, raw juices and slices in bulk keeping in view the demand of finished products for the year
- Explore the possibility of contract farming to get assured the supply of quality raw material
- Working days of processing unit should be increased to atleast 200 in a year.
- Utilize the unit to its maximum installed capacity
- Efforts should be made to utilize each and every part of the fruit and vegetable for minimizing the waste and utilizing it to prepare value added products
- Use most appropriate technology to minimize the cost of production
- Explore new markets for the products and maintain quality of products throughout the production
- Keep in contact with research and development institutions and look for new technologies and products

9. Guidelines for the establishment of Fruit processing unit:

The objective for establishment of fruit processing unit in fruits and vegetable growing areas is to provide processing services to the local growers by utilizing the locally available raw material. The detail about different types of units, machineries & equipments required for the establishment of processing unit along with the approximate expenditure is given in Table 5.5 to 5.7 and discussed as under:

Approximate dimensions for a fruit processing unit:

- Processing hall: 15×10 = 150 m2
- In plant quality control (QC) laboratory: 5×4 = 20 m2

- Raw material store: 4×4 = 16 m2
- Finished products store: 4×4 = 16 m2
- Office: 4×3= 12 m2
- Managers room: 3×3= 9 m2
- Boiler room: 3×3= 9 m2
- Wash rooms: 3×3= 9 m2

Total area = 241 m2 or say 250 m2

Categories:
1. Large Scale: Factories with floor area of 279- 372 m2 with capacity to process products about 250 MT/annum or 2 MT/day. Minimum availability of potable water should be 4.5 kilolitres per day. The factory should have well equipped inplant quality control laboratory of 19 m2 area with adequate analysis facilities.

2. Small Scale: Factories with minimum manufacturing area of 186 m2 (excluding store & office) with capacity to process products 50- 250 MT/annum or up to 2 MT/day. Minimum availability of potable water should be 1.13 kilolitres per day. The factory should have well equipped laboratory with adequate analysis facilities.

3. Cottage Scale: Factories with minimum manufacturing area of 23 m2 to 93 m2 including store and office with capacity to process about 10-50 MT products/annum. Minimum availability of potable water should be 0.45 kilolitres per day. The factory should have well equipped laboratory with adequate analysis facilities.

4. Home Scale: Factories with capacity to process up to 10-50 MT products/annum.

Important points to manage a fruit and vegetable processing unit

- Assure a raw material temporary storage (cold room for sensible raw material).
- Plan the equipment to operate during working shifts (about 7-9 hours per day), for 5 working days per week.
- Plan to operate the processing centre for a maximum number of working days per year).
- Proper investment on buildings and equipment for making unit able to process as many species of fruits and vegetables by using different preservation methods like dehydration, concentration, sugar preservation etc.
- Utilize the available raw materials during crop season by additional manufacturing semi-processed products for later conversion into finished products during the off-season.
- Raw material quality is a major element with positive impact on finished product quality.
- Initial and continuous personnel training and motivation is also an important factor in the success or failure of a processing centre.

The main priorities for marketing should be:

- Finished product quality should confirm specifications and standards set for different products by the national and/or international organizations.

- Continuous and reliable supply of finished products to the domestic and export markets throughout the year.
- Manufacturing and transport costs should be as low as possible.
- Plan to use as much as possible of the raw materials supplied / received to the processing centre.
- Be sure that an export specialized staff/organization will help with specific export advice to export successfully the processed products.

Thus a viable fruit processing unit can be established by taking into account various factors like selection of site, on the basis of available factories, making right selection of the product in view of demand and availability of raw material and making appropriate combination of finished products.

Lecture 6 - Preservation by using Chemicals

Objective: In this chapter, the use of different chemicals for preservation of fruit and vegetable products is discussed. Use of food additives, objective of adding additives, Class I and II preservatives used for chemical preservation and different factors affecting their action along with the mode of action of different preservatives are detailed in the chapter.

Introduction

Introduction

Many chemical substances are added to the food for functional purposes and in many cases these are found to occur naturally in some foods. An additive is defined as a substance or mixture of substances other than basic food ingredient present in a food as a result of any aspect of production, processing or packaging. Additives may be intentional as well as unintentional. Intentional additives are the substances deliberately added with the objective to perform a specific function and to increase the preservation life of products while, unintentional additives have no intended function in the finished product but become part of that particular product. They include preservative, antioxidants, stabilizers, thickening agents, firming agents, sequestrants, clarifying agents etc. The role of different chemicals added to the food is discussed as under:-

Objectives of adding an additive

1. To reduce wastage and improve keeping quality e.g., addition of potassium meta-bi-sulphite in squashes, benzoate in sauces, sodium propionate in bread and sorbic acids in cheese, etc
2. To improve and maintain nutritive elements e.g. addition of vitamins for enrichment, addition of vitamin D to milk, addition of iodine to salt, etc.
3. To enhance quality and consumers acceptability of the product e.g., addition of colouring agents, emulsifier, thickeners etc.
4. To facilitate the preparation of foods e.g., addition of acid to beverage, sugar in jams, jellies, etc.

Classification of food additives: Food additives are broadly classified into following categories:

1. Preservatives	5. Colouring and bleaching agents	9. Flavouring agents
2. Antioxidants	6. Stabilizers & thickeners	10. Anti-caking agents and humectants
3. Sequestrants	7. Buffers & acids	11. Non-nutritive and special dietary sweeteners
4.Surface-active agents	8. Nutrient supplements	

Preservative: Preservative is defined as a substance which when added to food is capable of inhibiting, retarding or arresting the process of fermentation, acidification or other decomposition of food. According to Indian Food Laws, the preservatives are classified into following two classes as Class I and Class II preservatives.

i) Class I preservatives: Class1 preservative broadly include naturally occuring substances and there is no maximum limit specified under law for their use. The common examples of class I preservative are common salt, sugar, dextrose, glucose syrup, spices, vinegar or acetic acid, honey and edible vegetable oils.

ii) Class II preservatives: Class II preservatives are chemical substances added to the food. They include sulphurous acid and salts thereof, benzoic acid and salts thereof, sorbic acid including its Na, K and Ca salts, nitrates or nitrites of Na or K, niacin, sodium and calcium propionates, methyl or propyl parahydroxy-benzoate (parabens), propionic acids including esters or salts and Na, K and Ca salts of lactic acid etc. In fruit and vegetable products generally sulphuric acid and its salts, benzoic acid and its salt and sorbic acid and its salt are used. Class II preservatives being chemical substances have maximum limit beyond which they should not be present in different products. Maximum limit for these substances under FPO (Fruit Products order) in different fruit and vegetable products vary between 40 to 2000 ppm (SO2), 120 to 750 ppm (benzoic acid) and 50 to 500 ppm (sorbic acid) depending upon the type and category of foods. When two or more preservatives are added to the food, their ratio shall be calculated proportionally to their maximum limit.

Factors affecting action of preservatives

Factors affecting action of preservatives

1. Molecular structure: Molecular structure affects the effectiveness of preservative. Out of parabens (p-hydroxy benzoic acid), m-hydroxy benzoic acid and benzoic acid; benzoic acid is more effective than parabens. Esterification of parabens leads to formation of much effective preservatives. So depending upon the requirement, the type of the preservatives can be used.

2. Position of Double Bond: Double bond in a compound in its cis form is more effective than in trans form. For example sorbic acid ($CH_3CH=CH-CH=CHCOOH$) a 2, 4- hexadienoic acid is a strong anti microbial agent since position of double bond is in cis form. With change in position of double bond to trans form the sorbic acid becomes less effective than cis form. Sorbic acid is the safest preservative as it undergoes ß- oxidation and changes to pyruvic acid.

3. Presence or absence of double bond: With the increase in degree of unsaturation, the effectiveness of preservative is increased.

4. Presence or absence of side chain: Straight chain molecules are more effective preservatives than the branched chain molecules.

5. pH of the medium: Acidic pH increases the effectiveness of preservative. For example, benzoic acid at pH 3.5 is 10 times effective than at pH 7. At low pH of 2, the effectiveness is 100 times because at low pH, the un-dissociated molecules of the acid are more and it is the unassociated molecules with create the effect.

6. Solubility: Some of the preservatives are insoluble in their natural form but when converted to their sodium salts, becomes more effective. For example sodium benzoate in place of benzoic acid.
The food additives having significance in fruit and vegetable preservation and their mode of action are discussed as under:

Mode of action of different preservatives

1. Salt: Salt is mostly used as preservative in pickles, raw mango slices, vegetables slices etc. It is used in brines and curing solution or applied directly to food. The minimum concentration of salt to act as preservative is 20%. Salt functions as a preservative through several mechanisms like i) creation of high osmotic pressure, ii) dehydration of food by drawing out water molecules iii) due to harmful effect of chloride ion on organisms iv) reduction in oxygen solubility in moisture v) interference with proteolytic enzymes action.

Mode of action: Salt (NaCl) acts as preservative in food by acting in following ways:

- **Dehydration:** Since sodium stays in its ionic form of Na^+ Cl^-, it attracts H^+ OH^- resulting in a desiccating effect leading to decrease in water availability. Under conditions of non availability of water many of the microbes fail to grow.
- **Effect on cell membranes:** NaCl (salt) increases the permeability of the cell wall and thus cause changes in the permeability. Only the haloduric microorganisms can tolerate these effects while others are unable to survive.
- **Bactericidal effect:** Cl^- (Chlorine) being good oxidizing agent is toxic to micro-organisms.
- **Effect on solubility of oxygen:** Salt affects the solubility of oxygen and thus aerobic micro-organisms cannot grow.
- **Inhibitor of protease enzyme:** Salt (NaCl) acts as inhibitor for protease enzyme system and affects the growth of micro-organisms.

2. Sugar: Sugar is added to many foods for purpose of preservation e.g. jams, jelly, preserves, candies etc. Generally the concentration of sugar in the final products should be above 66% at room temperature to act as preservative.

Mode of action: Sugar act as preservative by increasing the osmotic pressure and binding of water molecules. Due to non availability of water the microbes fail to grow.

3. Sulphur dioxide (SO_2): Sulphur dioxide is the most common class II preservative used in fruit and vegetable products in the form of sulphur dioxide gas and sodium or potassium salts of sulphide, bisulphite or metabisulphite. Dipping of fruit or vegetables in the solution of potassium metabisulphite is known as sulphiting while, using SO_2 fumes by burning sulphur in an enclosed chamber is called as sulphuring. In aqueous solution sulphur dioxide and sulphite salts form sulphurous acid and ions of bisulphite and sulphite.

$SO_2 + H_2O = H_2SO_3$

$2H_2SO_3 = H^+, HSO_3^- + 2H^+, SO_3^{2-}$

Mode of action:

1. Sulphitolysis: SO_2 acts on enzymes to cause sulphitolysis of S-S bonds in the proteins. When S-S bond is broken, the configuration is changed which results in loss of activity of the microbial protein.

SO_2 adds with the aldehyde group: When SO2 adds with the aldehyde group of the carbohydrate, the free CHO group is made limited and spoilage such as browning is stopped.

2. Reaction with thiamine: SO_2 reacts with thiamine and if vitamin B1 is short in foods, the micro-organism requiring vitamin B1 fails to grow.

3. SO_2 reduces oxygen tension resulting in anaerobiosis in the food system.

4. SO_2 reacts with NAD and inhibits many important enzymes and the whole energy processes are reduced.

Factors affecting action of SO_2

Factors affecting action of SO_2:

- Potassium meta-bi-sulphite ($K_2S_2O_5$) is commonly used as a stable source of SO_2. It is a crystalline salt which is fairly stable in neutral or alkaline medium but is discomposed by weak acids like citric, malic, tartaric and carbonic acids. When it is added to the fruit juice or squash, the potassium radical react with the acid of the juice forming the corresponding potassium salt and the sulphur dioxide, which is liberated to form sulphurous acid with the water of the juice.
- Potassium metabisulphite + citric acid= Potassium citrate+SO_2 +water
- $SO_2 + H_2O$ = Sulphurous acid.
- The preservative effect of sulphurous acid depends upon the availability of free sulphurous acid and not the total quantity.
- The presence of glucose, aldehydes, ketoses, pectin and breakdown products of pectin like arabinose present in fruit juices generally combine with sulphur dioxide and reduce its effectiveness as a preservative.
- The effectiveness of sulphur dioxide also depends upon the pH of the medium. Generally preservative action of sulphur dioxide increases with decrease in pH. SO_2 is about 100 times more efficient as a preservative in strongly acidic solutions than in neutral solution. The enhanced antimicrobial effect of sulphur dioxide at low pH is due to the ability of undissociated sulphurous acid to penetrate the cell wall more easily.
- The toxicity of SO_2 increases at higher temperatures.
- Sulphur dioxide is more toxic to moulds, mould spores and vinegar bacteria than to yeast, as such its use in conjunction with sodium benzoate, which is toxic to yeast than to vinegar bacteria is desirable for effective preservation of fruit juices.

Limitations on use of SO_2:

- Though, addition of sulphur dioxide in fruit juices and squashes retards oxidation to prevent discolouration and loss of flavour yet, sulphur dioxide is not used in naturally coloured juices like phalsa, jamun, pomegranate juices, strawberry pulp, rhododendron juice etc due to its bleaching action.
- The use of SO_2 recommended in juices which are packaged in tin containers as it causes pin holes in the containers.
- It also forms hydrogen sulphide to give disagreeable smell and results in formation of black compound with the iron of the base plate. Such coloured products are usually preserved by using sodium benzoate.
- Though, sulphur dioxide and sulphites are metabolized to sulphate and are excreted in the urine without any pathological complications, yet it may cause some reactions in asthmatics

Versatility of sulphur dioxide as a preservative
In comparison to sodium benzoate, the use of sulphur dioxide is preferred in most food products due to following reasons:

- SO_2 has a better preserving action than sodium benzoate against bacterial fermentations.
- SO_2 preserves colour of the beverages for a longer time than sodium benzoate.
- Being a gas, it helps in preserving the surface layer of the juice.
- Being highly soluble in juices and squashes, it mixes well and gives better preservation.
- Any excess of sulphur dioxide in the juices or pulps can be removed either by heating the juice to about 71^0C or by passing through a pulper or subjecting the juice to vacuum.
- Sulphur dioxide inhibits certain enzyme catalyzed reactions like enzymatic browning. Thus, use of sulphite or KMS spray or dips provides effective control of enzymic browning in unpeeled and pre-sliced potatoes, carrots, apples etc.
- Sulphur dioxide is used as effective inhibitor of non enzymatic browning in foods. It is probably involved in bisulphite interactions with active carbonyl groups.

4. Benzoic acid: Benzoic acid is used as a common preservative in many fruits and vegetable products like sauces, tomato ketchup, pickles, coloured squashes, carbonated beverages, sauerkraut etc. The antimicrobial activity is attributed to the presence of undissociated acid which exhibits optimum activity in the pH range of 2.5 to 4. Since sodium salt of benzoic acid is more soluble in water than the acid form, sodium benzoate is commonly used in the foods. One part of sodium benzoate is soluble in 1.8 parts of water while only 0.34 parts of benzoic acid dissolves in 100 parts of water. Pure sodium benzoate is practically tasteless and odourless. It is most effective against yeasts and bacteria and least active against moulds. It does not stop lactic acid and vinegar fermentations. The effectiveness of sodium benzoate depends upon the acidity of the medium in which it is added. At lower pH the effectiveness is increased. At pH 3.5, the benzoic acid is 10 times effective than at neutral medium, while at pH 2 the effectiveness is increased to 100 times. The preservative action of benzoic acid increases in presence of carbon

dioxide. For example Bacillus subtilis fails to survive in benzoic acid solution in the presence of carbon dioxide.
Mode of action: Benzoic acid inhibits the activity of decarboxylase enzymes which are essential for TCA cycle. With effect on TCA cycle, microbial growth is hindered. Benzoic acid changes the nature of cell membrane and affects the O_2 uptake. This causes anaerobiosis by checking the exchange of gases and increase of CO_2. Benzoic acid in optimum concentration does not cause any harmful effect as it is readily excreted from the body after conjugation with glycine to form hippuric acid.

5. Parabens (p-hydroxy benzoic acid): Parabens are non dissociating compounds and their anti microbial action is independent of pH as such they are far superior to benzoic acid. The parabens (p-hydroxy benzoic acid) are used as microbial preservative in baked goods, soft drinks, pickles, jams, jellies and syrups. They are effective against moulds and yeast and relatively ineffective against bacteria (gram negative bacteria).
Anti-microbial action of parabens increases with increase in length of alkyl chain. Parabens link to some extent to the proteins on account of their phenolic groups and thus proteins get inactivated. Further, parabens interfere in folic acid metabolism of microorganisms which is a growth factor. Parabens being structural analogue hinders fatty acid metabolism. Parabens are active at pH 7 and higher, due to their ability to remain undissociated at these pH values. The presence of ester linkage in parabens remains stable to hydrolysis even at higher temperatures used for sterilization.

6. Nitrates and Nitrites: K and Na salt of nitrates and nitrites are used in curing of meat to develop and fix colour, to check growth of micro-organisms and to develop characteristic flavour. Nitrite in meat form nitric oxide, which reacts with hemi compounds to form nitroso-myoglobin (pigment responsible for pink colour of cured meat). Nitrite is effective at pH 5-5.5 than at higher pH values. Nitrite is known to react with sulfhydral groups (-SH) to create compounds that are not metabolized by microorganisms under anaerobic conditions.

7. Sorbic acid: Na and K salts of sorbic acid (C-C=C-C=C-COOH) are used to inhibit growth of moulds and yeast in many food products like fruit juices, pickles, cheese etc. The sorbic acid is used directly in foods and as spray or dip coatings on packaging materials. The activity of sorbic acid increases with decrease in pH indicating that undissociated form is more effective up to pH 6.5. They inhibit the growth of yeasts and mould but are less effective against bacteria. Sorbic acid is the safest preservative.

8. Propionic acid: Na and Ca salts of propionic acid (CH_3-CH_2-COOH) are used as effective antimicrobials against mould and few bacteria in cheese and bakery products. It checks ropiness in bread caused by Bacillus mesentericus. The undissociated form of propionic acid is effective up to pH 5. The toxicity to mould and certain bacteria is related to the inability of these micro-organisms to metabolize the 3- carbon skeleton. In human beings, propionic acid is metabolized in a manner similar to other fatty acids and as such does not cause any toxic effect when used within the recommended limits.

9. Acetic acid: Acetic acid is used in a various food products like sauces, ketchups, pickles etc. in form of vinegar to serve as dual functions of inhibiting micro- organisms and contributing to flavour. It is used in various forms such as vinegar (4% acetic acid), glacial acetic acid and sodium, potassium and calcium acetate as well as sodium di-acetate. It is more effective against yeasts and bacteria than against moulds. The salts are used in bread and other baked products to prevent ropiness and growth of moulds without interfering with the activity of yeast. The antimicrobial activity of acetic acid increases with the decrease in pH.

10. Epoxides: Ethylene oxide and propylene oxides are used as chemical sterilants in low moisture foods and to sterilize aseptic packaging materials. They are used in vapour state to achieve intimate contact with micro- organisms and after exposure the residual unreacted epoxide is removed by flushing and evacuation. Epoxides are reactive cyclic ethers that destroy all forms of microbes including spores and even viruses. Ethylene oxide is more reactive than propylene oxide and is more volatile and flammable as such it is supplied as a mixture of 10% ethylene oxide and 90% carbon dioxide.

11. Antibiotics: Antibiotics like nisin, subtilin, tetracycline, oxytetracycline, etc are the metabolites secreted by micro organisms which have selective antimicrobial activity. Nisin - a poly peptide antibiotic is effective against gram-positive organisms, is used to prevent spoilage in dairy products including processed cheese and condensed milk. Nisin is generally non toxic to humans as it is degraded in the intestinal tract without causing any harm.

12. Antioxidants: These are the substances which can delay the onset or slow the rate of oxidation of auto-oxidizable materials. Common antioxidants are BHA (Butylated hydroxy anisole), BHT (Butylated hydroxy toluene), TBHQ (tertiary butyl hydroquinone), PG (Propyle gallate), Tocopherols (Vitamin E) and Ascorbic acid (Vitamin C). The maximum limit of antioxidant used in food is 0.02%. Antioxidants donate proton and act as free radical trap.

$R^* + O_2 = RO_2^*$

$RO_2^* + RH = R^* + ROOH$

13. Colouring agents: Two types of colouring agents (natural and synthetic) are used in the foods to improve the consumer appeal of the product. Natural colourants include carotenoids, chlorophyll, riboflavin, caramel, saffron etc. While, synthetic colourants are coal tar dyes which include tartrazine, sunset yellow, carmosine, amaranth, erythrosine fast red, etc. The maximum limit of use of synthetic colourants in fruit and vegetable products is 0.02% under Prevention of Food Adulteration Act (PFA).

14. Acid alkali control agents: Common acid-alkali agents used in most food products are citric acid, malic acid, lactic acid, tartaric acid, vinegar and sodium bicarbonate etc.

15. Sesquestrants or chelating agents: They are used for food stabilization by reacting with metallic ions and alkaline earth ions to form complexes that alter the properties of the ions and their effects in foods. Common chelating agents used in food industry are polycarboxylic acids (citric, malic, oxalic, succinic acid etc), polyphosphoric acids (adenosine tri phosphate, pyro-phosphate), macro molecules (porphyrin, protein) and salts of ethylene diamine-tetra-acetic acid (EDTA).

16. Emulsifiers: Emulsifiers are used for promoting foaming, whipping as well as stabilizations of foams in certain foods. Common emulsifiers include lecithin (in cake mixes),), stearyl-2-lactate (in confectionary products), mono and di-glycerides (to promote foaming and whipping), etc.

17. Stabilizers and thickeners: These are used for their textural, structural and functional characteristics in foods to stabilize emulsions, suspensions and foams and for thickening properties. Stabilizers and thickeners are hydrophilic and are dispersed in solutions as colloids, and are therefore also called as hydrocolloids. They also help in improving and stabilizing texture, inhibition of sugar and ice crystallization, and encapsulation of flavours. These are used in ice cream, jams, jellies, soups and preparation of foam mat dried products. Examples of stabilizers and thickeners are carboxy-methyl-cellulose (CMC), starch, gelatin, carageenan, agar, pectin, gum arabic and guar gum etc.

18. Firming agents: The substances used to prevent softening of fruit and vegetables tissues caused during heat processing or freezing are called as firming agents. Pectic substances are generally involved in structure stabilization through cross linking of their free carboxylic groups via polyvalent cations. Addition of calcium salts increases the firmness by cross linking with the carboxylic groups to form calcium pectinate and pectate. These stabilized structures support the tissue mass and thus the integrity is maintained even after heat processing. Similarly, trivalent aluminum ions are involved in crisping process through formation of complexes with pectic substances. The firmness in tomatoes, berries, apple slices etc is maintained by adding calcium salts prior to canning or freezing. Commonly used calcium salts are calcium chloride, calcium citrate, calcium sulphate, calcium lactate and mono calcium phosphate. Besides, acidic alum salts, sodium aluminum sulphate, potassium aluminum sulphate, ammonium aluminum sulphate and aluminum sulphate are also used to provide crisp and firm texture in fermented and brined cucumbers and other vegetables.

19. Clarifying agents: Formation of haze, sedimentation and oxidative deterioration due to action of natural phenolics are common problems encountered during storage of fruit wines, beer and many fruit beverages. Clarifying agents are generally used to control the desirable and undesirable effects of polyphenolics. Diatomaceous earth is used as filter aid to remove preformed haze. Bentonite is selective adsorbent used as clarifying/fining agent for wines to preclude precipitation. Clarifying agents having selective affinity for tannins, pro anthocyanidins and other polyphenols include proteins and synthetic resins like polyamides and polyvinyl pyrolidone (PVP). Gelatin and isinglass are proteins used to clarify beverages. The linkage between tannins and protein involves hydrogen bonding between phenolic hydroxyl groups and amide bonds in proteins. The addition of gelatin to apple juice causes aggregation and precipitation of a gelatin-tannin complex, which on settling enmeshes and removes other suspended solids.

20. Miscellaneous additives: Other chemicals used as an aid in food preservation include leavening agents, bleaching agents, anti caking agents, aerating agents and enzymes etc. Chlorine and hypochlorite of calcium and sodium are used for treatment of drinking and process water. Phosphoric acid is used in some soft drinks. Borax is used to wash vegetables and whole fruits like oranges.

a. Bleaching agents: Benzyl peroxide, Cl_2, ClO_2, NaCl, NO_2, $KBrO_3$, KIO_3, Ca $(IO_3)_2$, CaO are examples of some bleaching agents.

b. Anti-caking agents: Several conditioning agents are used to maintain free flowing characteristic of granular and powdered foods that are hydroscopic in nature. e.g., calcium silicate, calcium phosphate.

c. Aerating agents: Use of CO_2 in beverage like beer, carbonated fruit juices and aerated waters, N_2, N_2O in baby foods and baby milk are examples of some aerating agents.

Lecture 7 - Canning and bottling of fruit and Vegetables

Objective: This chapter gives an overview of the canning process for fruits and vegetables, history of canning, canning operations including reforming, flanging, seaming etc and the main steps involved in canning, different peeling methods, blanching, exhausting and sterilization methods along with specific requirements for canning of fruits and vegetables.

Introduction

Introduction
The term canning refers to a process which involves heating food stuff in hermetically sealed containers for a specific time at specific temperature to eliminate microbial pathogens that endanger public health and micro-organisms as well as enzymes that deteriorate food during storage.

History of canning: Important historical developments in canning are as under:

- The credit for invention of canning goes to Nicholas Appert, a French confectioner who was awarded a prize in 1809 by the French government for developing new method of heat preservation of food in sealed container and after whose name the process of canning is known as Appertization.
- In year 1810, Appert published the first book on canning entitled "The Art of Preserving Animal and vegetable substances for many years" which is the first known work on canning.
- The work of Appert consists of packing food in glass bottles, closing with corks and heating the container in boiling water for several minutes depending upon the type of the food.
- In 1810, Peter Durand got first British Patent on canning of foods in tin or metal containers.
- In 1813, Doukin, Hall and Gamble introduced the practice of post processing incubation of canned foods.
- In 1825 T Kensett and E Duggett were granted US patent for preserving food in cans.
- In 1825, Thomas Kenett, an American developed first kettle pan.
- 1837 Winshow was first to can corn from cob.
- 1839 Tin cans came into wide use in limited states.
- 1845 S. Elliott introduced canning in Australia.
- Louis Pasteur (1864) discovered that food spoilage was caused by micro-organisms which were destroyed at elevated temperature and technique was known as Pasteurization. This understanding helped to form a scientific basis for establishing and revolutionizing the canning industry.
- 1873 Andrew Shriver developed first retort pressure cooker.
- 1890 Max Ann developed first double seaming machine.
- 1895 Russel made first bacteriological study of canning.
- 1916 Bitting gave the index of processing time and temperature relationships for food products.

- 1920 Ball, a mathematician developed mathematical calculation for heat sterilization.
- 1921 Magoon and Culpepper, horticulturist by trade, gave idea of exhausting and vacuumin processed products.
- 1928 Heat process calculations were completed for the canning industry.
- The civil war in America and later the Boer war and the Great European war of 1914 with their enormous requirement of foods for the fighting forces gave a further impetus to the canning industry.

Presently large quantity of fruit, vegetables, meat, sauces, and confectionary products are preserved by canning. There is a great scope for the development of canning industry as it is one of the processes which does not involve the use of any chemical in preservation.

Manufacturing of cans: Metal cans are mainly used in the national and international trade for canning of fruits and vegetables. Open top sanitary (OTS) cans are made from tin plates which are very thin sheets of steel lightly coated with tin (0.00025 cm thick) on both sides. Tin can is cut into proper sizes with a trimming and slitting machine. The pieces provide body blanks. After notching and slitting, the flat can body is passed through an edging machine where hooks are formed. The can body is then bent into a cylindrical shape and side seam is soldered. These operations are carried in the can manufacturing factory. Now the cans are supplied in the flattened form to the users to lower the packing and transportation costs. The can ends are supplied separately along with the cans.

During preparation of can, the first step consists of reforming the cans in can reformer to give them a cylindrical shape. The cans are then flanged by using a flanger, which curls the rims/edges outward at each end. One end of the can is now fixed to the flanged can body by means of a double seaming machine which firstly form the seam and secondly tightens it. The finished cans are now tested for any leaks with the help of a vacuum/air pressure tester. Finally, after the filling of the cans with fruits or vegetables the second lid (end cover) after coding is fixed similarly for airtight sealing of cans.

ixed similarly for airtight sealing of cans.

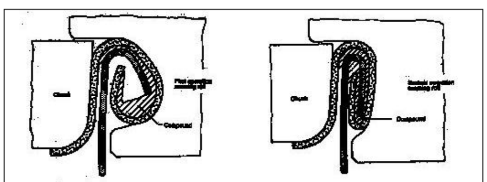


Figure 7.1: Cross section of the seam after the first operation and second operation (Courtesy of Standards Association of Australia.)

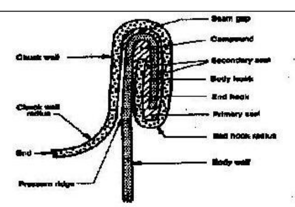


Figure 7.2: Cross-section of a double seam away from the side seam (Courtesy of Standards Association of Australia.)

The empty can after placing lid on both the sides can be tested for any leakage by using empty can tester. For testing, the probe of empty can tester is sealed empty can to which air is pumped to about 15-20 psi. Any leakage is judged by immersing can in water. In case of any leakage, the defect in the double seamer needs to be rectified before starting any production. Different sizes of the cans used in canning are showed in Table-7.1.

Table7.1: Trade name and sizes of cans used in canning of fruits and vegetables.

Trade name	Trade size	Size mm
A1	211×400	68×102
1 lb jam	301×309	78×90
A1 tall	301×411	78×119
A2	307×408	87×114
1 lb butter	401×212	103×70
2 lb jam	401×400	103×102
A 2 1/2	401×411	103×119
7 lb jam	603×513	157×148
A10	603×700	157×178

Canning of fruits and Vegetables

Fruit and vegetables are canned in the season when the raw material is available in plenty. Canned products are sold in off season and fetch better returns to the grower as well as processor. The canning of fruit and vegetables broadly involves the following steps (Fig. 7.3).

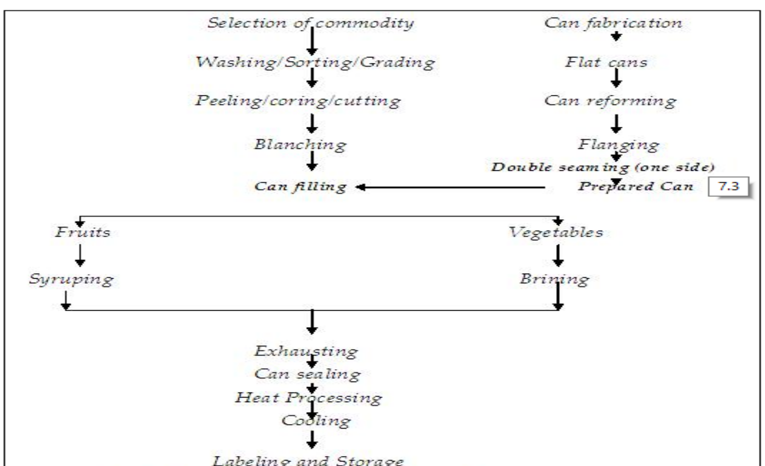


Figure 7.1: Flow sheet for canning of fruits and vegetables

Steps involved in canning of fruits and Vegetables

Steps involved in canning of fruits and vegetables

1. Preparation of fruit and vegetables: Preparation of food commodity for canning consists of washing, sorting, grading, peeling, halving, blanching etc.

2. Raw material selection/receiving: For canning, fruits should be ripe but firm, evenly matured, free from blemishes, insect damage and malformation. Thus, harvesting at proper maturity is an important step in selection of raw material for canning.

- Most fruits are harvested at soft ripe stage. However, apple, pear, peach and banana harvested at mature stage are preferred for canning.
- Over ripe fruits yield poor quality product, while under ripe/immature fruit generally shrivel or toughen on canning.
- Vegetables except peas, beans etc are harvested at mature stage to enable them to withstand cooking during sterilization.
- Vegetables like green beans, green peas, ladies finger should be tender and free from soil, dirt etc.
- Tomatoes should however, be firm, fully ripe and uniformly deep red in colour.

The specific requirements for canning of fruits and vegetables are given under Table 7.2 and 7.3.

Table 7.2 Specific requirement for canning of fruits

Table 7.2 Specific requirement for canning of fruits

Fruits	Preparation	Syrup Strength (°B)	Exhaust	Processing time at 100°C A2½ can) minutes	Type of can
Apricot	Use whole or halves, peel by dipping in boiling lye solution (2% NaOH) for 30 seconds to 1 minute, dip in cold water, cut two halves, remove pit, keep immersed in 2%salt solution until filled in can.	40 + 0.1 % citric acid	Exhaust can at 82-100°C for 6-10 minutes or until temperature in can center reaches 79°C.	20-25	Plain
Peach	Use whole fruit ,peel by dipping in boiling lye solution (2% (NaOH) for 30 seconds to 1 … keep immersed in 2% salt solution until filled in can.	40	-do-	25	Plain
Banana	Peel, cut in to slices 12mm thick	30	-do-	25	plain
Grape fruit	Dip fruit in hot water at 93°C-96°C for 3-5 minutes, remove skin. Dip the peeled whole fruit in 2% hot lye, wash and separate the segments, fill segments in can.	60	Exhaust can at 82-87°C for 25-30 minutes or until temperature at center of can reaches 79°C.	30-40	Plain
Guava	Peel, cut into pieces, remove seeds and keep in 2% brine to prevent browning and fill in can.	40	-do-	20	plain
Litchi	Peel by hand, remove pits.	40+0.5% citric acid	-do-	25	plain

	punch circular rings (5.6-8.8 cm diameter)				
Pear	Peel by hand, cut longitudinally into two halves, core and keep in 2% brine to prevent browning until filled in cans.	40+0.1%citric acid	-do-	20-25	plain
Jack fruit	Cut fruit into pieces, remove bulbs, separate seed from bulbs, use whole, halves or quarters.	50 + 0.5-0.75% citric acid	-do-	20-25	plain
Loquat	Cut into halves	40	-do-	25	plain
Mango	Peel ,cut into slice, dip in 2% salt solution until filled in can.	40+0.3%citric acid	-do-	25	plain
Papaya	Peel, cut into slices, discard seed	45+ 0.5% citric acid	-do-	25	plain

Table 7.3 Specific requirement for canning of vegetables.

Vegetable	Preparation	Brine strength (%)	Exhaust	Processing (A2½ can) at 121°C (0.7 kg/cm² steam pressure)	Type of can
Asparagus	Wash, grade, cut lengthwise into pieces of desired size, blanch for 2-3 min.	2.25%	Exhaust can at 90-100°C for 7-10 minutes, (79°C in can center)	24	Plain /sulphur resistant
Beans	Use tender, stringless beans, slice 2.5cm length, blanch and fill in can.	2.25	-do-	40	Plain/ sulphur resistant
Cabbage	Shred cabbage, blanch in 1% citric acid boiling solution for 5-6 min.	2.0	-do-	40	Plain

	brine prevents discolouration fill in cans				
Cauliflower	-do-	2	-do-	20	Plain
Carrot	Wash, scrape and blanch for 5-10 minutes in boiling water	2	-do-	25	Plain
Mushroom	Use tight buttons, blanch for 4-5 minutes, immerse in 2% salt solution, fill in cans.	2.0+ 0.3 % citric acid+ 1% sugar	-do-	25	Plain
Peas	Shell, grade, boil for 3-5 min	2+2.5% sugar	-do-	45	Sulphur resistant
Potato	Peel, keep in 2% brine, blanch in boiling water for 2-3 min, keep in 2.5% $CaCl_2$ for 1 hour, wash and fill in cans.	2	-do-	45	Plain
Okra	Tender whole, blanch in boiling water	2 or in tomato sauce	-do-	35	Plain

	minutes, immerse in 2% salt solution, fill in cans.	1% sugar			
Peas	Shell, grade, boil for 3-5 min	2+2.5% sugar	-do-	45	Sulphur resistant
Potato	Peel, keep in 2% brine, blanch in boiling water for 2-3 min, keep in 2.5% $CaCl_2$ for 1 hour, wash and fill in cans.	2	-do-	45	Plain
Okra	Tender whole, blanch in boiling water for 1-2 minutes, cool in brine solution of 1-2% for 10 minutes, fill in can.	2 or in tomato sauce	-do-	35	Plain

Steps involved in canning of fruits and Vegetables (Contd..)

3. Washing: Fruit and vegetables are generally washed with water to remove dust, dirt and adhering surface micro-flora. Fruits like peach, apricot etc are lye peeled so not washed before peeling. On the other hand, washing after peeling removes vitamins and minerals and should be discouraged. Different methods of washing include soaking or agitating in water, washing with cold or hot water sprays etc.

- Mechanical washers involve agitating or tumbling the commodity on moving belts or revolving screens while they are immersed in water or subjected to water sprays.

- Washing by using high pressure sprays is most satisfactory.
- Detergents are frequently used in the wash or rinse water.
- Vegetables may be soaked in dilute solution of potassium permanganate or chlorine (25-50 ppm) for disinfection.
- The water temperature should be kept low to keep the fruit firm and to reduce leaching losses.
- High pressure sprays should not injure the fruits.

Bacteria and other contaminants can accumulate in the wash water and hence appropriate cleaning and chlorination practices be followed.

4. Sorting and grading: Sorting and grading ensures the removal of inferior or damaged commodity. For sorting, inspection belt can be used, in addition to trained personnel who detect poor quality produce unsuitable for canning.

- Automatic colour sorters can be used for sorting to reduce labour cost.
- The fruit and vegetables are graded to obtain uniform quality with respect to size, colour etc. after preliminary sorting.
- Grading can be done either manually or with the help of grading machines.
- For mechanical grading, the fruit and vegetables are passed over screens with holes of different diameter.
- Different types of mechanical graders include screen grader, roller grader, rope or cable grader etc. Screen graders fitted with vibrating screens of copper with circular openings are most commonly used. A set of six screens is generally provided to accommodate different sizes.
- Soft and berry fruits are generally graded manually.
- Plums, cherries and olives are graded whole while peaches, apricot, pears, mangoes etc are graded after cutting them into halves or slices for canning.
- White button mushrooms are graded on cap size basis. Only healthy and light buttons with cap diameter up to 2.5cm and compact head are graded as A grade while, cap diameter beyond 2.5cm as B grade.

5. Peeling, coring and pitting: These are the primary unit operations for preparing fruit and vegetables for canning. Depending upon the type of commodity, peeling and coring methods are selected such as (1) by hand or knife (2) by machine (3) by heat treatment (4) by using lye solution. Cores and pits in fruits like apple, peach, apricot etc are removed by hand or by machine (de-corer).

Typical examples of different methods of peeling fruit and vegetables are given in the Table-7.4.

a) Peeling by hand: Many fruit and vegetables are peeled and cut by hand with the help of peeling knives. The peeling knife with a curved blade and a special guard to regulate the depth of peeling can be used for uniform peeling in case of irregular fruit shapes.

Table-7.4: Common methods for the peeling of fruit and vegetables

S.No.	Peeling method	Commodity
1.	Knife peeling (manual)	All fruit and vegetables
2.	Mechanical knife peeling	Apple, pear, pineapple
3	Hot water peeling	Tomato
4	High pressure steam/water peeling	Potato, tomato
5	Abrasive peeling	Potato, ginger, carrots
6	Flame peeling	Brinjal, onion, garlic
7	Lye peeling	Orange segments, peach, apricot, nectarines, pears.

b) Mechanical peeling: Mechanical peeling, coring and cubing machines are used for peeling pears, apples, carrots, turnip, potatoes etc. Similarly, automatic peelers are used for peeling of peaches and cherries.

c) Mechanical /Knife peeling: Mechanical knife peelers are used for peeling of fruits like apples and pears. In mechanical knife peeler either stationary blades are pressed against surface of rotating food commodity or the rotating blades are pressed against the stationary food to remove the skin.

d) Abrasive peeling: It is used for peeling potatoes, ginger, carrots etc. The food commodity is fed on to the carborundum rollers or placed into a rotating bowl which is lined with carborundum crystal acting as abrasive surface. With the continuous supply of water, the rotating abrasive surface removes the skin from the surface of the food.

e) Flame peeling: Flame peeling is used in onions, garlic and brinjal. The peeler consists of a conveyor belt which carries and rotates food through a furnace heated to more than 1000oC. The outer layer and root hairs of onion are burnt off and charred skin is removed manually.

f) Peeling by heat or hot water: In this method peaches and potatoes are scalded in steam or boiling water to soften and loosen skin, which is subsequently removed manually. Infra-red heat peeling can also be used for peeling of apples and tomatoes.

g) Flash steam peeling: In flash-steam peeling, the fruit and vegetables are fed into a slow rotating (4-6 rpm) pressure vessel. High pressure steam (1500 kPa) is then introduced into the rotating vessel to expose all food surfaces to the steam for specified period depending upon the type of fruit. When the pressure is instantly released, the steam formed under the skin causes the surface of the food to flashes off. Most of the peeled material is discharged with the steam and finishing is done with additional water sprays to remove any skin traces.

h) Lye peeling: Lye is an boiling aqueous solution of caustic soda (Sodium hydroxide) or Potassium hydroxide (1-2%) used in conjunction with ample water supply and heat source for peeling. Fruit and vegetables like peaches, nectarines, apricot, sweet orange segments, carrots and sweet potatoes are peeled by dipping them in boiling caustic soda (1-2%) for 1-2 minutes (depending upon the strength of lye, temperature/maturity and nature of fruit or vegetable) followed by dipping in cold water. The hot lye loosens the skin from the flesh underneath which is removed by gentle rubbing of fruit by hand. The fruit can also be dipped in a dilute solution of hydrochloric acid or citric acid for few seconds to neutralize the alkali. The method is very quick and efficient to reduce wastage and peeling cost. The effectiveness of lye peeling depends upon lye concentration and temperature, product holding time and agitation.

- Lye peeling equipment varies from simple stainless steel (SS) pan for lye solution with SS baskets as cages for holding the food commodity to fully automatic system.
- In cottage and small scale canning units, the peeling system consists of three SS tanks attached in series, the one of which is having provision for steam, the second tank contain dilute solution of citric acid or hydrochloric acid while the third is filled with tap water.
- The fruit or vegetables placed in perforated SS crates/ basket or cage are dipped in the first tank which contains boiling hot lye solution. After 1-2 minute of dipping treatment, the crates are immediately dipped in second tank to neutralize the lye and final washing is carried out in third tank.

6. Cutting/halving/ slicing: After peeling, the fruits are halved or cored either manually or mechanically. However, peeled fruit should always be kept submerged in either water, containing 1-2 % salt solution or acid to avoid enzymatic browning. Peaches, apricot, pears, tomatoes etc are peeled before canning. However, the fruits which are canned retain better nutrients as compared to peeled fruits.

7. Blanching: Treatment of fruit and vegetables with boiling water or steam for short periods followed by immediate cooling prior to canning is called blanching. The basic objectives of blanching are as under:

- To inactivate enzymes
- To clean the product initially to decrease the microbial load and to preheat the product before processing
- To soften the tissue to facilitate compact packing in the can
- To expel intracellular gases in the raw fruit to prevent excessive pressure built up in the container.
- To allow improved heat transfer during heat processing
- To ensure development of vacuum in the can and to reduce internal can corrosion.

Blanching is carried out either by hot water or using live steam. Water blanching is generally of the immersion type or spray type as the product moves on a conveyer. Only soft water should be used for blanching as hard water toughens the tissue and destroys the natural texture.

8. Prevention of browning: Some fruits which cannot be blanched due to their delicate tissue structure are treated with some chemicals to prevent oxidative browning, occurring due to exposure to oxygen during peeling and slicing. Oxidative browning is caused by action of oxidase enzyme with catechol and tannins and is common in peach, apple, potato, mushroom, cherry, apricot, grapes and persimmon. Pineapple, tomato and melons are however not prone to browning. Common methods used to prevent browning are as under:

- **Sulphite treatment:** Fruits are dipped in a solution containing 2000-4000 ppm SO2 for 2-5 minutes. SO2 fumigation can also be used commonly for grapes dehydration.
- **Acids:** Common acids used to increase acidity include citric, fumaric, tartaric, acetic, phosphoric etc. Low pH of solution is known to act as inhibitor for enzyme polyphenol oxidase thus inhibits the browning of fruits. The peeled fruits, slices or cut surfaces are dipped in a 1-2 % citric acid solution to prevent browning.
- **Antioxidants:** Ascorbic acid is commonly used as an antioxidant in most canned fruits. It acts as an inhibitor of peroxidase in some fruits like kiwi fruit. It also reduces quinones, which are generated by polyphenol oxidase upon oxidation of polyphenols to phenolic compounds thus preventing their conversion to brown pigments. Ascorbic acid can be used as such or mixed in dry sugar, citric acid or in syrups.
- **Sugars:** Sugar syrup is used to prevent browning in peeled and sliced fruits by inhibiting oxidation by partially excluding air in the tissues. Sugar is mixed with ascorbic acid and citric acid as an effective agent against loss of texture, colour and flavour. Addition of chitosan in filtered apple and pear juices also prevents enzymatic browning.
- **Salt:** Dipping of peeled and sliced fruit and vegetables in 1-2% salt solution also prevent enzymatic browning, as salt acts as inhibitor for polyphenol oxidase.

9. Filling in cans: Tin cans are washed in hot water or in steam jet to remove any adhering dust or foreign matter. The cans are then sterilized by dipping in hot water tank or the cans are passed through a steam sterilizing tunnel before use. Generally plain cans are used however, for coloured fruits like plums, black grapes; strawberries etc lacquered cans are employed. The fruit and vegetable either slices, halves or whole are filled into the cans keeping in view the declared drain weight.

10. Syruping or brining: The cans are filled with hot sugar syrup (35-55%) for fruits and with hot brine (2-10%) concentration for vegetables. The purpose of syruping or brining is to help in transfer of heat within the food pieces during processing. It also improves the taste of the canned product, fill up the inter-space between the fruit or vegetables in the can. The syrup or brine is added to the can at a temperature of 79-820C, leaving 0.32-0.47cm head space either manually or in automatic machines. In automatic machines, the prepared syrup or brine is drawn into the cans through a horizontal pipe having a row of small holes. The cans travel on a continuous belt in an inclined position below the syrup or brine pipe and get filled, the overflowing excess syrup is pumped back into the syrup tank by a centrifugal pump.

11. Exhausting: Exhausting is a unit operation in which practically all air from the contents in the can is removed before sealing. The purpose of exhausting and creation of vacuum is to create an anaerobic environment in the can that would inhibit microbial spoilage. The removal of air from the contents also reduces the risk of corrosion and pin holing of the tin plate and discoloration of can contents. Exhausting helps in better retention of vitamin C. Expansion and shriveling of contents during heating help to avoid over filling or under filling of the can. (Corn and peas expand on boiling in brine while strawberries shrivel upon heating in sugar syrup). The vacuum in can prevents bulging of the can during storage at higher attitudes or in hot climate. It also prevents excessive pressure and strain during sterilization.

Methods of exhausting: There are generally three methods of exhausting the cans to remove headspace gas and creation of vacuum.

a) Heat/thermal exhausting: Heat exhausting is used in cans. The can covered with the lid or loosely sealed or clinched is passed through a tank of hot water at about 82-87oC or on a moving belt through a covered steam box. In water exhaust box, the cans are placed in such a manner that the level of water is 1.3-2.5 cm below their tops. The time of exhausting varies from 5 to 25 minutes depending upon the nature of the product. At the end of the exhausting, the temperature at the centre of the can should be about 79oC. During exhausting, the steam replaces the air inside the can and it is sealed while still hot.

b) Steam flow or steam-vacuum closing: In this system, high steam pressure is injected into the can headspace (at 100oC for 5-8 minutes) just prior to closing. Thus, all the air inside the can is quickly replaced with steam, which will condense and form vacuum following seaming. Steam vacuum closure coupled with hot fill, assures very high vacuum in the can.

c) Mechanical vacuum sealing: In high speed mechanical vacuum sealing, the cans filled with the product and covering syrup or brine, are passed through a clincher that clinches the cans (first operation roll seam) but does not form an airtight seal. The cans are subjected to a vacuum for a short period of time to remove the free headspace air but not all dissolved gases within the product. However, during this process some syrup may be drawn along with the dissolved air. To avoid syrup spillage, a pre-vacuumizing step before vacuum closing is recommended. High vacuum closing is also used in case of glass jars where the jar is placed in a closed chamber in which high vacuum is maintained.

12. Seaming/closing: Immediately after exhausting, the cans are sealed by using a double seamer. Double seaming is a two step operation. In the first operation, the can lid is inserted on the can body hook by holding and rotating the lid-in-position can between two rollers. This operation is called as clinching; during which first operation roller gently guides the lid in the body hook. The next step is to press the seam using the second operation roller, which results in an appropriate overlap of the body hook and cover hook which results in an appropriate countersink. Between the cover hook and body hook lies a layer of sealing compound which ensures the sealing process. The critical parameters for an ideal hermetic seam are body hook, cover hook, seam thickness, seam width and overlap which need to be carefully controlled to prevent leakage in the can.
Immediate closing of the cans is required to prevent excessive cooking of the surface of the product. Double seamers are of different designs and capacities like hand operated, semi-automatic and fully automatic. Modern double seamers operate at high speeds (300 cans per minute) while liquid products are sealed in cans at speed of up to 1600 per minute.

13. Coding/Embossing: Coding of lid of the can is essential to identify the can, once it is closed. The code provides the necessary information about the product like name of canning unit, product packed in the can, date of packing; lot number etc. Coding is done on the second lid (end cover) of the can just before sealing.

14. Heat processing: The cans after sealing are immediately transferred to the heating retorts to achieve sterilization of contents. Heat processing consists of heating cans to a predetermined time and temperature of heating to eliminate all possibilities of microbial spoilage. Over cooking should be avoided as it spoils the texture, flavour and appearance of the product. Generally all fruits and acid vegetables can be processed satisfactorily in boiling water (100oC) as the presence of acid retards the growth of bacteria and their spores. While non acidic vegetables (except tomato and rhubarb) are processed at higher temperatures of about 115-121oC under pressure. It needs to be ensured that required temperature reach the centre of the can. The temperature at the centre of the can should be maintained for sufficiently long period to destroy spores of more heat resistant bacteria.

Processing methods: Processing methods differ with the kind of fruit and vegetables to be processed. The cans containing most fruit and acid vegetables (pH < 4.5) are heated in open cookers, continuous non-agitating cookers and continuous agitating cookers.

- Open cooker consists of stainless steel (SS) or galvanized iron tanks to which perforated water pipes are placed underneath the false bottom to supply the steam for heating of water. The sealed cans are placed in SS or GI crates and immersed in the tank containing boiling water.
- In continuous non-agitating cookers, the cans travel in boiling water in crates carried by over-head conveyors on a continuous moving belt.
- While in continuous agitating cookers, the sealed cans while moving on the belt are rotated by a special mechanical device to agitate the contents of the cans. This helps in reducing the processing time.
- For low acid foods like vegetables (pH > 4.5), with hard texture, the processing is carried out in a pressurized vessel (retorts) at elevated temperatures (= 110oC) under higher steam pressure (2-3 atmospheres). The retorts vary in shape and size (horizontal or vertical), type of operation (batch to continuous, non-agitating to agitating) and with different types of heating media such as water, steam, steam/air or flame.
- In small scale canning units, vertical stationary retorts are generally used. They are made of cast iron cylinders and are fitted with a lid which can be bottled steam tight. They are provided with steam and water feeds, drain cock, safety valve, pressure gauge and thermometers.

Factors affecting Sterilization

Factors effecting sterilization

- **Altitude:** As boiling point of the water decreases with the increase in altitude, the processing time for a particular product standardized at sea level should be increased with the increase in altitude.
  - For every increase of 152 meters above mean sea level (a.m.s.l.) in altitude, the boiling point of water decrease by about 1oC and normal processing time has to be increased by about two minutes.
  - Similarly, as the altitude above mean sea level increases, the pressure required to maintain the specified processing temperature also increases.

- It is necessary to maintain higher gauge pressure if processing is carried out at altitude greater than 305 meter a.m.s.l. (1000 ft a.m.s.l.).

- **pH:** Inherent pH value of the food commodity greatly influence the processing schedule to achieve required destruction of micro-organisms. The lower the pH, the greater is the ease with which a product can be processed or sterilized. On the basis of pH, the foods are classified into following four distinct classes:

i) Low acid foods (pH = 5.0): The low acid foods is the class of foods which require greater care in its preservation as they are subjected to spoilage by thermophilic and mesophilic putrefactive anaerobes including Clostridium botulinum. These foods include most of the vegetables like peas, beans, corn, asparagus, mushroom and corn etc. They are necessarily required to be processed above 110^{o}C temperature and under steam pressure.

ii) Medium acid foods (pH 5.0-4.5): Medium acid foods like meat and vegetable mixtures, spaghetti, soups and sauces also need processing above 110^{o}C under steam pressure. They are subjected to spoilage by thermophilic and mesophilic anaerobes. They also include thermophilic anaerobes not producing hydrogen sulphide but causing flat sours.

iii) Acidic foods (pH 4.5-3.7): Most of the fruits including peas, fig, pineapple, nectarines, mango, apple, tomato, subject to spoilage by non spore forming aciduric, butyric anaerobe like Clostridium pasteurinum and thermophilic anaerobe are classified as acidic foods. They can be processed in boiling water at temperature of 100^{o}C.

iv) Highly acidic foods (pH = 3.7): Highly acidic foods like Sauerkraut, berries, citrus juices, grapefruit, rhubarb and pickles are included in this group. As the bacterial spores do not germinate and grow at pH values below 4.5 and do not harm the product even if they are not destroyed in canned fruits. A canned product having pH value of less than 4.5, can be processed in boiling water at 100^{o}C, but a product with a pH value above 4.5 requires processing at 115-121^{o}C under pressure of 0.7 to 1.05 kg cm-2(10-15 pounds inch-2).

15. Cooling: Immediately after processing, the sealed cans are rapidly cooled to approximately 35-40^{o}C to stop the cooking process and to prevent stack burning. Prolonged heating results in an inferior and uneven product, like peaches and pears become dark in colour, tomatoes turn brownish and become bitter in taste while peas becomes mushy with a cooked taste. Cooling is done by immersing or passing hot cans in cold water tanks, by spraying cans with jet of cold water, by passing cold water in to a pressure cooker or exposing cans to air. Water used for cooling should be non corrosive, low in bacterial and yeast count and chlorinated with 2 ppm of available chlorine.

16. Storage: After cooling, the cans are stacked to allow the outer surface to dry, as even a small traces of moisture are likely to induce rusting. The cans are then labelled either manually or by using labeling machine and packed in wooden or corrugated cartons. They should be stored in cool and dry place (below 30^{0}C). Adequately processed cans usually ensure an acceptable product quality up to at least one year. Storage of cans at higher temperatures should be avoided to prevent the risk of thermophilic growth and spoilage.

Bottling of fruits and vegetables

Bottles have proved to be very good containers for home preservation of fruits. Although their initial cost is high, they can be used several times and last for many years if carefully handled. The fruits look attractive through the glass and do not develop metallic flavour. Bottling does not need a sealing machine but is not suitable from the manufacturer's point of view as the initial capital required is high. There are many types of glass containers of different shapes and sizes and with various types of hermetic seals. Jars fitted with wire clamps are considered to be the best. The products remain in a very hygienic condition and do not come into contact with rubber or metal.

Glass containers: Glass containers are chemically inert, clear, transparent, rigid, resist internal pressure, heat resistant and are cheap in comparison to other packaging materials. Glass containers are the excellent barriers to solid, liquids and gases. They preserve food against odor and flavour contaminations. But when faulty closures are used odour and flavour contamination may occur, hence; the closure should be air tight. Glass does not deteriorate with age in comparison to other packaging material but are light in weight and are fragile (breakable) with thermal shock and impact.

Types of glass containers

1. **Bottles:** The bottles have narrow neck and small closure over the top. Narrow neck facilitates pouring and reduces the size of closure. Bottles are used for packing liquids and small sized solids.
2. **Jars:** They do not have any appreciable neck but are wide mouthed bottles. They are easy to clean and easy to take out product from them. They are used for packing jams and powders.
3. **Tumblers:** They are similar to jars but do not have any neck and no finish. They can be used for packing jams and jellies.
4. **Jugs:** These are large sized bottles with carrying handlers. Used for packing liquids, foods in large quantities like ½ gallon or more.
5. **Vials:** These are small glass containers. Vials used for packing pharmaceuticals while ampoules are used for packing small quantity like spices, food colors, aroma, essences etc.

Properties of glass containers

1. Glass containers are chemically inert: Almost all types of chemicals can be packed in the glass containers except hydrofluoric acid (it eats the glass hence packed in plastic container). Oils and fats have no reaction with the glass. Water has little or negligible reaction with the glass at low temperature. The products like drugs and transfusion liquids are packed in specially treated glass containers as at higher temperature (during sterilization) the hydrogen from the water is displaced.

2. Clarity of glass containers: Products packed in glass containers are easily visualized from outside especially useful for the products kept on the shelves. But some nutrients are packed in colored bottles e.g. brown bottles, amber colored bottles. Opal glass is a ground glass, in which visibility is lost. Gin or opal glass is also used in bathrooms.

3. Glass containers are rigid containers

- Rigidity helps in filling of containers and
- Make it possible for stacking
- It also helps in loading and vacuum filling of containers. It also provides support to the material.

4. Glass containers resist the internal pressure: Glass containers offers resistant against internal pressure brought about by CO_2 or other gases in the product e.g. beer, beverages, soft drinks etc.

5. Heat resistant: Glass containers are heat resistant in comparison to other packaging material except cans. A temperature of 1500^0C is applied during manufacturing of glass. Melting point of alumina is 2000^0C, which is used for making glass. Viscous hot materials are poured into glass containers while they are still hot.

Disadvantages of glass

- Glass containers are fragile/brittle, hence great care is required to be exercised during handling.
- Glass containers are heavy in weight.
- Glass containers are not easy to dispose.

Closures: Closures should prevent loss of contents and must make reseal (crown corks do not make reseal). Closure should not react with the product e.g. in ketchup, formation of black neck takes place. Different types of closures are Crown corks, roll on cap, lug cap, vacuum seal, temper proof, snap fit, press on caps and screw caps.

Procedure for bottling

- The bottles are thoroughly washed and sterilized.
- The fruit slices are filled leaving about 3 cm space at the top of the jar or bottle.
- The sugar syrup recommended for different fruits is filled boiling hot leaving a head space of 1-1.5 cm.
- Exhausting and sterilization: Separate exhausting of bottles is not required and it is done simultaneously with sterilization by putting a pad of cloth (false bottom) under the bottles.
- The bottles should not be abruptly immersed in hot water, otherwise they may break because of sudden rise in temperature. The temperature of the water should be about the same as that of the contents and should be raised gradually and the bottles kept in the boiling water for the required time.

- At the start of sterilization the lids are left loose and the level of boiling water should come up to the neck of the bottle.
- When sterilization is over, the mouths of bottles and jars should be immediately closed or corked tightly.
- Cooling of bottles is done and the bottles are labeled after drying. The products preserved in bottles require more attractive labels.
- Store in cool and dry place.

Thus, canning and bottling is a well tested acceptable method of preservation of fruit and vegetable for conversion into stable products. For canning no chemical preservative is used. Shelf-life of adequately processed product in cans is around one year. Keeping in view the versatility of the process, canning and bottling of fruit and vegetable can be adopted as a successful enterprise.

Lecture 8 - Fruit juice and Beverages

Objective: This chapter contains information about different fermented and unfermented fruit juices and also deals with extraction and clarification of fruit juices, juice concentration and evaporation techniques, preservation techniques, limit of preservatives used, method for preparation of beverages and wines from different fruit juices, cider from apple and their FPO specifications etc.

Introduction

Introduction

Fruit juice and beverages generally comprise of naturally extracted juices, drinks, ready to serve (RTS) beverages, nectars, squashes, cordials and appetizers etc. These products are highly refreshing, thirst quenching, appetizing and nutritionally superior to many synthetic and aerated drinks. Fruit juice is the natural liquid expressed by pressure or other mechanical means from the edible portion of the fruit. Fruit juices are generally extracted from fruits in a number of ways, depending on their structure and composition.

The composition of juice is unaltered during preparation and preservation while for fruit beverages like drinks, squashes, cordial etc the fruit juice or pulp, sugar, acid, colour, flavour etc are mixed in appropriate proportions to a desirable taste. Apple juice, orange juice, mango squash, guava drink, pineapple juice and squash, mixed fruit drink, mango nectar etc are the commercial products available in the market.

Types of fruit juice and beverages

a) Unfermented beverages

Fruit juices which do not undergo alcoholic fermentation are termed as unfermented beverages. They include natural fruit juices, sweetened, ready to serve drinks, nectar, cordial, squash, crush, syrup, fruit juice concentrate and fruit juice powder. They are prepared by following minimum standards as prescribed under Food Safety and Standards Regulation, 2011 and Fruit Products order (Table 8.1) and discussed as under:

Table 8.1: Fruit Products Order (FPO) specifications for fruit beverages

Product	Minimum % of total soluble solids in final product (w/w)	Minimum % of fruit juice in final product (w/w)	Maximum acidity expressed as citric acid (%)
Unsweetened juice	Natural	100	3.5
Fruit syrup	65	25	3.5
Crush	55	25	3.5
Squash	40	25	1.5
Fruit nectar (excluding orange and pineapple)	15	20	1.5
Orange and pineapple nectars	15	40	1.5
[illegible]	[illegible]	[illegible]	[illegible]
Sweetened juice	10	85	-
Lime/lemon Ready to serve beverage	10	5	-
Ready-to-serve beverage/drink	10	10	-
Fruit juice concentrate	32	100	-
Synthetic syrup/sherbet	65	-	-

Preservative SO_2/BA ppm specified by Food Safety and Standards Regulation, 2011. SO_2- sulphur dioxide; BA- benzoic acid

- **Fruit juice:** It is a natural juice pressed out of the fruit and remains practically unaltered in its composition during processing and preservation. It is also called as unfermented fruit juice or pure fruit juice, for example apple juice.
- **Fruit juice beverage:** It is fruit juice which is considerably altered in composition during preparation. It may or may not be diluted before consumption. Ready to serve (RTS) drinks, nectar, squash, cordial, appetizer are all fruit juice beverages.
- **Synthetic drinks:** Synthetic drinks are prepared by using sugar, water, flavourants, acidulents, colour etc. These drinks do not contain any fruit juice or pulp.
- **Ready to serve (RTS) drink:** This is a type of fruit beverage which contains atleast 10% fruit juice (for lime drink 5% juice) and not less than 10% total soluble solids. The acidity in these drinks shall not exceed 3.5% as citric acid. RTS beverages are preserved by using class II preservatives not exceeding 70 ppm SO2 or 120 ppm benzoic acid. It is not diluted before serving hence it is known as ready to serve drink for example mango drink, guava drink, pineapple drink etc.
- **Fruit nectar:** This type of fruit beverage contains atleast 20% fruit juice or pulp and 15% total soluble solids and is preserved by heat processing. The acidity in fruit nectars shall not exceed 1.5% as citric acid. No class II preservative like SO2 or benzoic acid is permitted in fruit nectar as per Indian Food Laws. It is not diluted before serving.

- **Squash:** Fruit squash consists of fruit juice or pulp to which cane sugar is added for sweetening. According to Indian Food Laws, the fruit squash shall contain atleast 25% fruit juice or pulp and not less than 40% TSS. It shall not contain class II preservative in excess of 350 ppm SO2 or 600 ppm benzoic acid. Acid content in squashes generally remain between 1-1.5% but shall not exceed 3.5% as citric acid. Squash is generally diluted with water in 1:3 ratio before serving. Lime, lemon, mango, orange, guava and pineapple squashes are commercially manufactured.
- **Fruit juice cordial:** It is a sparkling, clear, sweetened fruit juice from which pulp and other suspended substances have been completely removed. It contains atleast 25% juice, 30% total soluble solids and not exceeding 350 ppm SO2 or 600 ppm benzoic acid as preservative. It is also used for mixing with alcoholic drinks for example lime juice cordial.
- **Fruit Appetizer:** Fruit appetizer is similar to fruit squash but also contains spices, condiments and herb extract. Spices like black pepper, cumin, large cardamom, ginger along with mentha extract and salt are used for manufacture of appetizer. They are also called as spiced fruit squash. Plum and apricot appetizers are quite common.
- **Fruit crush:** Fruit crush contains minimum of 25% fruit juice or pulp, 55% total soluble solids (TSS) and not exceeding 350 ppm of SO2 or 600 ppm of benzoic acid. It is diluted before serving.
- **Fruit syrup:** It is prepared by using minimum of 25% fruit juice or pulp and sweetened by using cane sugar. It shall contain not less than 65% total soluble solids and not exceeding 350 ppm SO2 or 600 ppm benzoic acid as class II preservative.
- **Synthetic syrup:** Heavy sugar syrup of 70-75 percent strength is used as the base of all synthetic syrups, which are flavoured and coloured with artificial flavour and colours. They may or may not contain fruit pulp or juice. Rose, sandal, almond, khuskhus, kewra sherbets/syrups are quite common.
- **Carbonated fruit beverages:** It is a ready to serve fruit juice beverage which contains variable amount of fruit juice, sugar, acid etc and impregnated with carbon dioxide gas. Apple juice, lime, lemon and grape juice can be used for the preparation of carbonated fruit juice beverages. They are prepared either by pre mix or post mix method.
- **Fruit juice concentrate:** It is a fruit juice, which has been concentrated by removal of water either by evaporation, freezing or reverse osmosis. Several products can be made from fruit juice concentrate. Apple juice concentrate, orange juice concentrate etc are commercially prepared in the industry.
- **Fruit juice powder:** This is a fruit juice which has been converted into a free flowing powder. They can be prepared either by freeze drying, foam mat drying or spray drying processes. They are readily reconstituted to yield full strength fruit juice drinks.

b) Fermented beverages

Fermented fruit beverage is a fruit juice which has undergone alcoholic fermentation by yeast like Saccharomyces cerevisae. The product contains varying amount of ethyl alcohol. Apple cider, plum wine, grape wine, vermouth etc are common fermented beverages.

A). Method for preparation of fruit juice beverages

SELECTION OF FRUITS: All fruits are not suitable because of difficulties in extracting the juices or due to poor quality juice. The variety and maturity of the fruit and locality of cultivation influence the flavour and keeping quality of its juice. Only fully ripe fruits are selected. Over ripe and unripe fruits adversely affects the quality of the juice.

SORTING AND WASHING: Diseased, damaged or decayed fruits are rejected or trimmed off. Dirt and spray residues of arsenic, lead etc are removed by washing with water or by using dilute hydrochloric (HCl) acid solution (0.5%) followed by washing in water.

JUICE EXTRACTION: Generally juice is extracted by crushing or grating the fruit and pressing the crushed mass in a basket or hydraulic press. Juice can also be extracted by using a screw type juice extractor. Common equipment used for juice extraction are fruit grater or mill, basket or hydraulic press, screw type juice extractor, rosing or burring machine, fruit pulper etc. There are two types of extraction methods i.e., single and double operation system.

- **Single operation:** In single operation, screw type, plunger type or roller type press is generally used to crush and press the prepared fruit to extract the juice. Citrus fruit segments are fed through a hopper, passed through conical screws and the juice flows out through the perforations while the pomace comes out at the end of the conical jacket. The screw type extractor is operated either manually or by using electricity depending upon the requirement. The juice extracted is generally thick and cloudy and contains a considerable amount of macerated pulp. Care should be taken to remove the rind of citrus fruits completely otherwise it makes the juice bitter. Citrus fruits like lemon, kinnow etc can also be extracted by using a rosing or burring machine. Finally, the juice is strained through a thick cloth or a sieve to remove seeds.
- **Double operation:** In this system, the fruits are crushed and then pressed separately. Fruit like apple, aonla, berries, grapes, jamun, phalsa etc are crushed in fruit grater or crusher and the crushed mass is pressed by means of basket press and hydraulic press.

Process variables for juice extraction for some fruits are:

- Soft fruits such as berries or tomatoes can be pressed through a fruit press or pulped by using a juicer attachment to a food processor.
- Citrus fruits are usually reamed to extract the clear juice.
- Harder fruits like pineapple are peeled, pulped and pressed to extract the juice.
- Apple and pear fruits are crushed in a fruit grater and pressed in a hydraulic/basket press to extract a clear juice.
- Passion fruit juice is prepared by using a pulper-finisher that separates skin and seeds from the pulp.

The fruits like mango, guava, apricot, peach etc from which the clear juice extraction is difficult are passed through the pulper to make pulp and then the pulp is utilized for preparation of juice, fruit drinks and ready to serve beverages.

DEAERATION: Freshly extracted juice contains appreciable quantity of oxygen which may affect the quality of juice if not removed before packing. Air in juice is due to the presence of intra-cellular spaces present in the fruits. Most of the air as well as other gases are removed by subjecting the fresh juice to a high vacuum. This process is called as deaeration and the equipment used for the purpose is known as the deaerator. Heating of juice during heat processing also helps in removal of the air.

Clarification of Juice

Clarification of Juice: Fruit and vegetable juices are clarified by using different methods like straining or screening, settling or sedimentation and filtration.

a. Straining or screening: Unclarified fruit juices contain varying amounts of suspended matter consisting of broken fruit tissue, seed, skin, pectic substances and protein in colloidal suspension. Seeds and skin which adversely affect the quality of juice are removed by straining through a muslin cloth or sieve. The fruit juices are strained or screened by muslin cloth or stainless steel mesh sieves manually to remove coarse particles in a small-scale industry. But in large industries power operated screening system or filter press is used.

b. Finishing: Citrus juices need finishing for separating cloudy but otherwise clean juice from pulp, rag and seeds. The finisher separates the pulpy matter from the juice by the action of a rotating auger inside a cylinder screen. Screen hole size range from approximately 0.020 to 0.030 inch in diameter, depending on the condition and softness of the fruit. Finishing is judged by the pulp content in the orange fruit juice.

c. Decantation: Decantation is the simplest method of clarification, in which the juice containing solids is allowed to settle down and then clear juice is decanted or siphoned out. Keep juice at low temperature for long periods also helps in setting of solid to allow clarification.

d. Centrifugation: The clouding particles can be separated by centrifugal action. The juice containing solids is fed into a basket or disc type centrifuge, where the centrifugal force separates the light and dense components in each layer. The clear juice is collected and unwanted solids are separated.

e. Enzymes: The plant carbohydrates, pectin, starch and proteins make the colloidal suspension in the freshly extracted fruit juice. The pectinol enzyme is widely used for better juice recovery as well as clarification of fruit juices as it breaks pectin into soluble form thereby freeing the suspended particles which settle down and leaves the juice clear. Similarly, proteolytic and starch liquefying enzymes i.e. amylases are used to remove protein and starch from fruit juices. Pectinol is more effective in the case of acidic juices. Fruit juices can be clarified in about 1-2 hours at 40-50^{0}C but requires 20 hrs at 20^{0}C.

f. Physical finings: Certain fining agents, which have physical or mechanical action are kaolin, diatomaceous earth, Spanish clay, bentonite or china clay and are known as filter aids. Generally 0.5 to 0.1 percent earth is mixed with fruit juice and then passed through the filter press. Ultra filtration is a process that separates particles based on molecular weight and has better retention of the nutrients in the juice. It is necessary to degrade the pectin enzymatically before ultra-filtration, to reduce viscosity and allow a satisfactory juice.

g. Chemical finings: Gelatin and casein are used to clarify the fruit juices and act partly to neutralize the electrical charged particles and partly by forming insoluble precipitate with the constituents of the juice. The gelatin combines with tannins and casein with acid of the juice. The gelatin may cause juice cloudy if used in excess. Depending on the tannin content of the fruit juice, gelatin solution is mixed and allowed to stand for 18 to 24 hrs to ensure that the precipitated matter clots together and settles down. The clarified juice is then siphoned off. Albumin (egg white) can also be used in clarification of juices.

h. Clarification by freezing: Grape juice contains cream of tartar or potassium hydrogen tartarate along with pulp and skin which is removed by freezing and thawing the juice or by refrigeration for a long storage. Apple juice can also be clarified using this method after freezing is precipitated on thawing.

i. Clarification by heating: During heating, the colloidal material in fruit juices coagulates and settles down on cooling which can be separated by using a filter press. For clarification of apple and pomegranate juice, the juice is heated to 80-85^{0}C for few minutes and cooled immediately followed by filtration by passing the juice through a filter press.

j. Addition of sugars: All juices are sweetened by adding sugar, except those of grapes and apple. Sugar can be added directly to the juice or as syrup made by dissolving it in water. Fruit squash, cordial, syrups are made by adding appropriate quantity of sugar into the pulp or juice using cane sugar. Similarly ready to serve drinks and fruit nectar are sweetened by using cane sugar.

Preservation of Juices

Preservation of Juices: Fruit juices, RTS and nectars are preserved by pasteurization or by using chemical preservatives. Squashes, crushes, syrups and cordials are preserved by adding chemical preservative like potassium metabisulphite or sodium benzoate.

1. Pasteurization: Preservation of fruit juices by application of heat is the most common method. Pasteurization is a process in which juice is heated to 100^{0}C or slightly below for a sufficient time to inactivate/kill the micro-organisms, which cause spoilage. Usually the fruit juices are pasteurized between 75 and 880C with times ranging from 30 sec to 30 min depending on the type of heating system, the nature of the juice and the size of the container. Pasteurization can be performed either by heating at low temperature for a long time (LTLT) or heating at high temperature for short time (HTST). Commonly followed methods are:

a. Holding pasteurization: In this method, the prepared juice is filled into glass bottles with a proper head space and the bottles are sealed airtight. After sealing the bottles are pasteurized.

However, this method is not followed for commercial scale products.

b. Pasteurization by overflow method: In this method, the juice is heated to a temperature about 2.5^{o}C higher than the pasteurization temperature and filled into the hot sterilized bottles up to the brim. Care should be taken to maintain the temperature during filling and sealing operation. The sealed bottles are processed in boiling water for specified period. After processing the bottles are cooled. On cooling, the juice contracts to leave a small headspace in the bottle which does not contain any air. The method is commercially followed in preservation of all types of juices in the food industry.

c. Flash Pasteurization: In this process, the juice is heated only for short time at a temperature about -5.5^{o}C than the pasteurization temperature, filled into the containers and sealed air tight under cover of a steam to sterilize the seal and then cooled. This process is also known as HTST (High temperature and short time) method and the juice is heated vary rapidly. Flash pasteurization helps to minimize the loss of flavour, better retention of vitamins, keep juice uniformly cloudy and minimize the cooked taste of the juice.

2. Aseptic processing and packaging of fruit juices: Aseptic processing and packaging is defined as the process in which a commercially sterile product is packed into pre-sterilized container in a sterile environment. The system make use of high temperature short time (HTST) sterilization in the temperature range of 90-110^{o}C for acid products ($pH<4.6$) and ultra high temperature (UHT) sterilization 121^{o}C and above for low acid foods ($pH>4.6$). The commercial aseptic sterilization process takes place in a continuous, closed system. Aseptic processing may produce products with better retention of nutrients and excellent sensory quality. Apple, mango, litchi, pineapple drinks etc. in tetra pack are processed commercially using aseptic processing and packaging system.

3. Preservation with chemical: Fruit juices, pulps, squash, cordial, syrup, RTS drinks etc, are preserved with chemical preservatives. Fruit juice and pulps in bulk are preserved with chemical preservatives. Two chemical preservatives most commonly used in preservation of fruit and vegetable products are

(i) Benzoic acid (benzoates)

(ii) Sulphur dioxide (Sulphites).

i) Benzoic acid: Benzoic acid is the effective agent but sparingly soluble in water, thus its sodium salt, which is water soluble, is generally used. Benzoic acid is more effective against yeast as compared to moulds. However, it does not stop lactic acid and acetic acid fermentation. The quantity of sodium benzoate required depends on the nature of the juice, its acidity and type of microbial infection. The limit of benzoic acid to be added in various products as per FPO (Fruit Products Order) is given in Table 8.2.

ii) Sulphur dioxide: Potassium meta-bi-sulphite ($K_2O_2SO_2$ or $K_2S_2O_2$) is commonly used as a source of sulphur dioxide. On addition to fruit juice or beverage it reacts with acid of the juice and form potassium salt and sulphur dioxide, which is liberated and form sulphurous acid with the water of the juice. Sulphur dioxide is more effective against mould spores and bacteria than yeast and also inhibits enzymes etc. It acts as antioxidant and bleaching agent thus help in the retention of ascorbic acid, carotene and other oxidisable compounds. It also retards non-enzymatic browning or discoloration of the product. Its effectiveness depends on the acidity, pH, temperature and other substances present in the fruit juice.

- The SO_2 should not be used in naturally colored juices like phalsa, Jamun, pomegranate and strawberry juices, on account of its bleaching action.
- It should also not be used in those juices, which are to be packed into tin containers, because it may act on the tin of the containers causing pinholes, forms hydrogen sulphide and black compounds.
- The potassium meta-bi-sulphite should be first dissolved in a small quantity of water and then added to the juice to be preserved. The limit of SO_2 to be added in different processed products according to Food Safety and Standards Regulation 2011 and FPO specification is given in Table. 8.2

Table 8.2: Limits for permitted preservatives in fruit juice and beverages as per Fruit Products Order.

Fruit juice/beverages	Preservative	Part per million (ppm)
1.Fruit pulp or juice for conversions into jams and other products	SO_2	3,000
a. Cherries	SO_2	2,000
b. Strawberries & Raspberries	SO_2	1,000
c. Other fruits	SO_2	1,500
2. Fruit juice concentrate	SO_2	350
3. Squashes, crushes, fruit syrup, sharbats, cordials,	Or	600
fruit juice and barley water.	Benzoic acid	70
4. Sweetened ready to serve Beverages	SO_2	120
	or	
	Benzoic acid	

4. Preservation by sugar: Fruit juice containing 66% sugar generally does not ferment. Fruit syrup or sharbats with high total solids (65% and above) have a very low water activity hence micro-organism do not grow. The sugar acts as a preservative by osmosis and does not support the growth of micro-organism. However, the growth of mould and yeast can occur on the surface of jams or jellies which need to be protected by using airtight packing or covering the product with molten paraffin wax.

5. Preservation by freezing: The properly frozen juice retains its freshness, colour, taste and aroma for a long time. De-aerated juice is transferred into containers, which are hermetically sealed and frozen. Freezing does not sterilize fruit juices, it merely reduces the temperature to the point where micro-organisms do not multiply and chemical changes take place very slowly. The more rapidly a juice is frozen, the smaller the ice crystal formed and the less the amount of colloidal matter coagulates. When the juice is frozen to -18oC, practically all of the juice will be solid except for a little thick syrup in the centre of the containers. This method is particularly useful in the case of juices whose flavour is adversely affected by heating.

6. Preservation by drying: Micro-organisms need water for their growth and multiplication and as the water is removed, they are unable to grow. Fruit juices can be preserved in the form of powder by different methods viz., spray drying, drum drying, freeze-drying, foam-mat drying etc. Fruit juice powders are highly hygroscopic and require special care in packing. It should be packed in free flowing powder form in hermetically sealed containers with in package desiccant to prolong the shelf-life of the product. Lemon juice powder can also be prepared by using foam mat drying process.

7. Preservation by carbonation: Carbonation is a process of mixing carbon dioxide under pressure with water, juice or beverages so that the product when served; gives off gas in fine bubbles and has the characteristics taste. Carbonated beverages are generally bottled with carbon dioxide content ranging from 1 to 8 g/litre. Though this concentration is much lower than that required (14.6 g/litre) for complete inhibition of microbial growth, yet it is significant in supplementing the lethal effect of acidity on pathogenic bacteria. Carbonation also helps in removal of air which creates anaerobic condition and reduces the oxidation of ascorbic acid. Since moulds and yeasts require oxygen for their growth and as such become inactive in the presence of carbon dioxide. Thus the absence of air and presence of carbon dioxide in fruit beverages help to prevent the growth of moulds and yeast. The keeping quality of carbonated beverages is enhanced by adding about 50ppm sodium benzoate. Carbon dioxide in beverages is measured in terms of gas volume. The gas volume is defined as the amount of gas in millilitres that a given volume of water will absorb at atmospheric pressure i.e. 760 mm of Hg at 15.5^0C temperature. Generally 1.3-4.0 gas volume CO_2 is used for carbonation of fruit juice. Lime, lemon, grape, apple juice can be carbonated by using carbonation process.

8. Preservation by filtration: In this method, the clarified fruit juices (particularly apple and grapes) are passed through special filters, which are capable of retaining yeasts and bacteria. Various types of germ proof filters are used for this purpose and the method is used for soft drinks, fruit juices and wines.

FILLING and PROCESSING: Bottles are thoroughly washed with hot water and filled leaving 1.5-2.5 cm headspace. The bottles meant for heat processing are sealed by using crown corks whole those preserved by using chemical preservative can be sealed by using PP (pilfer proof) caps.

B). Method for preparation of fermented fruit beverages

Fruit juices which have undergone alcoholic fermentations by yeasts, contains varying amounts of alcohol are called fermented fruit beverages. These beverages include wine, champagne, cider, port, sherry, musket, perry, orange wine, berry wine etc.

1. Wine: Wine may be defined as a fermented beverage prepared from grapes after alcoholic fermentation. When other fruits are used for preparation of wine then these are called by prefixing the name of fruits for example plum wine, peach wine etc. Wines are of two kinds viz. dry and sweet.

- Dry wines contain practically very little or no sugar, whereas sweet wines contain some sugar and taste sweet. The alcohol content of these wines ranges from 7 to 20 percent.
- The wines are also categorized on the basis of alcohol contents as Light, medium or strong wines
- 'Light wine' contains alcohol contents of 7 to 9 percent.
- 'Medium wine' with alcohol 9 to 16 percent and,
- 'Strong wine' with alcohol of 16 to 20 percent.
- Generally wine with more than 12% alcohol are fortified with fruit brandy (alcohol) prepared by distilling grape wine.
- Still wines are without any carbon-dioxide.
- Sparkling wines contain carbon-dioxide.

Method for preparation of wine

Fruits suitable for wine making: Wine can be prepared from the apple, custard apple, pear, plum, jamun, muskmelon, coconut toddy, pomegranate, banana, guava, ber, strawberry, peach, kiwi fruit, raspberry, cherry, pineapple, date, apricot, litchi and mixed fruits (Table 8.3). Wine may be red or white depending on the grapes used. The red coloured grapes are crushed and fermented to give red wine, whereas white wine is prepared from fermentation of white grape juice.

Preparation of fruits for fermentation
Beauty Seedless, Arka Shyam, Concord etc. cultivars of grapes are generally used for wine making. In case of white grapes, the juice is taken whereas, in case of coloured grapes, crushed grapes without any stems (must) are taken for fermentation. Fruits are crushed to extract the juice or in pulpy fruits, the fruit pulp is used. The sugar content is maintained between 22-24 percent and an acidity of 0.6 to 0.8 percent should be maintained. In low sugar fruits, the cane sugar is added to raise the TSS to 22 percent. Sulphur dioxide is also added to the must at the rate of 50-70 ppm to check the growth of wild yeasts and bacteria, which are undesirable.

Table 8.3: Different types of wines.

Type	Characterization
Champagne	It is made chiefly in France with certain varieties of grapes. Champagne is a sparkling clear wine and also made in several other countries. Generally the fermentation is allowed to proceed to completion in bottles. These bottles are specially made to withstand high pressure of gas produced during fermentation.
Port	This is fortified sweet red wine originally in Portugal, but now produced in other countries.
Muscat	It is prepared from Muscat variety of grapes in Australia, California, Italy and Spain
Tokay	It is famous fortified wine of Hungary
Sherry	Sherry is a Spanish wine, which is matured by placing the filled barrel in sunlight having a temperature of 54 to $60^{o}C$ for 3 to 4 months
Perry	The wine prepared from pears is called as Perry. It can be prepared from the culled fruits and fruit trimmings of the canneries.
Orange wine	Sweetened orange juice is fermented to produce orange wine. The method of preparation is similar to that of grape wine. Orange peel oil should be minimum in the juice, otherwise its presence stop the fermentation completely.
Berry wine	The wine made from fruits like strawberry, blackberry and elderberry is known as berry wine.
Feni	Feni is a wine made from fermentation of cashew apple, in some places like

Inoculation and Fermentation

Inoculation and Fermentation
The grape juice (must) after addition of sugar syrup is fermented by addition of a culture of pure wine yeast Saccharomyces cerevisae var. ellipsoideus as a starter @ 2-5%. For proper fermentation temperature should be maintained between 27-29^{o}C. A low temperature below 10^{o}C and higher than 38^{o}C, almost ceases the fermentation process. After three days the contents are filtered through muslin cloth and again allowed to ferment for another 10 days, so that yeast cells and other solids settle at the bottom. For other fruits the time taken for completion of fermentation varies between 15-20 days.

Aging and packaging: When fermentation is complete, the clear wine is siphoned out and further clarified with the help of fining agent like bentonite. When all the colloidal materials settle down along with bentonites, the clear wine is siphoned off and filtered if necessary. The clear wine is filled into bottles or barrels completely and sealed airtight to exclude air and allowed to mature for 6-8 months. During this aging process, the wine loses its raw and harsh flavour to a smooth and characteristic aroma. Generally, oak wood barrels are used for aging as they impart a finer aroma to the wine. During maturation dissolved carbon dioxide escapes and spontaneous clarification occur. The extraction of oak flavours and limited oxidation also occur during this process. Astringent tannic substances precipitate and result in slow smoothing of the taste. Generally wines are pasteurized at 82-88^{o}C for 1-2 minutes followed by bottling. To produce fortified wines, alcohol is added in the form of brandy or wine spirit. For improving the taste sugar may be added before final packing of the wine.

2. Cider: Cider is fermented apple juice, which is made from apples. In India, dessert apples are employed for preparation of good quality of cider. The alcohol content ranges from 4 to 6 percent in cider. Apples with high tannin (0.1 to 0.3%) contents are generally used for the preparation of cider.
Apples are crushed and pressed to extract juice, then its sugar content is raised to 220 Brix by addition of cane sugar. It is preserved with 100 ppm SO_2 and pure culture of wine yeast is added for fermentation. Sometimes di-ammonium hydrogen phosphate (DAHP) (0.02 to 0.05%) is added as a food supplement for the yeast. The method of fermentation is similar to that of other

wines. The cider is aged in oak wood barrels after filtration. The matured cider is heated to 65^0C filled into bottles, crown corked and pasteurized at 60^0C for 30 minutes. Apple cider is also carbonated for better acceptability.

3. Vermouth: It is a fortified wine in which alcohol contents ranges from 15 to 21%, and flavoured with mixture of herbs & spices.

4. Brandy: Brandy is a distillate obtained from the distillation of wine and generally aged in small oak cooperage, example cognae and armagnae.

C). Vegetable juices: Generally fruit juices are consumed either fresh or processed form. Certain vegetable juices are also consumed in fresh form but for mostly medicinal purpose. Tomato juice is consumed in processed form either canned or bottled. Tomato is also used as soup, a warm beverage prior to meal.

D). Fruit juice powders: Fruit juice powder process includes the evaporation of water from fruit juices to bone dryness. These powders are highly hygroscopic in nature, therefore proper packaging is required. These powders are prepared from strained fruit juices by different drying techniques such as spray drying, double-drum drying, vacuum drying, freeze drying and foam-mat drying. The powder has a long shelf-life and is soluble in cold water. Reconstitution of the powder yields full strength fruit juice drinks.
During the drying process much of the characteristic fresh flavour is lost, which is compensated by adding natural fruit flavour in powder form. Mango, orange, lemon, guava, passion fruit and tomato juice etc can be dried into powder.

E). Fruit juice concentration and evaporation: Concentration is a process of removal of water from juice to increase concentration of soluble solids in fruit juices. It is also used to pre-concentrate a juice for further use in processing such as spray drying or drum drying. Concentration has the significant advantages to the processing, to reduce storage, packaging and transport costs, concentration of soluble solids aid in preservation by reduction in water activity. The juice concentrate can be used as base material for making various food and beverages formulation. Concentration of juice can be carried out by evaporation, freeze concentration by using reverse osmosis.

Evaporation is most commonly used for preparation of apple juice concentrate at commercial scale. The evaporator consists of a steam fed heat exchanger to heat the fruit juice to a desirable temperature for evaporation. There is a separator from which vapour is separated from the concentrated liquid phase, a condenser to effect condensation of the vapour and its removal from the system, and a fractionating still for aroma recovery. Generally, falling film evaporator is used to concentrate the apple juice. Final concentration is carried out in centritherm evaporator. Apple juice is concentrated to 6-7 folds from its initial total soluble solids. Apple juice concentrate is immediately cooled and stored in cold store in large barrels.

Advantages of concentration and evaporation

- Reduced weight and bulk compared to fresh juice result in economy in packaging, storage and transport.
- The whole crop of fruit is fully utilized during peak season, helps in lowering the prices.
- The product can be used as base material for making various beverages.

Concentrates of pure fruit juices particularly of orange, apple, pineapple and grape are highly popular.

Lecture 9 - Preservation by using Sugar: Jams, Jellies, Marmalades, Preserves, Candies and Crystallised fruits

Objective: This chapter deals mainly with the preparation procedures for jams, jellies, marmalades, preserves, candies and crystallized fruits. Complete procedures along with flow-sheets have been incorporated in the chapter for easy understanding. Pectin grades, theories for jelly formation, determination of end point, problems and defects, spoilage causing problems etc are also discussed in this chapter.

Introduction

Introduction
Jams, jellies and marmalades constitute an important class of preserved fruit products. Apple jam, pineapple jam, strawberry jam and mixed fruit jam prepared by using pulp of two or more fruits are quite common. Similarly, guava jelly and orange marmalade are also examples of such products.

A fruit preserve is made from properly matured fruit by cooking it whole or in the form of large pieces in heavy sugar syrup, till it becomes tender and transparent. A fruit impregnated with cane sugar and glucose, followed by subsequent draining and drying is called a candied fruit e.g. petha candy, ginger candy. Further, candied fruit covered or coated with a thin transparent coating of sugar, which imparts a glossy appearance is referred to as a glaced fruit. When candied fruit is coated with sugar crystals either by rolling it in powdered sugar or by allowing the sugar crystals from glucose syrup to deposit on it, it becomes a crystallized fruit. The use of high concentration of sugar in these products acts as the preservative. The products like Petha candy, aonla preserve, apple rings; candied citrus peels, ginger candy, ginger in syrup; bael, pineapple and carrot preserve are the commercial products in this category.

1. JAM: Jam is prepared by boiling the fruit pulp with a sufficient quantity of sugar to a thick consistency, firm enough to hold fruit tissues in position. The method for preparation of jam and jelly is the same except that pulp and pieces of fruit are used in jam while, for jelly making clear fruit extract is used. According to FPO specifications, minimum soluble solids in the final product shall not be less than 68 percent (w/w).

Procedure for jam preparation (Fig 9.1)

Fruit preparation: The fruit is washed thoroughly to remove any adhering dust and dirt. The fruit is then subjected to preliminary treatment which varies with the type of fruit.

- Strawberries are crushed between rollers; raspberries are steamed, crushed and passed through sieves to remove the hard cores.
- Plums, peach and apricots are heated with a small quantity of water until they become soft and are then passed through a wide mesh sieve to separate the stones.
- Fruit after softening by boiling with small quantity of water can be passed through the pulper to extract the pulp.
- Pears are peeled, cored and cut into small pieces.

- Mangoes are peeled, stones separated and then the slices are passed through a pulper.
- Pineapples are peeled, sliced and the cores punched. The slices are then cut into smaller pieces and passed through a screw type crusher to get a fairly coarse pulp suitable for making the jam.
- When two or more fruits or fruit pulps are mixed in appropriate proportion for preparation of jam, the jam is called as mixed fruit jam.

Addition of sugar: Generally 55 parts of cane sugar (sucrose) is used for every 45 parts of fruit for preparation of jam. The prepared jam should contain 30 to 50 percent invert sugar to avoid crystallization of sugar in the jam during storage. If the percentage of invert sugar (reducing sugar) is less than 30, then jam develops crystallization and if it is more than 50%, the jam will develop into a honey like mass due to the formation of small crystals of glucose. Sugar should not be added in excess as jam with higher total soluble solids becomes gummy and sticky.

Addition of acid, colour and flavour: Citric, tartaric or malic acid are used to supplement the acidity of the fruit for jam making. Addition of acids to fruits which are deficient in acid is required to get appropriate combination of pectin, sugar and acid for proper setting of jam. The pH of the mixture of fruit juice and pectin should be 3.1 before sugar is added. Only permitted edible food colours should be used and these should be added towards the end of the boiling process. Flavours are added at the end of cooking process and just before packing.

Boiling: The fruit is placed in the boiling pan along with a small quantity of water to facilitate pulping. It is then cooked sufficiently to liberate the pectin. After addition of sugar, the mixture is boiled to concentrate the soluble solids to about 68.5 percent and also to allow the necessary degree of inversion of the sugar. Boiling can be performed in steam jacketed kettle or stainless steel or aluminium boiling pan. Boiling in a vacuum pan using reduced pressure is used to prepare jam at lower temperature (65-75^{0}C) to minimize undesirable changes and for retention of vitamin.

End Point: The end point can be determined by carrying out a jelmeter test. Generally, fruits which are fairly rich in pectin, the weight of the finished jam is one and a half times (11/2 times) the weight of sugar used. Jam containing 68.5 percent of soluble solids boils at 105^{0}C at sea level. It should yield a definite quantity of the finished jam.

Storage: The jam is packed in sterilized glass jars. It should be noticed that unless the jars are stored in a fairly cool place, moisture will evaporate from the jam resulting in shrinkage of the jam. If jam is prepared from fresh, unsulphited fruit pulp then it is advisable to add about 40ppm of sulphur dioxide in the form of potassium meta-bi-sulphite to the jam, which is permitted by law. A layer of molten paraffin wax can be put on the top surface of the cooled jam in the glass jar, which on cooling sets. This acts as a safeguard against any possible moulding on the surface of the jam.

2. JELLY: Jelly is prepared by boiling the fruit with or without addition of water, straining the extract and mixing the clear extract with sugar and boiling the mixture to a stage at which it will set to a clear gel. The jelly should be transparent, well set, but not too stiff and having original flavour of the fruit. It should be of attractive colour and should keep its shape with a clean cut surface. In the preparation of jellies, pectin is the most essential constituent. Pectin is present in the cell wall of fruits. In order to get a good quality jelly fruits rich in pectin, but deficient in acid should be preferred.

Procedure for jelly preparation (Fig 9.1)

Selection of fruits: The fruits should be sufficiently ripe, but not over ripe and they should have good flavour. Slightly under-ripe fruit yields more pectin than over-ripe fruit; as during ripening the pectin present is decomposed into pectic acid, which does not form a jelly with acid and sugar. The amount of pectin extracted from a fruit depends on the degree of disintegration of protection during the heating process.

Pectin requirement: Usually 0.5 to 1 percent of pectin in the extract is sufficient to produce a good jelly. If the pectin content is in excess, a firm and tough jelly is formed and if it is less, the jelly may fail to set. Pectin, sugar, acid and water are the four essential constituents of a jelly and must be present approximately in the following proportions:
Pectin 1 percent
Sugar 60 to 65 percent
Fruit acid 1 percent
Water 33 to 38 percent
However, the exact proportion of the sugar depends on the pectin grade.

Pectin grades: Grades of pectin means the weight of sugar required to set one gram of pectin under suitable conditions to form a satisfactory jelly. e.g. 100 grade pectin means 100g of sugar is required for setting of 1 g pectin.

Problems in Jellies

Problems in Jellies

A). Failure of jellies to set: Sometimes the jellies do not set due to the following reasons:

i) Lack of acid or pectin: A jelly may fail to set due to lack of acid or pectin in the fruit from which it is made. It may also fail to set due to insufficient cooking of the fruit resulting in inadequate extraction of pectin and acid.

ii) Addition of too much sugar: If sugar is added in excess of the required quantity, a syrupy or highly soft jelly results. It can be corrected by adding fresh clarified juice rich in pectin.

iii) Cooking below the end point: If the cooking is stopped before the concentration of sugar reaches 65 percent, the jelly may fail to set and may remain syrupy and highly soft.

iv) Cooking beyond the end point: If heating is continued beyond the end point, the jelly becomes tough due to over-concentration. This occurs when the juice is rich in both acid and pectin and enough sugar has not been added. If the acid is in excess, the pectin breaks down and forms syrup like jelly.

B). Synersis or weeping of jelly: The phenomenon of spontaneous exudation of fluid from a gel is called synersis or weeping of jelly. It is caused by following factors:

i) Excess of acid: Addition of excess of acid results in the breakdown of jelly structure due to the hydrolysis or decomposition of pectin.

ii) Too low concentration of sugar or soluble solids: This causes the network of pectin to hold more liquid than it possibly can do under normal conditions.

iii) Insufficient pectin: This results in the formation of a pectin network which is not sufficiently dense and rigid enough to hold the sugar syrup.

iv) Premature gelation: Gelation is caused due to breakdown of pectin during pouring of jelly into the containers. The jelly becomes weak and remains broken.

v) Fermented jellies: Fermentation usually takes place in those jellies in which synersis has taken place.

C). Cloudy or foggy jelly: It might be due to use of non-clarified extract, use of immature fruits (immature fruits contain starch which is insoluble in juice), Over cooking and cooling, non-removal of skum, faulty pouring (when jelly poured from a great height, air get trapped in bubbles form and jelly become opaque) and premature gelation is also a reason for cloudy or foggy jelly.

D). Formation of crystals: Crystals in the jelly may be formed due to addition of excess sugar.

3. MARMALADE: It is similar to fruit jelly but the slices of the fruit or of the peel are suspended. Marmalades are generally made from citrus fruits like oranges and lemons in which peel shreds are added as a suspended material. As per FPO specifications, the quantity of fruit and soluble solids in the final product shall not be less than 45 and 65 per cent (w/w) respectively for jelly and marmalade.

Procedure for marmalade preparation

Preparation of fruits: The outer yellow flavedo portion of the peel of citrus fruits contains colouring matter and volatile oils, whereas the inner white albedo portion contains pectin. The yellow portion of the peel is peeled off thinly from the fruit with a stainless steel knife. The thin yellow peel is cut into fine shreds with a knife or by using a shredding machine. The shreds are boiled and drained to remove the bitterness. The sliced or crushed fruit is boiled gently by simmering with 2 or 3 times water to extract the pectin. While it is being boiled, a teaspoonful of the clear extract is taken from the pan and tested with alcohol for its pectin content. The boiling process usually takes 45 to 60 minutes. After boiling the extract is filtered through a muslin cloth. The pectin extract can be clarified by using a filter aid by passing through a filter press.

Preparation of peel shreds: The peel is cut into shreds (1.9-2.5 cm long and 0.8-0.12 cm thick).

The shreds are softened by boiling before they are added to the marmalade. If they are added directly without preliminary softening to the sugar solution and boiled, they become tough. Generally, three methods are employed for softening the shreds.

i) The shredded peel is boiled for 10-15 minutes in several changes of water. The bitter principles present in the peel are also removed in this process.

ii) The shreds are boiled in 0.25 percent solution of sodium carbonate or 0.1 percent ammonia solution.

iii) The shreds are then autoclaved at 116^0C to 121^0C (70-105 k Pa). The time required to soften shreds depends upon their size and shape.

Cooking: The extract is boiled along with required quantity of sugar in a steam-jacketed kettle or stainless steel vessel. Boiling is continued and the impurities rising to the surface are removed. When the temperature of the boiling mixture reaches 103^0C at sea level, the prepared shreds are added to it at the rate of 62 g for each kg of the original extract. Boiling is continued till the jellying point is reached which is determined by using either sheet test, drop test or weight test.

Cooling: The marmalade is cooled in a shallow pan or in a water-cooled pan by slow stirring to allow the uniform distribution of shreds in the marmalade. During cooling, when the temperature reaches 82 to 88^0C, a thin film begins to form on the surface of the marmalade which becomes sufficiently thick to prevent floating of the shreds onto the surface.

Addition of flavour: Due to volatilization of natural flavour during cooking process, addition of artificial flavour is desirable to compensate the loss. It is desirable to add a small amount of flavour to the product, because most of the natural flavour volatilizes during the boiling and cooking processes. Generally, a small quantity of orange oil is added to the marmalade at the time of filling into jars or cans as a flavourant.

Packing: After cooling the marmalade is filled into jelly glasses or glass jars, which can be closed air-tight or is packed in cans which are hermetically sealed. In jelly glasses, the marmalade is allowed to set overnight and on cooling a thin layer of molten paraffin wax is poured on the top. When packed in A21/2 size cans, the cans are inverted upside down to sterilize the lids and stored in a cool dry place.

4. PRESERVE: A fruit preserve is made from properly matured fruit, by cooking it whole or in the form of large pieces in heavy sugar syrup, till it becomes tender and transparent.

Procedure for preserve preparation: In preparation of preserve, at least 45 kg of the fruits are used for every 55 kg of sugar and cooking is continued till a concentration of at least 68 percent of soluble solid is reached.

Selection of fruit: Fruit should be fully developed, firm and slightly under-ripe. Unripe or over-ripe fruit with loose pulp should be rejected.

Preparation of fruit: Fruit are washed thoroughly and damaged portions are removed. Thin skinned fruits like berries are not peeled. Thick skinned fruits like mango, apple, bael, petha are peeled. The cores, seeds or stones are removed. Fruits are preserved either whole or in pieces.

Pricking/puncturing: The whole fruits or slices are uniformly punctured/pricked with stainless steel/wooden pickers to enable proper permeation of sugar syrup. Excessive pricking should be avoided to prevent softening of fruit/slices. Aonla and petha (ash gourd) can be pricked by using mechanical prickers.

Soaking: The fruits or their slices are soaked in water, brine or alum solution for few hours to few days before blanching and to enable proper permeation of syrup. Soaking make hard fruits porous, check browning, remove astringency, minimize shrinkage and prevents stiffening of fruits.

Blanching: The soaked fruits or slices after thorough washing are placed in muslin cloth and blanched in boiling water for few minutes (5-10) according to their texture to soften the hard texture. Excessive blanching should however be avoided.

Preparation of syrup: The quantity of sugar varies for various fruits, ranging from equal to double of the prepared fruits or slices. Syrup is prepared by boiling the sugar with 2-3 times of water and adding 0.3-0.4% citric or tartaric acid. Addition of acid also helps in removing the dirt from the sugar.

Cooking in syrup: The prepared fruits or slices are cooked in syrup in three different ways i.e.

a) Open kettle one-period process
b) Open kettle slow process; and
c) Vacuum cooking process

a) Open kettle one period process: The fruits are cooked in syrup containing low sugar contents. Boiling is continued with gentle heating until the syrup become sufficiently thick. The final concentration of sugar should not be less than 68^{o}Brix corresponding to a boiling point of 106^{o}C. Rapid boiling should be avoided, as it makes the fruit tough.

b) Open kettle slow process: In this process, the sugar equal to half the weight of fruit is added to the prepared fruit or slices in alternate layers in a vessel and allowed to stand for 24 hours. During this period, excess water from the fruit is leached out and sugar turn into a solution of 37-38^{o}Brix. The concentration of syrup is raised to 60^{o}Brix by adding more sugar. Citric or tartaric acid is added @ 0.06-0.12% to invert the portion of sugar. The whole mass is boiled for 3-4 minutes and kept for overnight. On the third day, concentration of syrup is raised to 68^{o}Brix by adding more sugar and the whole mass is boiled again for 3-4 minutes and the fruit is then left in the syrup for another 3-4 days. Finally the strength of syrup is raised to 70oBrix and the preserve is packed in containers. However the stages may vary with the type of fruit.

c) Vacuum cooking: Vacuum cooking results in better retention of flavour and colour of the product. In this process, the fruit is initially softened by boiling and then placed in the syrup of

30-35°Brix concentration. The fruit syrup blend is then transferred to vacuum pan and concentrated under reduced pressure to 70°B. To facilitate sugar penetration, slow boiling is practiced for hard fruits.

Precaution during cooking: In both methods, deep pans should be used otherwise the syrup becomes concentrated within a short period in shallow pans and fails to permeate the fruit. While adding fruit slice in boiling syrup, the consistency should not be too thick. The thick coating of the juice prevents the sugar syrup to enter and the product becomes tough or shriveled. Fruits should always be covered in the syrup to prevent drying of top pieces and improve the quality.

Cooling and packing: For storage in bulk, the preserve is cooled quickly after final boiling to avoid discoloration. For packing in A2½ size cans, the preserved fruits are drained and filled in to the cans. Freshly prepared boiling syrup (68°B) is then poured into the containers (A2½ size can), exhausted for 8-10 minutes at 100°C in steam, hermetically sealed, sterilized for 20-25 minutes at 100°C and cooled immediately.

5. CANDIED FRUITS: The method for making candy is practically the same as that followed for preserves, with a minor variation that the fruit is impregnated with a higher concentration of sugar or glucose. The total sugar content of the impregnated fruit is kept at about 75 percent to prevent fermentation. The most suitable fruits for candying are those which possess pronounced flavour like peels of orange, lemon, grape fruit and ginger.

Procedure for preparing candied fruits

Preparation of fruit: Stored fruit or peel is taken out from barrels and washed thoroughly in running cold water to leach out as much of the brine as possible. The fruit or peel is then placed in a cooking pan and boiled for about 15 minutes to remove traces of salt and to soften its texture.

Cooking in syrup: The prepared fruit or peel is boiled in cane sugar syrup (30°B) containing 0.1% citric or tartaric acid for 10-15 minutes and then left in syrup for about 24 hours. Next day, the syrup concentration is raised to 40°B by adding more sugar. The whole mass is boiled for about 5 minutes and left for another 24 hours. The process is repeated until the syrup reaches 60°B. Beyond this concentration, the syrup strength is progressively raised to 75°B at the rate of 5°B and boiling the mass on every alternate day.

Draining and drying: After syrup treatment, the fruits or the slices are removed from syrup and drained for about half an hour and sorted out to separate any defective and unwanted pieces. After this, the fruit/slices are dipped for a moment in boiling water to remove the adhering syrup followed by slow drying in the shade or in a drier at 66°C for 8 to 10 hrs.

Glacing: For glacing process, the sugar syrup is prepared by boiling sugar and water in 2:1 ratio in a steam pan at 113-114°C followed by cooling to 93°C. Sugar granulation is achieved by rubbing the syrup with a wooden ladle on the side of pan. Dried candied fruits are passed through this granulated portion of the syrup and then placed on the trays for drying in drier at 49°C for 2-3 hours. When the pieces become crisp, they are packed in air tight-containers.

Packaging: For retail trade, tin containers (15-20 kg capacity) and glass jars are used for storing preserves. Candied and crystallized fruits and peels are packed singly or in combination in layer in water proof paper or in polythene. Attractive china and porcelain jars are sometimes used for packing these products intended for exclusive export market. In addition to metal and glass containers, the newer flexible films can also be used, which are cheaper and highly effective.

Defects and spoilage: Spoilage due to fermentation occurs in the initial stages of preparation of preserves and candies when the concentration of sugar in the syrup is low. This can be checked by proper boiling of product at proper intervals. Storing of candied/glaced fruit in wet containers or under humid conditions brings about spoilage due to mould growth. Thus, storage of such product in air tight dry containers is recommended. Common defects and spoilage in preserves, candies, glazed and crystallized fruits is given in Table 9.1.

S. No.	Defect	Causes	Prevention
1.	Shrunken preserve	Use of heavy syrup	Use correct amount of sugar and water
2.	Dull brownish colour or cloudy appearance	Inferior fruit quality Over cooking after addition of sugar Failure to remove scum.	Use good quality fruit Use correct cooking time
3.	Tough fruit skin or peel	Fruit or peel not cooked until tender before sugar addition	Cook the fruit or peel until tender and then add sugar.
4.	Moulds on surface	Use of inferior quality fruits Under cooking Warm or damp storage	Use good quality fruit
5.	Fermented preserve after storage	Not enough sugar used Insufficient cooking Storage in warm place	Store in a cool and dry place.
6.	Sticky candy (after drying)	Final syrup not sufficiently concentrated	Always prepare syrup of correct concentration.
7.	Sticky during storage	Poor packing Damping storage	Always prepare syrup of correct concentration.

Table 9.1: Common defects and spoilage in preserves, candies, glaced and crystallized fruits

Lecture 10 - Drying of fruits and Vegetables

Objective: In this chapter, drying and dehydration of fruits and vegetables have been discussed. Advantages of drying, mechanism of drying, drying curve, advantage of dehydration over open sun drying, factors affecting dehydration, pre-drying treatments like blanching, sulphuring, drying methods, different types of driers alongwith advantages and disadvantages and osmotic dehydration are the major topics discussed in this chapter.

Introduction

Introduction

Drying refers to the method of removal of moisture content from the food to a level at which the activities of food spoilage and food poisoning micro-organism are inhibited. Drying under open sun is probably the oldest method of food preservation used for agricultural crops including food grains, oilseeds as well as fruits and vegetables. Most of the fruits and vegetables contain enough moisture to permit the activity of enzymes and micro-organisms for spoilage and drying is necessary to reduce the water activity. Therefore, reduction in water activity of the food is the main principle of preservation by drying. Two commonly used terms for dried foods are low moisture foods and intermediate moisture foods (IMF). During drying, a single layer of fruit and vegetables, either whole or sliced after primary pretreatments is spread on trays which are placed inside the dehydrator or in the open sun for drying. In mechanical dehydrator, the initial temperature is generally kept at 43^{o}C which is then gradually increased to 60-66^{o}C for vegetables and 66-71^{o}C for fruits.

- Dried foods or low moisture foods generally do not contain more than 25% moisture and have a water activity (aw) in the range of 0 to 0.6.
- Intermediate moisture (IMF) foods on the other hand contain 15 - 50% moisture with a water activity (aw) of 0.6 to 0.85.
- Drying under open sun is probably the oldest method of food preservation used for agricultural crops including food grains, oilseeds as well as fruit and vegetables.

Dried grapes (raisins and munacca), apricot, dates, Morchella (Guchhi), bael, peas, chillies, aonla, fig, etc are the commercial products prepared by drying. However, the temperatures used for drying are usually insufficient to cause killing of micro-organisms and enzymes. Therefore, any increase in moisture content during storage due to faulty packaging can spoil the product. Thus greater care is required for packaging and storage of dried products.

Advantages of drying

1. Helps in food preservation by reduction in water activity.
2. Reduction in weight and volume of the food (weight or volume of the dried product is reduced by 4 to 10 times from its initial fresh weight /volume).
3. Reduction in space requirement due to reduction in bulk and hence involves lower cost of packaging, storage and transport.
4. In comparison to other methods, drying is the cheap and simplest method of preservation.

5. Dried foods add variety to the diet and supply convenient ready to eat foods to the consumers.
6. Nutrient concentration is very high per unit weight of dried product.

Drying v/s dehydration: Drying and dehydration are inter-related terms and are used interchangeably to describe the unit operations involved in removal of water by evaporation or sublimation. Drying generally refers to the method of removal of moisture from the food under natural condition such as sunlight and wind such as open sun drying, shade drying etc. Whereas, dehydration refers to a process of removal of moisture by application of artificial heat under controlled conditions of temperatures, humidity and air flow

Mechanism of drying: Drying or dehydration involves the simultaneous application of heat and removal of water from the food. When hot air is blown over a wet food, the water vapour diffuses through a boundary film of air surrounding the food and is carried away by the moving air. A water vapour pressure gradient is established from the moist interior of the food to the dry air which provides the driving force for water removal from the food. The boundary film acts as a barrier to both heat transfer and water vapour removal during drying. The moving air velocity determines the thickness of the boundary film. Water vapour leaves the surface of the food and increase the humidity of the surrounding air, to cause reduction in the water vapour pressure gradient which reduces the rate of drying. Therefore, the moving air should be faster to reduce the thickness of boundary film and hence to achieve faster rate of drying. Hence, for drying of moist horticultural produce the parameters taken into consideration are moderately high dry bulb temperature, low relative humidity and high air velocity.

Drying curve: For each and every product, there is a representative curve that describes the drying characteristics for that product at specific temperature, velocity and pressure conditions. This curve is referred to as the drying curve for a specific product. Fig 10.1 shows a typical drying curve. Drying occurs in three different periods or phases like the first phase or initial period, the second phase or constant rate period and the third phase or falling rate period.

Advantage of dehydration over open sun drying:

1. The dehydration is much more rapid, controlled and efficient than open sun drying.
2. Dehydration requires less space (floor area) as compared to sun drying.
3. Dehydration is more hygienic as compared to open sun drying.
4. Dehydration is not dependant on weather conditions while drying is not possible under cloudy weather or during rains.
5. The colour of dehydrated product remains uniform due to uniform drying temperature.

Factors affecting dehydration

Factors affecting dehydration

Important factors affecting the rate of drying are:

1. Initial moisture content of the raw material
2. Composition of raw material
3. Initial load of the food kept in drier
4. Size, shape and arrangement of stacking of the raw material
5. Temperature, relative humidity and velocity of air used for drying
6. Rate of heat transfer on the surface of the food
7. Pre-treatment of the raw material prior to drying (peeling, blanching, sulphuring etc.)

During drying process the control of air temperature and its circulation in the system is important. If temperature is too low and humidity is too high, the food will dry more slowly and microbial growth may occur. Conversely, if the temperature is too high in the beginning, a hard shell will develop on the surface of the food which will prevent the removal of moisture from the interior portion of the fruit and moisture will trap inside the food material. This condition is known as case hardening. Further, the temperature that is too high at the end of drying period causes the food to scorch. Temperature between 49^{o}C to 60^{o}C is recommended for drying of fruits and vegetables. Temperature up to 65^{o}C may be used at the beginning, but should be lowered as food begins to dry. While, during the last hour of drying period, the temperature should not exceed 55^{o}C.

Procedure for drying

Drying of fruit and vegetables generally involves three stages: pre-drying treatments, drying and post drying handling, packaging and storage. Common flow-sheet consisting of different unit operations for drying of fruits and vegetables is shown in Fig 10.2.

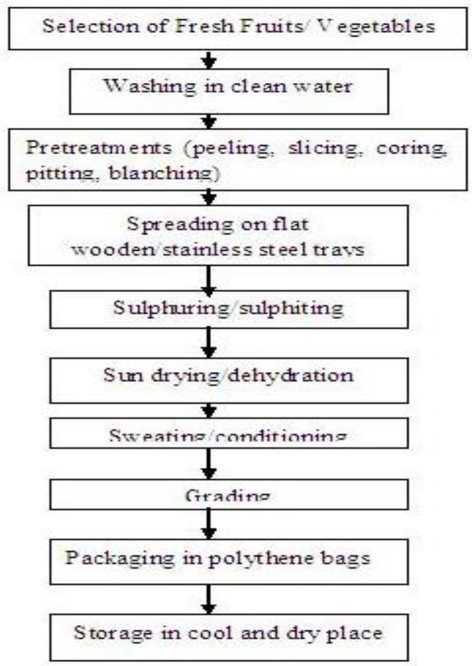


Figure 10.2: Process flow-sheet for drying of fruits and vegetables

1. Pre-drying treatments: Fruit and vegetables are selected and sorted according to size, maturity and soundness. They are then washed in running water to remove dust, dirt, insects, mould spores, plant parts, soils, debris and other materials that might contaminate or affect colour, aroma, flavor or taste of final product. Depending upon the type and quantity of produce to be dried, any method of peeling can be selected like hand peeling, steam, hot water, lye peeling or abrasive peeling. Fruits like grapes, plums, apricot are dipped in boiling caustic soda (0.5% NaOH) for few seconds and immediately placed in cold water to remove the waxy layer (grape, plum), pubescence (apricot, peach). After peeling and washing, the fruit and vegetables are sliced or cut into desired size and thickness as it affects the rate of drying (grapes, plums, apricots are dried whole).

2. Blanching: Generally all vegetables and mushrooms either whole or slices after preliminary preparations are blanched in boiling water or under steam to pre-determined period followed by immediate cooling to inactivate enzymatic activity prior to drying.

3. Sulphuring /Sulphiting: Majority of fruits are treated with sulphur dioxide by placing them in an enclosed chamber in which sulphur (3 g/kg fruit) is burnt to allow the SO_2 fumes to be absorbed by the fruits. The process is called as sulphuring or sulphur fumigation. Sulphiting on the other hand refers to dipping of prepared fruit or vegetables in a solution of potassium meta-bi-sulphite to serve the same purpose as that of sulphuring. Sulphuring or sulphiting helps to preserve colour, retard browning, reduces destruction of carotene and ascorbic acid besides checking spoilage of the dried product.

2. DRYING METHODS

a) Sun Drying: It consists of spreading fruit/vegetable either on roof tops or floor for drying in open sun.

This method is limited to certain fruits such as raisins, figs, apricots, dates, peaches and salted fish. After 10-12 days of drying the product is packaged in gunny bags/wooden boxes and sent to market for local or distant sale. The moisture content is generally not lowered below 15% which is too high for storage. The quality of product is inferior, characterized by brownish outer appearance and contaminated with insect dirt/dust particles. The quality can be improved by spreading the produce on black polythene sheet and covering it with thin muslin cloth to avoid entry of insects, dust or dirt particles on to the product.

b) Solar drier: Solar drier is an inclined rectangular box of 1.8 x 0.9 x 0.3 cubic meters. The internal dimensions made up of wood and lined internally with thermocol and tin sheets. Its top is covered with a glass sheet and inner sides are painted black. The air inlets and outlets (dampeners) are provided at the lower and upper ends to help in regulation of air flow and temperature. On an average 20-30^{o}C higher temperature can be attained inside the dehydrator as compared to ambient temperature. The loading capacity in solar drier of this size is 25-30 kg fresh fruit/vegetable spread on the trays each measuring 0.9 m× 0.45 m in size. Its fabrication cost is 5,000 (app.).

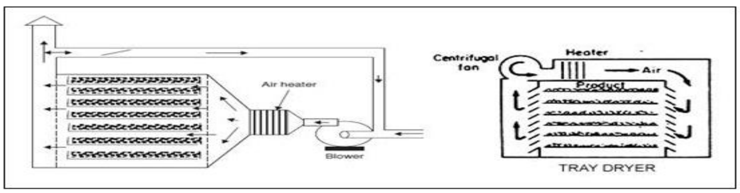
c) Polytunnel solar drier/ polyhouse solar drier: The basic principle is similar to solar drier. Polyhouse solar drier developed at Acharya N G Ranga Agriculture University, Baptla has a capacity to dry about 22-24 quintals of ripe chilies. It consists of 12×7.8×2.4 m (40'x26'x8') size arch type polyhouse with 1600 sq ft as tray area. Thirty two trays of size 10'×5'×3 (L×B×H) each are used to load 22-24 quintals of ripe chillies. Whole frame structure is covered with a UV stabilized 150 Gsm cross laminated transparent polyethylene sheet with well crow type ventilators at bottom and top of all three sides except on one side (north side) and two chimney ventilators on the roof cover to facilitate removal of moist air. Two chimney ventilators are placed on the top of the roof at a spacing of 4 meters. The height and diameter of each chimney ventilator are 0.6 and 0.25 meters respectively. Generally, temperature of about 15-17^{0}C higher than the ambient temperature can be obtained inside the drier.
Solar radiation is predominantly short wave radiation. The transmitted radiation through polyethylene sheet becomes long wave radiation after absorption and cannot escape from the polyethylene sheet thus leading to increase in temperature inside the drier. Covering of floor with black polyethylene sheet helps to retain better heat. Drying takes place due to convective movement of air caused by the difference in density of air inside the drier. The cold air enters through bottom 'well crow' ventilators and gets heated due to higher temperature inside the drier. The hot air moves through the bed of commodity being dried due to natural convection and transports moisture through the top well crow ventilators and chimney ventilators. The cost of drier is approximately Rs 1.20 lakh.

4. Dehydration equipment

A. Hot air Driers: In hot air driers the food is in contact with a moving stream of hot air. Heat is supplied to the product mainly by convection. Kiln drier, cabinet tray drier, tunnel drier, conveyor drier, bin drier, fluidized bed drier, pneumatic drier, rotary drier and spray drier use hot air for drying of fruits and vegetables.

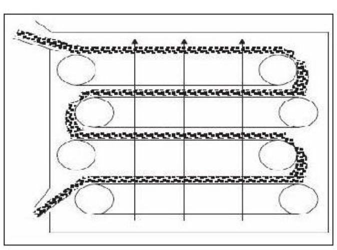
1) Kiln drier: These are mainly used for hops, apple rings and slices and malt drying. It consists of two storeys with a furnace or burner located on the ground floor and wet material placed on the top floor. The heated air from the furnace rises by natural or forced convection and passes through the slotted floor of the second storey, on which the wet material is spread in an even layer of 10-20 cm. The humidified air is exhausted through a flue in the upper story. However, in kiln drier there is limited control over drying condition and drying time is longer. Besides, regular turning of product is necessary.

2) Cabinet (tray) drier: In tray driers the wet food is spread evenly/thinly on trays in which drying takes place. These consist of an insulated cabinet fitted with shallow mesh or perforated trays, each of which contains a thin (2-6 cm deep) layer of food. Hot air is circulated through the cabinet at 0.5- 5 m/s per square meter tray area. Ducts or baffles are used to direct hot air through each tray, to promote uniform air distribution. Heating is by conduction from heated trays or by radiation from heated surface. The heated air also removes the vapours. Tray driers are used for small scale production (1-20 t/day) or for pilot scale work. They have low capital and maintenance costs but have poor control and more variable product quality.

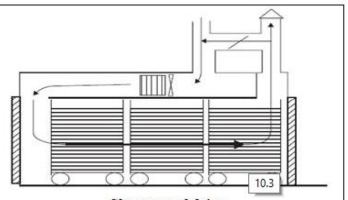


3) Conveyor drier (Belt drier): These are similar to tunnel drier, but the wet material is conveyed on moving belts rather than trucks. Continuous conveyer driers are up to 20 m long and 3 m wide. Food is dried on the belt in beds of 5-15 cm deep. The air flow is initially upward through the bed of food and then downwards in later stages to prevent dried food from blowing out of the bed. There can be 2 or 3 stage driers in which the food is mixed, repiled into deeper beds (15-25 cm in two stages and up to 250-900 cm in third stage). Major factors of conveyor driers are:

1. It improves uniformity of drying and saves floor space.
2. Food is dried up to 10-15 % moisture contents and finished in bin driers.
3. This equipment has good control over drying conditions and offers high production rates.
4. Can be used for large scale drying of foods (fruit and vegetable dried in 2.0-3.5 hours with a capacity up to 5.5 t/h).
5. Reduces labour costs, since it has independently controlled drying zones and is automatically loaded and unloaded.
6. Offers good replacement for tunnel driers.



Tunnel drier: It is the improvement of tray drier, in which trays move through a tunnel where heat is applied and vapours are removed. In most cases, air is used in tunnel drying and the material can move through the drier either parallel or counter current to the air flow. Typically a 24 m long tunnel contains 12-15 racks with total capacity of 5000 kg of food. The



Short tunnel drier

time taken for drying is 5-16 hrs

Parallel or co-current air flow: In this arrangement wet product as well as hot air moves in the same direction.

Advantages

- High rates of evaporation at the wet end without over heating of the material.
- Rapid initial drying.
- Little shrinkage of food
- Low bulk density
- Less heat damage to food.
- No risk of spoilage, since moisture content is removed at once.

Limitations

- Low moisture content in the finished product is difficult to achieve as cool moist air passes over dry food at the outlet.Flow patterns in tunnel driers

b) Counter current type: As such, relatively low initial rates of drying at the wet end are achieved. This causes high shrinkage of cellular material.

Advantages

- More economical use of energy.
- Low final moisture content can be achieved as hot air passes over dry food at the outlet.

Limitations

- Relatively low initial rates of drying at the wet end.
- Causes high shrinkage of cellular material.
- Possible risk of heat damage to the product due to the heat at dry end.
- Long exposure of food to a warm moist atmosphere and may lead to shrinkage.
- Two or more tunnels can be used in series.

c) Central exhaust tunnel drier: In this both features of co-current and counter current flow are combined.

Advantages: Combined benefits of parallel and counter current driers, but less than cross flow driers.

Limitations: More complex and expensive than single direction air flow.

d) Cross flow tunnel drier: In this arrangement the hot air is introduced at different compartments of wet food, thus the rate of drying is uniform.

Advantages

- Flexible control of drying conditions due to air heating facility between stages.
- Uniform drying due to frequent changes in direction of hot air.
- High drying rates.

Limitations

- More complex and expensive to buy
- Operate and maintain.

5). Foam mat drying: In this the liquid foods (fruit juices) are formed into stable foam by the addition of a stabilizer and aeration with nitrogen or air. For drying of lemon juice, carboxy methyl cellulose (CMC) can be mixed with juice to convert into foam. The foam is spread on a perforated belt to a depth of 2-3 mm and dried rapidly in two stages by parallel and thin counter current air flows. Foam mat drying is about three times faster than drying a similar thickness of liquid owing to thin surface area. The thin foam mat of dried food is ground to a free flowing powder which has good rehydration properties. The rapid drying and low product temperature give rise to high quality product.

Limitation: Large surface area is required for high production rates and capital costs are high.

6). Bin drier (Deep bed drier): Bin driers are used for final drying of dried food material. They are provided with cylindrical or rectangular containers fitted with mesh (false bottom). Hot air passes up through a bed of food at relatively low speed 0.5 ms-1 per square meter of bin area. In bin drier, the food stuff is contained in a bin with perforated bottom through which warm air is blown vertically upwards, passing through the material and drying it. Bin driers are also used for equalization of moisture content within the bulk of dried food material.

Advantages

- These driers have a high capacity and low capital and running costs.
- Bin driers improve the operating capacity of initial driers by taking the food when it is in falling rate period, when moisture removed is most time consuming.
- The deep bed permits equalization of varied moisture content in different layers of food.

7). Fluidized bed drier: Heated air is forced up through a bed of solids under such conditions that the solids are suspended in to the air. The heated air acts both a fluidizing and drying medium. Some units have vibrating bases to assist movement of the product. The drier may be batch or continuous type. The drier is used successfully for drying of peas, beans, carrots, cocoa, coffee etc. In some cases, dust separators (cyclones) are included in the exhaust air line to remove fumes.

Advantages

- Fluidized bed driers are compact and have good control over drying conditions.
- They provide high thermal efficiencies and high drying rates.
- Since product is mixed by fluidization, it leads to uniform drying.
- Fluidized bed driers are limited to small particulate foods that are capable of being fluidized without excessive mechanical damage.

8). Pneumatic drier: It is the extension of fluidized bed drier where higher air velocities are used. In this, the solid food particles are conveyed rapidly in an air steam, the velocity and turbulence of the air maintain the particles in suspension. Heated air accomplishes the drying and often classifying device is included in the equipment. The dry matter passes out as product and the moist product is recirculated for further drying.

In pneumatic driers, powders or particulate foods are continuously dried in vertical or horizontal metal ducts. A cyclone separator is used to remove the dried product. The moist food (less than 40% moisture content) is placed into the ducting and suspended in hot air. In vertical driers, the air flow is adjusted to classify the particles; lighter and smaller particles, which dry more rapidly, are carried to a cyclone more rapidly than are heavier and wetter particles which remain suspended to receive additional drying required.

Rotary drier: In rotary drier, slightly inclined rotating cylinder is fitted internally with flights to cause the food to move through a stream of hot air as it moves through the drier. Air flow may be parallel or counter current.
The food stuff is contained in a horizontally inclined cylinder through which it travels. The heating is done either by air flow through the cylinder or by conduction of the heat from the cylinder walls. In some cases, the cylinder rotates and in others the cylinder is stationary and the paddle or screw rotates through the cylinder conveying the material. The drier is used for drying of sugar crystals and cocoa beans.

Advantages

- The agitation of the food and the large area of food exposed to the air produce high drying rates and uniformly dried product.
- The drier is suitable for the products that tend to mat or stick on the belt or tray driers.

Limitations

- It may cause damage to the product by impact or abrasion in the drier.

10). Trough drier (belt-trough drier): Small, uniform pieces of food like peas and other dried vegetable are dried in a mesh conveyor belt which hangs freely between rollers, to form the shape of trough. Hot air is blown through the bed of food, and the movement of conveyor mixes and turns it to bring new surfaces continually into contact with the drying air. The mixing action moves food away from the drying air and then allows time for moisture to move from the interior of the pieces to dry the surface. The moisture is then rapidly evaporated when the food again contacts the hot air. The drier operates in two stages to 50-60 % moisture and then to 15-20 % moisture content. Final finishing of dried product is carried out in bin driers.

Advantages

- These driers have high drying rates (55 minutes for dried vegetable compared to 5 hours in a tunnel drier).
- High energy efficiencies with good control over drying conditions.
- Minimum heat damage to the product.

Limitation: Not suitable for sticky foods.

11). Spray driers: A fine dispersion of pre-concentrated food is first “atomized” (sprayed) to form droplets (10-200 µm in diameter) which are sprayed into the drying chamber at a temperature of 150-300^{0}C of heated air. The feed rate is controlled to produce an outlet air temperature of 90-100^{0}C, which corresponds to a wet-bulb and product temperature of 40-50^{0}C. Very short drying time and relatively low product temperature are the main features of spray driers. The main components of a spray drier include:

- Air heating and circulating system
- A spray forming system comprising of pressure nozzle, centrifugal atomizer and bowl nozzle
- A drying chamber
- Cyclone separator for product recovery (2 cyclones, scrubber with cloth filter)

For successful drying, complete and uniform atomization is necessary. Different types of atomizers are centrifugal atomizer, pressure nozzle atomizer, two fluid nozzle atomizer and ultrasonic atomizer.

Advantages:

- Due to very large surface area of the droplets, the drying is very rapid (1-10 s)
- The temperature of the product remains at the wet bulb temperature of the drying air.
- There is minimum heat damage to the food.

In spray drier, liquid or fine solid material in slurry form is sprayed in the form of fine dispersion into a current of heated air. Drying occurs very rapidly, thus this process is very useful for foods that suffer heat damage on long exposures. Spray driers are mostly used for milk, egg, coffee, cocoa, tea, potato, ground chicken, ice cream mix, butter, cream, yoghurt, cheese powder, coffee whitener, fruit juices, meat, encapsulated flavours, wheat and corn starch products.

B). Heated surface driers: Unlike hot air driers, the heat in heat surface driers is supplied to the food by conduction, thus resulting in higher thermal efficiency.

Advantages:

- It is not necessary to heat large volumes of air before drying commences.
- Drying can be carried out in absence of oxygen to protect foods that are sensitive to oxidation.
- Heat consumption is less than that of hot air driers. Heated surface drier utilize 2000 – 3000 kJ energy per kg of water evaporated while in hot air driers it is about 4000-10,000 kJ energy per kg of water evaporated.

Limitations: Since, foods have low thermal conductivities, which become further lower as the food dries. Therefore, the thin layer of food is required to conduct heat rapidly without causing heat damage.

Types of Heated Surface driers

Types of Heated Surface driers
1). Vacuum drum drier: Vacuum drum drier is the same except that they operate under a vacuum and heat transfer is by conduction or by radiation. The rollers are enclosed in a large cabinet which is evacuated. Vacuum drum driers are used for drying of potato flakes, dry soup and fruit juices.

2). Drum drier (Roller drier): In drum drier, slowly rotating hollow steel drums are heated internally by pressurized steam to 120-170^{0}C. A thin layer of food is uniformly placed over the outer surface of drum either by dipping, spraying, or spreading by feed rollers. Before the drum completes one revolution (within 20 seconds to 3 minutes) the dried food is scrapped off by a 'doctor' blade which contacts the drum surface uniformly along its length. Driers may have single drum, or double drum (twin drums). Drum driers are used for drying of milk powder.

Specific features of drum driers include:

- High drying rates with high energy efficiencies and their suitability for slurries where particles are too large for spraying.
- Heat damage to sensitive foods and high capital cost are the major limitations of such driers.

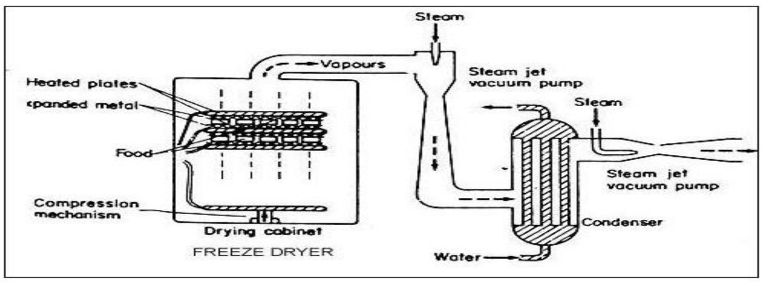
3). Vacuum shelf drier
Vacuum shelf driers consist of hollow shelves in a vacuum chamber. Food is placed in thin layers on flat metal trays which are carefully made to ensure good contact with the shelves. A partial vacuum of 1-70 torr (1.3 kPa to 93.3 kPa) is drawn in the chamber and steam or hot water is passed through the shelves to dry the food. They are used to produce puff dried foods.
Advantages

- It gives rapid drying and limited heat damage
- Suitable for heat sensitive foods.

Limitations: Relatively high capital and operating costs and low production rates.

4). Explosion puff drying: It involves partially drying of foods to moderate moisture content and then sealing it into a pressure chamber. The pressure and temperature in the chamber are increased and instantly released. The rapid loss of pressure causes the food to expand and develop a fine porous structure. It allows faster final drying and rapid rehydration. Sensory and nutritional qualities are well retained in this type of drying.

5). Freeze drying: Freeze drying is the sublimation/removal of water content from frozen food. The dehydration occurs under a vacuum, with the food product solidly frozen during the process. In the process of freeze drying, the food is first frozen at -18^{0}C in the lower chamber of a freeze drier and then the frozen material is dried initially at 30^{0}C for 24 hrs then at 20^{0}C until complete drying under high vacuum (0.1 mm Hg) in the upper chamber. The final product is highly hygroscopic, excellent in taste and flavour. Mango pulp, concentrates, passion fruit juice and guava pulp are dehydrated by this method and give freeze-dried powders of excellent quality for taste, flavour and reconstitution property. Freeze dryer utilizes the principle that under high vacuum (27-133 Pa pressure) frozen water can be removed from a food and collected without going through a liquid phase. Because the material remains frozen, no heat damage occurs. The material is directly dried by sublimation of ice without passing through intermediate liquid phase.



Osmotic dehydration

The fruit which are highly acidic and have sensitive aroma can be dried by using osmotic dehydration. In this method the fruits after preliminary treatment are placed in hypertonic solution of 70^{0}B sugar syrup and kept for 4 hrs to overnight. During this period, the water oozes out in syrup due to osmosis. About 50% of moisture from the fruit is removed in can process. The fruits are then drained from the syrup, rinsed and further dried in hot air drier to desired moisture content. During osmotic drying, acid from the fruit oozes out in the syrup while some sugar enters in the fruit thus the final product attains the required sugar acid balance. Apricots, grapes, apple etc. can be dried by using osmotic drying.

Packaging and storage of dried products

After foods are dried, cool them completely. Then packaging is done in clean moisture-vapor-resistant containers. Glass jars, metal cans or freezer containers are good storage containers, if they have tight-fitting lids. Fruit that has been sulfured or sulfited should not touch metal. Place the fruit in a plastic bag before storing it in a metal can. Dried food should be stored in a cool, dry, dark place. Most dried fruits can be stored for 1 year at 60°F, 6 months at 80°F. Dried vegetables have about half the shelf-life of fruits. Polypropylene (PP), laminate of metallised polyester (PET), low density polyethylene (LDPE) is suitable for a shelf-life of at least 6 months.

Different types of packaging materials used are:

1. Rigid containers like metal cans and plastic containers, which are air-tight and light proof and check the entry of moisture and oxygen. They are easy to handle during transportation.
2. Semi-rigid packs, like line carton and bag-in-box, maintains the freshness of the food product till it is opened. An ideal laminate is made up of layers of paper/low density polyethylene (LDPE)/Al-foil/ which ensures the shelf life required.
3. Flexible pouches can be handled and opened easily.

Lecture 11 - Preservation with Salt and Vinegar: pickles, Chutney and Sauces

Objective: This chapter deals with the methods of preservation by using salt and vinegar. Salt is mostly used as preservative in pickles in combination with acid. Different types of fermented pickles, pickles in oil, pickles in vinegar, vegetable pickles are discussed in detail in this chapter. Procedure for making chutney and sauces from different fruits and vegetables are also discussed along with common defects during storage of pickles and FPO specifications are also discussed for manufacture of different products in view of demand.

Introduction

Introduction

The preservation by using common salt, spices and vinegar is a common method for preparation of pickles, sauce and chutneys. Salt is mostly used as preservative in pickles in combination with acid. Minimum concentration of salt to act as preservative is about 12%. It inhibits enzymatic browning/discoloration by acting as an anti-oxidant. It exerts its preservative action by:

- Causing high osmotic pressure and thus suppress the microbial cells.
- Dehydrating food by tying up the moisture thus making it unavailable for the growth of microorganisms.
- Salt in the food affects the solubility of oxygen and thus growth of aerobic microorganisms is inhibited
- Chlorine in sodium chloride being good oxidizing agent is toxic to microorganisms
- Salt increases the permeability of the cell wall and thus cause changes in the permeability. Only the haloduric microorganisms can tolerate these effects while others are unable to survive.
- Similarly addition of acid to the food lowers the pH of the food which inhibits the growth of spoilage causing microorganisms.
- Addition of spices and edible oil in these products besides improving flavour and taste also help in preservation.

Thus preservation by using salt, spices and acid is one of the most ancient and effective methods of food preservation. Vegetable sauce, continental sauce, tomato sauce, mixed fruit chutney, mango pickle, lime/lemon pickle, mixed vegetable pickle etc are common products made in this category.

PICKLES: The preservation of fruit and vegetables in salt and vinegar is called pickling. Pickles may prepare without fermentation or with partial or complete fermentation. Spices, edible oil, sugar/jaggery etc are added to improve taste and palatability of the product. Thus, pickles are good appetizer and help in digestion by stimulating the flow of gastric juices. The nutritive value of pickle varies with the kind of raw material used and method of preparation such as with or without fermentation. Manufacturing of pickle has developed as an industry in the country. Mango pickle, cauliflower, turnip, carrot (mixed vegetable), anola, lime/lemon pickle etc. are the commercial products available in the market.

Pickling process: Pickling is the process of fermentation by lactic acid forming bacteria, present on the surface of commodities. Lactic acid bacteria (active at 30°C) convert fermentable sugar in the food to lactic acid and volatile acids. The acid and brine acts upon vegetable tissues to produce characteristic taste and aroma of pickle. The salt and lactic acid formed preserve the pickle by preventing the growth of putrefactive bacteria provided oxygen is excluded. Fermented cucumber and olive pickles are quite common. Pickle is prepared by using either of following processes followed by finishing and packing:

- Curing or fermentation with dry salting
- Fermentation in brine
- Salting without fermentation

A). Dry salting

The dry salt added to the prepared vegetables, extracts the juice from the vegetables and forms the brine. The brine is then fermented by lactic acid forming bacteria which serves the purpose of pickling. The method is known as dry salting.

Procedure for dry salting

1. Vegetables are washed, sliced and placed in barrel in layers to which salt is sprinkled followed by placing another vegetable layer and sprinkled with salt. Generally, 3 kg dry salt is used for each 100 kg of prepared vegetable. The salt is added in layers till the barrel is ¾ full. The vegetables are covered with a cloth and wooden board along with a weight to press the vegetable. Brine is formed in 24 hours.
2. The barrel is placed in warm and dry place to allow the fermentation to proceed within short period. Once brine is formed, fermentation and bubbles of CO_2 begin to rise from the liquid. The fermentation temperature is 27-32^0 C and completes in 8-10 days.
3. When the gas bubbles cease to form, the fermentation is considered as complete. This may be confirmed by taping the barrel gently. The pickle is then pressured and packed by excluding the air.
4. If air is not removed from the pickle, pickle scum (a type of mould yeast) appears on the surface, which destroys the lactic acid formed by fermentation and spoils the pickle.

Methods to remove air /expel air from the pickle:

1. 1. By making air seal on the surface of brine by pouring 0.6 cm thick layer of edible oil (rapeseed oil/mustard oil or cotton seed oil) on the top of it. The oil being lighter than brine floats on the surface and prevents the access of air in to the pickle.
2. 2. After dry salting and fermentation, the barrel is filled with the prepared vegetables to its maximum capacity and covered with a lid. A 1.25 cm hole is bored in the lid (cover). The barrel is filled up to the brim with the brine so that

very little air is left inside. It is allowed to stand for 48 hours till all gas bubbles ceases to rise. When the bubbling stops the vent hole is closed tightly and barrel kept in a cool dry place.

3. 3. The barrel is kept undisturbed. The molten paraffin wax is poured over the surface of the brine. It imparts air tight-seal. The paraffin wax can be easily separated from the brine and the wax can be remelted and reused.

B). Fermentation in Brine (Brining)
Immersing vegetable or unripe fruits like mangoes in salt-solution of known concentration for a certain length of time is called brining. Brining is generally used for pickling of cucumber, olives, raw mangoes and similar other vegetables, which do not contain sufficient juice to form brine with dry salt.

Brine preparation: Brine is prepared by dissolving common salt in water and filtered through a muslin cloth. The amount of brine required to cover the vegetable is approximately equal to about half the volume of the material to be fermented (for each barrel of 100 litres, about 50 litres of brine is required). Brine with 8 -10 % strength is considered optimum for the growth of salt tolerant lactic acid bacteria.
Thus vegetables are placed in 10 % brine to allow lactic acid fermentation to take place and then the proportion of salt is increased gradually, so that when pickle is ready, salt concentration would have reached 15 % level. The brine strength can also be maintained by adding dry salt. Brining takes about 4-5 weeks.

C). Salting without fermentation
In this method, vegetables raw mango slices are packed with a large quantity of salt to inhibit fermentation. Generally, 25 kg salt is mixed with 100 kg of prepared vegetable. The cured vegetables are drained and excess salt is removed by soaking in cold or warm water. After removal of salt, the vegetables are stored in plain vinegar 10% (100 grain) strength. This treatment reduces the tendency of the vegetable to shrivel when packed in sweetened and spiced vinegar and also helps in absorption of vinegar by the vegetable tissues.

Packing: After curing, the vegetables become semi translucent in appearance with their colour changing from green to dark olive green or yellowish green. During this process the raw flavour of the vegetables is lost and the texture becomes firm and crisp. For good keeping quality they are packed by using salt, vinegar and lactic acid in sufficient quantities which act as preservative either singly or in combination.

1. Salt: The concentration of 15-20% salt is used for pickling. Mould and lactic acid forming bacteria do not grow at this concentration. The fermentation of vegetables is inhibited when they are covered with strong brine or packed with fairly large quantity of salt. This method of preserving is applicable to those fruit and vegetables which contain very little sugar because sufficient lactic acid cannot be formed by fermentation to act as preservative.

2. Vinegar: Vinegar acts as preservative in vinegar pickles by lowering down the pH of final product. The final concentration of acid as acetic acid in the finished pickle shall not be less than 2%. However, vegetables are placed in strong vinegar of 10 % acidity to avoid dilution of the vinegar by the water liberated from the tissues. This treatment helps to expel the gases present in the intracellular spaces of vegetative tissues and prevents subsequent dilution of the vinegar in the pickle. Spiced vinegar can be prepared by soaking the ground spices in vinegar, boiling the spices in the vinegar or by adding essential oil of spices and added to the prepared pickle.

3. Lactic Acid: Though bacteria do not grow in acidic media, yet lactic acid bacteria are capable of growing in acidic media and can also produce acid through their action on the substrate. They can also grow in high salt concentration of 8-10%. This principle is used in pickling as growth of undesirable organism is inhibited by adding salt and allowing the lactic fermentation to proceed. The pickled vegetables (onion, garlic, green chilies, olives etc) are then packed in to the glass jars without damaging the shape and appearance of the pieces and covered with fresh vinegar to fill up the spaces between the pieces. The closed jars are then stored in a cool dry place for some time to allow thorough absorption of vinegar before sending them to the market. Brined vegetables and raw mango slices are also used for preparing different types of pickles by using combinations of spices, salt and vinegar.

Types of Pickles

Types of Pickles: Pickles are generally categorized into fermented pickle and partial or non-fermented pickles. Cucumber and olive pickles are examples of fermented pickles. While non-fermented pickles are of four general types depending upon the covering medium used.

1. Pickles preserved with salt: lime and mango pickle.
2. Pickles in oil: Mango, lime, lemon, cauliflower, aonla, karonda.
3. Pickle in vinegar (acetic acid): Garlic, green chilli etc.
4. Pickle in mixture of salt, oil, spices and vinegar: Cauliflower, carrot, jackfruit, mixed vegetable pickle etc.

A. Fermented pickles: Cucumber pickle, dill pickle and olive pickle.

i. Fermented cucumber pickle: For preparation of fermented cucumber pickle, the immature cucumber are washed, placed in barrels or tanks and filled with brine (salt solution). Salt is added either by using low salt method or high salt method. In low salt method 8% brine (30o salometer) is added to the cucumber along with 9 kg salt per 100kg cucumber. In high salt method, the brine of 10.5% salt (40o salometer) and 9 kg salt per 100 kg cucumber is used. The cucumbers are kept submerged in brine and brine strength is increased weekly by about 3o salometer up to 60o salometer (15.9% salt). In low salt method, increase in brine strength is about2o per week up to 50o salometer and 1o per week up to 60osalometre. It lakes about 6-9 weeks for completion depending upon the method of salting and temperature of fermentation. During fermentation, most of the lactic acid is produced by the action of Lactobacillus planetarium. However, Lactobacillus brevis, Streptococcus faecalis, Pediococcus cereviseae, Leuronostoc mesenteroides and Coliform bacteria. Total titratable acid on completion of fermentation range between 0.6-0.8 percent. Initial colour of the cucumber from chalky white and opaque in cross section changes to olive or yellow green with translucent flesh after completion of fermentation. The prepared pickle is too salty to taste which is freshened by soaking and made into sour, sweet sour or mixed pickles.

ii. Dill pickle: Dill pickle is also a cucumber pickle prepared by using dill herbs as flavourant along with spices, garlic and onion. Overnight dill pickle and genuine dill pickle are the common types of dill pickle.

iii. Olive pickle: In preparation of olive pickle, fully developed but still green or straw yellow olives are treated by dipping in 1-2% lye solution to remove the bitterness of olives due to glucoside oleuropein. During this treatment, the lye penetrate up to ½ to ¾ towards the pit; which is detected by placing a drop of phenolphthalein to give faint pink colour. This treatment removes most of the bitterness of olives. The fruit after washing are placed in barrels containing 10-15% brines which results in a salt concentration in olives of about 6-9% after stabilization. During fermentation the salt concentration is mainted 7-8% throughout by adding more salt. Lactic acid fermentation takes about 6-9 months depending upon the atmospheric temperature. Generally 29oC is the optimum temperature for rapid fermentation. During the initial stage of fermentation lasting for 7-14 days the brine stabilizes, food for micro- organissum leach out from the olives and potential spoilage organism like Pseudomonas, Enterobacter, Clostridium, Bacillus and yeasts may grow in Leuconostoc mesenteroides starts. In the next intermediate state lasting for 2-3 weeks Lectronostoc become permanent in growth and acid production and Lactobacillus brevis began to grow and produce acid. In the final stage, Lactobacillus plantarum become predominant and produce acid. The final acidity is about 0.7-1.0 percent with a pH of 4.0 -3.8 or lower. After fermentation, the olives are sorted and graded, washed and packed into glass jar or other containers and covered with fresh brine (7% salt) containing edible lactic acid. They may be pasteurized in container at 60oC or brined at 79-82oC for good keeping quality.

iv. Spiced olive pickle: The fermented olives can also be used for preparation of spiced pickles. For preparation of spiced pickles, the olives after draining from brine are kept in shade for removal of surface moisture. Chopped onion, garlic and ginger are fried in oil to which olives are mixed. Ground spices like cumin, cardamon, black pepper along with salt and turmeric are mixed thoroughly. Acetic acid and sodium benzoate are mixed during the packing of pickle in glass jars. Jars after filling with mustard oil are sealed and stored in cool and dry place.

B. Pickles preserved with salt: Lime and mango pickle.

i. Mango pickle

Recipe: Mango slices 1.0 kg, Salt 200g, red chilli powder 10g, turmeric powder 10g, asfoetida (heeng) 5g, black pepper, cardamom (large), fenugreek, cinnamon (ground) and cumin 10g each.

Procedure: Wash the mature green mango fruits, cut into 4 equal pieces (depending upon fruit size) and remove the kernel. Mix the fruit slices with salt and turmeric powder. Fill mango slices in glass jars and keep the covered jars in sunlight for 7-10 days. Shake the jar at least 2-3 times during drying (Fig 11.1). Mix the ground spices in well dried mango slices. Store the pickle in cool and dry place.

ii. Lime pickle

Recipe: Lime 1.0 kg, Salt 200g, red chilli powder 15g, black pepper, cardamom (large), cumin 10g each.

Procedure: Wash the lime fruits, cut into 4 equal pieces. Squeeze the juice from ¼ of fruits and mix the salt and ground spices with juice. Mix the lime pieces with the mixture and fill into glass jars. Cover the jars with lid and keep in sunlight for 4-6 days. Shake the jars atleast 2-3 times during drying. Store the pickle in cool and dry place at ambient temperature. Similarly the sweet pickles from mango and lime is made by adding 500-700g jaggery or sugar to the above recipe.

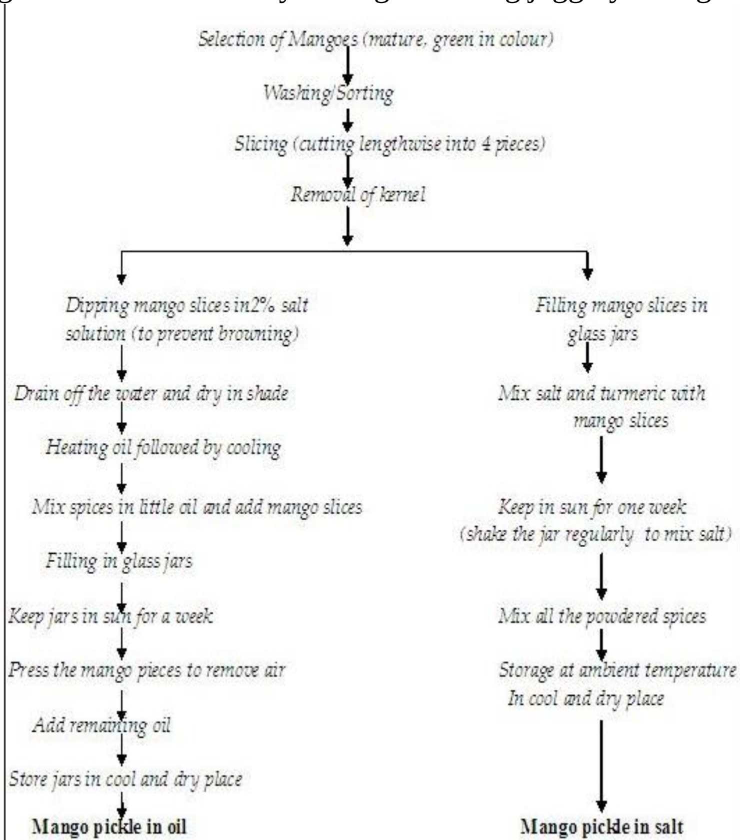


Figure 11.1: Flow sheet for preparation of mango pickle in oil and salt

C. Pickles in oil: Mango, lime, lemon, cauliflower, aonla, karonda etc.

i. Mango pickle

Recipe: Mango slices 1.0 kg, salt 150g, powdered fenugreek 25g, red chilli powder 10g, turmeric powder 15g, black pepper, cardamom (large), cinnamon (powdered), cumin, powdered aniseed 15g each, asafoetida 2g and mustard oil 350ml.

Procedure: Wash the mature green mango fruits, cut into 4 equal pieces length wise (depending upon fruit size) and remove the kernel. Dip the mango slices in 2% salt solution to prevent browning. Drain off the water and dry the slices in shade for 4-5 hours (Mango slices preserved in salt can also be used for pickle preparation). Heat the oil, cool and mix spices in a little oil and mix the fruit slices thoroughly. Fill mango slices in glass jars and keep the covered jars in sunlight for a week. Shake the jars atleast 2-3 times during drying. Press the mango slices to remove the air, add remaining oil to cover the mango slices. Store the pickle in cool and dry place at ambient temperature (Fig. 11.1).

ii. Aonla pickle

Recipe: Aonla 1.0 kg, salt 150g, powdered fenugreek 30g, red chilli powder 10g, turmeric powder 10g, cumin 10g and mustard oil 350 ml.

Procedure: Wash the mature healthy aonla fruits. Boil for 15 minutes to soften segments, cut and remove the seed. Heat the oil and fry all spices. Mix the segments with spices. Mix salt with aonla segments and fill in the jar. Keep the jar in sunlight for a week. Press the aonla pieces to remove the air, add remaining oil. Store the pickle in cool and dry place.

iii. Karonda pickle

Recipe: Karonda 1.0 kg, salt 200g, red chilli powder 15g, turmeric powder 10g, cumin 10g, powdered fenugreek 10g, aniseed 10g and mustard oil 300 ml.

Procedure: Select mature, pink colour karondas and wash in clean water. Cut into two pieces and remove the seed. Mix salt with karonda and fill in the jar. Keep the jar in sunlight for 4 days. Heat the oil, fry all spices and mix the segments with spices thoroughly. Add remaining oil and store the pickle in cool and dry place.

iv. Green chili pickle

Recipe: Green chilies 1.0 kg, salt 150g, mustard 100g, lime juice 200ml, powdered fenugreek, aniseed, turmeric, cardamom large, cumin, 15g each and mustard oil 400 ml.

Procedure: Select healthy green chilies and wash in clean water. Make incision and mix all spices in a little lime juice. Mix all spices in chilies and fill in clean jars. Add lime juice and keep the glass jars in sunlight for a week. Store the pickle in cool and dry place.

D. Pickle in vinegar (acetic acid): Garlic, green chili, papaya etc.

i. Papaya pickle

Recipe: Green papaya slices 1kg, salt 150g, red chilli powder 10g, black pepper, cardamom (large), cinnamon (powdered), cumin 10g each and vinegar 750ml.

Procedure: Select green but mature papayas. Wash the fruits, peel, cut into equal sized slices and remove the seeds. Dip the cut pieces in boiling water to soften, remove papaya slices from boiling water. Mix with salt and dry in shade for few minutes. Mix the slices with spices thoroughly. Fill in glass jars and add vinegar to cover all the slices. Keep the covered jars in sun for a week and store the pickle in cool and dry place.

ii. Cucumber pickle

Recipe: Cucumber 1.0 kg, salt 200g, red chilli powder 15g, black pepper, cardamom (large), black pepper powder, cinnamon (ground) and cumin 10g each, clove 6 numbers and vinegar 750ml.

Procedure: Select green immature cucumbers. Wash, peel, cut into equal 5 cm thick slices. Mix slices with salt and fill in glass jars. Keep for about for about 6 hours and drain off water. Add all the spices and vinegar to the drained slices. Keep the covered jars in sun for a week and store the pickle in cool and dry place. Similarly pickle from other fruits can be made by following the same method.

E. Pickle in mixture of salt, oil, spices and vinegar: Cauliflower, carrot, jackfruit, mixed vegetable pickle, etc.

i. Cauliflower pickle

Recipe: Cauliflower florets/slices 1.0 kg, salt 150g, ginger (chopped) 25g, garlic 10g, red chilli powder, turmeric, black pepper, cardamom (large), cinnamon (powdered), cumin, aniseed powder 15g each, tamarind pulp 50g, mustard seeds 50g, vinegar 150ml and mustard oil 400ml.

Procedure: Select healthy and fresh cauliflowers. Wash and cut into equal pieces 2-2.5 cm. Blanch in boiling water for 2-4 minutes, drain and keep in sunlight for 2 hours. Fry all the spices in a little oil and mix them with cauliflower slices. Heat for 5 minutes and cool. Make paste of tamarind pulp in vinegar and add with cauliflower slices. Fill in the jar, keep in sunlight for a week. Add oil after heating and cooling to keep the pickle for long time. Store the pickle in cool and dry place. Sodium benzoate @ 250 ppm can be added as a preservative.

ii. Turnip pickle (sweet)

Recipe: Turnip 1.0 kg, salt 100g, ginger (chopped) 20g, garlic 10g, red chilli powder, turmeric, black pepper, cardamom (large), cinnamon (powdered), cumin, aniseed powder 10g each, tamarind pulp 100g, mustard 20g, vinegar 100ml, jaggery 200g and mustard oil 200ml.

Procedure: Select healthy, sound and tender turnip. Washing, trimming and peeling is done to remove rough and thick skin. Cut into equal pieces of 1-1.5cm thickness. Blanch for 5 minutes, drain the water and dry in shade to remove moisture. Fry the spices in a little oil except tamarind. Mix the turnip slices with spices thoroughly. Make paste of tamarind pulp in vinegar along with jaggery and mix paste with turnip slices. Fill in the jar and keep in sun for a week. Add oil after heating and cooling to keep the pickle for longer time. Store the pickle in cool and dry place. Sodium benzoate @ 250 ppm can be added as a preservative.

iii. Mixed vegetable pickle

Recipe: Cauliflower + carrot + turnip 1.0 kg, salt 100g, red chilli powder 15g, ginger (chopped) 20g, onion chopped 50g, red chilli, turmeric, black pepper, cardamom (large), cinnamon (powdered), cumin, aniseed powder 10g each, mustard 50g, vinegar 200ml and mustard oil 350ml.

Procedure: Mixed vegetable pickle is prepared similarly to that of sweet turnip pickle. If sweetness is required then jaggery may be added by making a paste with vinegar. Sodium benzoate @ 250 ppm can be added as a preservative.

iv. Jackfruit pickle (sweet) (Fig. 11.2)

Recipe: Jackfruit slices 1.0 kg, salt 100g, red chilli powder 15g, ginger (chopped) 20g, turmeric, black pepper, cardamom (large), cinnamon (ground), cumin, aniseed powder 10g each, mustard 20g, vinegar 150ml, jaggery 250g and mustard oil 350ml.

Procedure: Select small mature jackfruits, wash, peel and cut into equal suitable sized slices. Steeping in 10% salt solution is done for a week. Drain off the brine and wash the slices with plain water. Fry all the spices in oil except vinegar, jaggery or sugar. Mix spices with jackfruit slices and fry for 5 minutes, allow to cool and fill in the glass jars. Keep the jar in sunlight for a week. Make paste of sugar/jaggery with vinegar and mix the paste to the prepared slices. Store the pickle in cool and dry place (Fig 11.2).

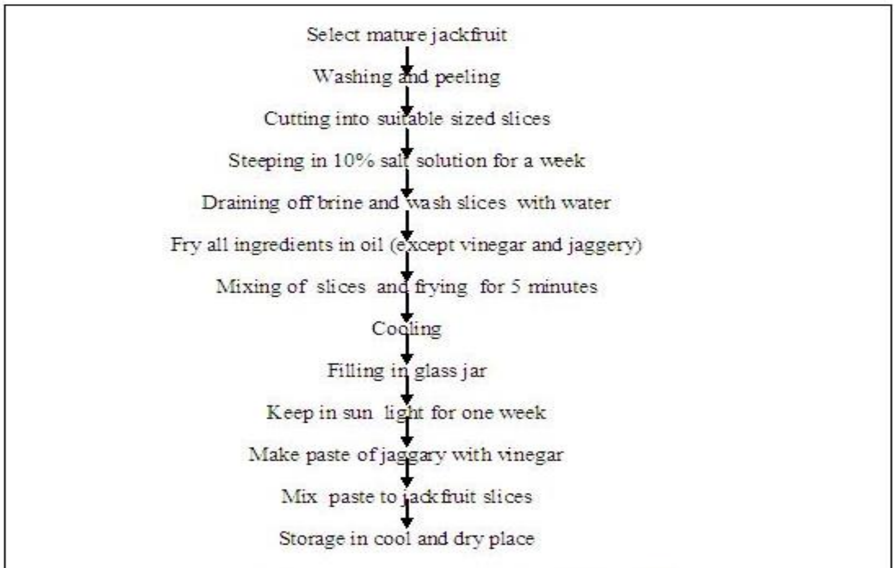


Fig. 11.2: Flow sheet for preparation of jackfruit pickle

Common defects of pickles during storage (Table 11.1)

Table 11.1: Common defects noticed in different pickles during storage.

S.No.	Common Defects	Cause
1.	**Blackening**	It is mainly due to the presence of iron which enters through the brine or from the equipments. Blackening may also be caused by the action of microorganisms.
2.	**Dull and faded pickle**	It is due to either insufficient curing or use of water of inferior quality.
3.	**Shriveling**	It occurs when vegetables like cucumber are placed directly in a very strong solution of salt or vinegar. To avoid this, use weak solution at the start and increase gradually.
4.	**Softness and slipperiness**	It is the most common type of spoilage caused by the action of bacteria. Use of weak brine or improper covering with brine results in these defects. Thus this defect can be checked by using brine of proper strength and keeping the pickle well below the surface of the brine.
5.	**Bitter Taste**	It is due to the use of very strong vinegar or cooking the spices for a long time or by using spices in excess.
6.	**Scum formation**	It is due to growth of film yeast on the brine kept for curing of vegetables. The scum may be thin or thick varying from imperceptible film to a thick wrinkled layer. It retards the formation of a lactic acid and helps in the growth of putrefactive bacteria which makes the vegetable soft or slippery. The scum may be removed as soon as it is

		formed. Use of 1% acetic acid to the brine prevents the growth of wild yeast on the brine, without hindering the formation of lactic acid.
7.	**Cloudiness**	In many fermented solid vegetables like onion, cucumber, olives etc the vinegar becomes cloudy and turbid, thus spoiling the appearance of the product. It is due to non-penetration of acetic acid from vinegar deep in to the tissues to check the activity of bacteria or other micro organisms. This results in fermentation which make the vinegar cloudy. Use of brine and vinegar of proper strength prevents cloudiness.
8.	**Blemishes in pickles**	In onion pickle in brine, white blotch is seen under the first layer of the skin which is termed as blemish. Blemishes are generally caused by improper fermentation or non removal of all brine prior to the final pickling of cured onion in vinegar.

FPO specifications for pickles: According to FPO specifications the minimum percentage of salt (w/v) in pickle in brine shall be 12% while for pickle in citrus juice the acidity as citric acid shall not be less than 1.2% and only citrus fruit juices should be used . For oil pickles any edible vegetable oil like rapeseed, mustard, olive etc can be used. Other general characteristics for these pickles include use of wholesome fruit and vegetables which are free of fungal or insect attack or any rotting. All ingredients shall be thoroughly clean and free from of extraneous matter. Only substances that may be added are spices, salt, sugar, jaggery, onions, garlic, benzoic acid, soluble calcium salts. Pickles shall be free from added copper, alum, mineral acids or other preservatives.

Chutney and Sauces

Chutney and sauces are the important products prepared from fruits and vegetables. Salt, spices, sugar, acid in these products is added to improve taste and to act as a preservative. These products are well known for their palatability and appetizing nature. Mango, apple, plum, apricot, tomato, carrot etc are the raw materials for these products. Mango chutney, plum chutney and mixed fruit chutney are quite popular. Fruit chutney is a product-made in the same way as that of jam except that spices, salt and vinegar are also added. Vinegar extract of the spices is added most preferably in place of whole spices. The chutney shall contain minimum of (40% fruit)(w/w) in the final product with total soluble solids not less than 50% and acidity not exceeding 2.1%. Sauces are also prepared from more or less similar ingredients and in same manner as chutney. Except the fruit pulp is sieved after cooking to remove the skin, seeds and stalks of vegetables; to give a smooth consistency to the final product. The consistency of sauce is comparatively thin than of fruit chutney. According to FPO specifications, the quantity of total soluble solids and acidity as acetic acid in the sauce shall not be less than 15% and 1.2% respectably. Sauces may be of two kinds. Thin sauces of low viscosity mainly consist of vinegar extracts of flavouring spices, herbs etc and thick sauces which are highly viscous.

Fruit Sauce: A fruit sauce of better quality should be cooked to such a consistency that it can be poured freely without fruit tissues separating out in the bottle. The colour should be bright. The neck of jar/bottle should be covered with paraffin wax layer for airtight sealing.

Fruit chutney: The recipe for preparation of fruit chutney from different fruits is given in following table as a general guideline and method is discussed as under:

Table 11.2: Recipe for preparation of chutney from different fruits.

Recipe	Mango	Apple	Plum	Apricot	Papaya
Fruit slices/pulp, kg	1	1	1	1	1
Sugar, gm	750	750	750	1000	750
Cumin, black pepper, cinnamon, aniseed, g (each)	10	10	10	10	10
Cardamom (large), red chillies powder, g (each)	10	10	10	10	10
Salt, g	45	45	45	45	45
Onion chopped, g	50	250	50	50	100
Garlic chopped, g	15	15	15	10	15
Vinegar, ml	170	200	175	150	200
Clove (headless), No's	4-5	4-5	5	5	5
Sodium benzoate (ppm)	250	250	250	250	250

Procedure for preparing chutney

The fruit/vegetable is cut into slices of suitable size. Softened by dipping in boiling water. Slow cooking is preferred to yield better product than that of bristle heating at high temperature. Onion and garlic are added at the start to mellow their strong flavour. Spices are coarsely powdered and added. Spices can also be added by placing all ingredients in a cloth bags, loosely tied and placed in the mixture during cooking. Vinegar extract of spices can also be added. The vinegar is added just little before final stage of boiling. In place of vinegar, acetic acid can also be used as source of acidity. The product is cooked to a consistency of jam and filled hot into sterilized jars. The product can be pasteurized and processed at 82^0C for 30 minute. The storage of chutney in done at ambient temperature in cool and dry place.

1. Mango chutney

Procedure: The complete process for mango chutney is given in flow sheet (Fig. 11.3) **Figure 11.3: Flow sheet for preparation of mango chutney**

2. Apple chutney

Procedure: Apple chutney is also prepared as mango chutney. The fruit slices are cooked with salt. All spices except vinegar and sugar are added and the mixture is cooked gently to the desired consistency. Sugar is then added and cooking for 5 minutes is done. Hot filling of chutney in glass jars followed by sealing helps to keep chutney for longer time. The jars are stored in dry and cool place.

NOTE: Chutney from plum, apricot, papaya etc is also prepared similarly as mango chutney.

SAUCE: Recipe used for preparation of fruit sauce as a general guideline is given in following table and explained as under:

Procedure for preparing sauces

Sauces are of thinner consistency as compared to ketchups and contain not less than 15^0B total soluble solid. Plum apple, papaya and mushroom etc are used successfully for preparation of sauces. High quality sauces are prepared by maceration of spices, herbs, fruits and vegetables in cold vinegar or by boiling. Thickening agents can also be added to sauces to prevent sedimentation of solid particles. Flow sheet for the preparation of sauce is given in Fig 11.4.

Table 11.3: Recipe for preparation of sauces from different fruitsFigure 11.3: Flow sheet for preparation of mango chutney

2. Apple chutney

Procedure: Apple chutney is also prepared as mango chutney. The fruit slices are cooked with salt. All spices except vinegar and sugar are added and the mixture is cooked gently to the desired consistency. Sugar is then added and cooking for 5 minutes is done. Hot filling of chutney in glass jars followed by sealing helps to keep chutney for longer time. The jars are stored in dry and cool place.

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Table 11.3: Recipe for preparation of sauces from different fruits

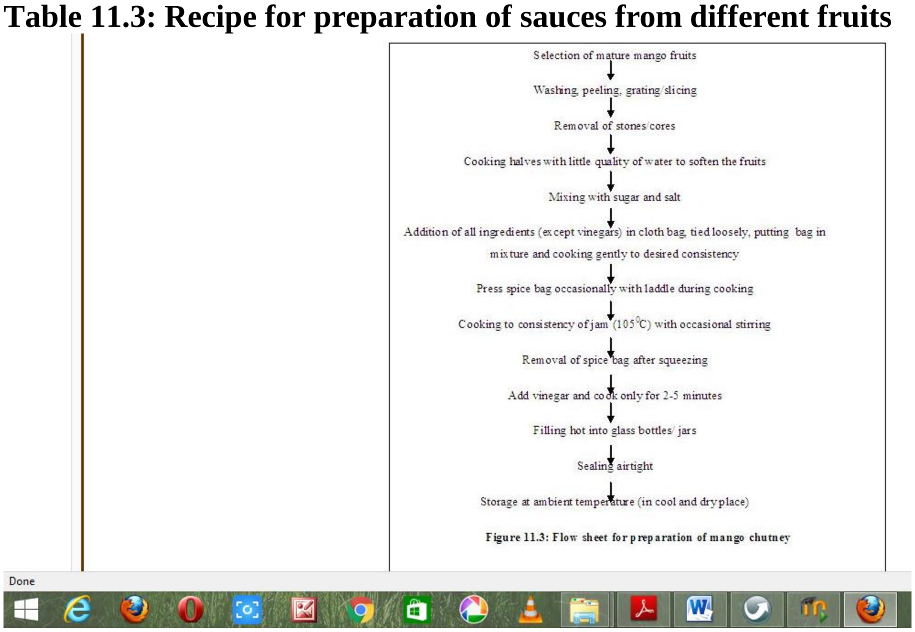

Table 11.3: Recipe for preparation of sauces from different fruits

Recipe	Tomato	Apple	Plum	Mushroom	Papaya
Fruit pulp, kg	1	1	1	1	1
Sugar, g	75	250	100	75	50
Salt, g	10	10	20	25	14
Cardamom, red chilies powder, g (each)	5	10	10	5	5
Ginger chopped, g	10	100	25	10	10
Onion chopped, g	50	200	50	100	50
Garlic chopped, g	5	50	10	10	5
Acetic acid, ml	5	50	40	40	40
Aniseed powder, cumin, g (each)	10	15	10	10	10
Sodium benzoate, g/kg sauce	0.25	0.7	0.7	0.25	0.7

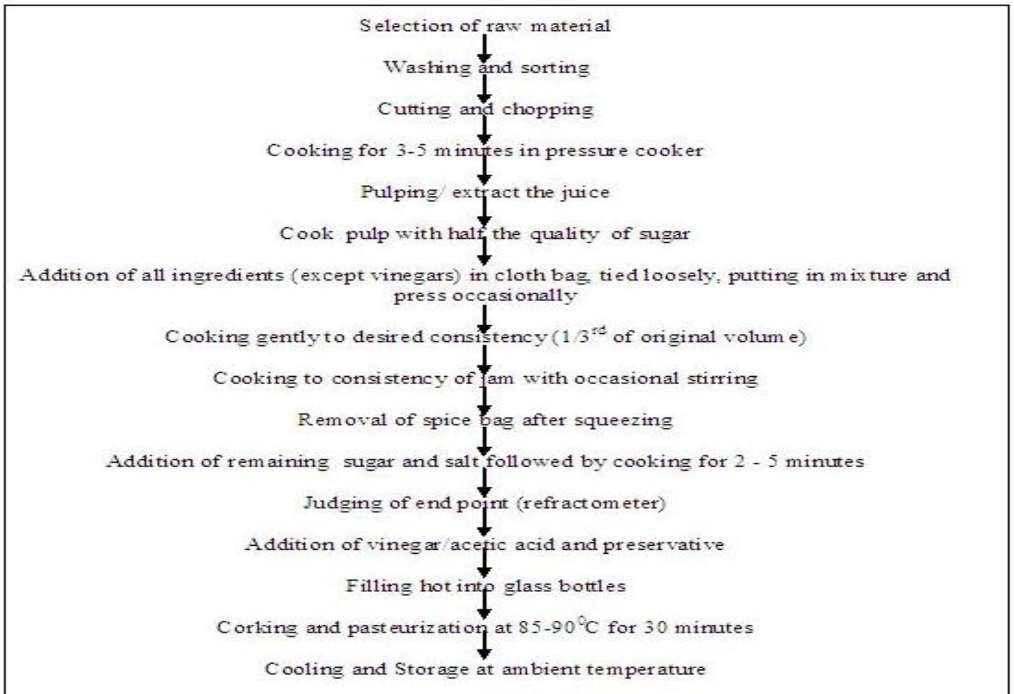

Fig 11.4: Flow sheet for preparation of sauce

Fig 11.4: Flow sheet for preparation of sauce

The fruits are washed and cut in to pieces (plum and apricot are used as whole). Cook for 10 minutes by adding little quantity of water in stainless steel (SS) pan or in pressure cooker. Pass heated fruits through pulper to separate skin and seeds. Fruit pulp can also used in preparation of sauce. Add half the quantity of sugar and place the spices in a muslin cloth bag and immerse in the pulp during cooking. Cook till the pulp is reduced to half the original volume. Remove the muslin bag and squeeze into pulp. Add acetic acid salt and remaining sugar. Heat the mass for few minutes. To judge the end point, place a spoon of sauce in plate, if no water oozes out, it indicates the end point or else more cooking is needed. Fill the finished product in sterilized glass bottle, crown corked and process in boiling water for 25-30 minutes. Keep the bottles in cool and dry place.

Problem during preparation of sauce or chutney

Black neck: It is a formation of black ring in the neck of the bottles. It is caused by the iron which gets into the product from equipment metal or cap/crown cork. This iron when come in contact with tannins in spice forms ferrous tannate which on oxidation change to black colour.
Prevention of black neck

- Fill hot sauce at temperature not less than 85^0C.
- Leave less head space in bottles (more air in bottles will result in more blackening).
- Reduce the chances of iron contamination.
- Partial replacement of sugar by corn syrup or glucose may prevent blackening.
- Store bottles in horizontal or inverted position to diffuse the entrapped air/oxygen.

Lecture 12 - Tomato and Mushroom products

Objective: This chapter deals with methods for preparation of different products from tomato and mushroom. Major tomato products includes chutney, juice, puree, paste, ketchup and tomato powder and method for hot and cold pulping are discussed. Among mushroom products; canning of mushroom and method for preparation of mushroom pickle, chutney and drying are explained. To judge the ability of the students to grasp the subject; frequently asked questions and multiple choice questions are also given in the end of the chapter.

Introduction

Tomato is grown in India in abundance both in summer and winters. Tomato though botanically a fruit is generally considered as vegetable because of the way in which it is consumed. Fresh tomatoes are very refreshing and appetizing but can not be stored for a long period. During peak season, about 25% of the produce is spoiled due to mishandling and such losses can be avoided by converting tomatoes into different value added products. Tomato can be processed into pulp, paste, puree, juice, ketchup and sauce. In India, tomato sauce and ketchup are very popular. High quality products can be prepared from tomatoes by:

1. using uniformly ripened, red coloured tomatoes.
2. avoid prolonged heating and cool the product immediately after cooking.
3. avoid using iron and copper equipments and utensils at any stage of processing.

Tomatoes can be processed into different value added products as detailed further in this chapter:

A. TOMATO AND TOMATO PRODUCTS

Fresh tomatoes are highly refreshing and appetizing. They are rich source of vitamins particularly vitamin C. Commercial products from tomatoes include juice, puree, paste, ketchup, soup canned and dehydrated tomatoes. As a semi finished product, tomato puree is prepared on a small scale while at large scale tomato paste has gained commercial significance. Both puree and paste are used for preparation of different finished products like ketchup, juice, soup etc. The method for preparation of different tomato products are discussed as under:

I. Tomato juice/pulp

Plant ripened and fully red tomatoes are used for juice making. All green, blemished and over-ripe fruits should be removed. The yields, colour and flavour of the juice depend on the degree of ripeness of the tomatoes and the variety. Tomatoes are washed thoroughly with water. They are crushed by means of fluted wooden roller-crushers. Tomato juice is either hot pulped or cold pulped. It is also extracted through screw type juice extractor. The juice is mixed with 0.4 to 0.6% salts to counteract the astringent taste of the juice. Sometimes, sugar is also added to improve the taste. The juice is packed in glass bottles or cans.

Tomato juice is the unconcentrated product consisting of the liquid with a substantial portion of the pulp, expressed from ripe tomatoes with or without the application of heat and addition of salt. Tomatoes pulp/juice is the basic ingredient for preparation of different tomato products such as tomato puree, paste, ketchup etc.

Method for preparation of tomato juice

1. Washing: Tomatoes should be washed in plenty of running water to remove dust, dirt etc present in cracks, wrinkles, folds and stem cavities not easily dislodged by gentle washing.
2. Crushing: Tomatoes, after trimming are cut into four to six pieces for extraction of pulp. Alternatively, they may be crushed by means of fluted roller crushers or by passing through the fruit grater.
3. Pulping: Tomato pulp can be extracted either by passing through the pulper after crushing without heating (cold pulping) or after boiling the crushed or whole tomatoes till softening followed by extraction of pulp in a pulper (hot pulping). During pulping, the fine juice and pulp passing through the sieves of pulper are collected while skin and seeds are separated through another end.

a) Cold pulping: It is commonly referred to as cold break process in which the tomatoes after washing are sliced or crushed in a fruit grater and immediately passed through a pulper to extract the pulp. The characteristics of cold break process are as under:

- The yield of juice is less as extraction in cold process is comparatively difficult.
- The extracted juice is lighter in colour as natural red colour in tomatoes is released only after heating the skin.
- Cold break process results in destruction/oxidation of natural vitamin C in juice due to incorporation of air during cold extraction.
- The extracted juice is thin in consistency probably due to action of inherent pectinase enzyme on the natural pectin.
- The flavour of cold break juice is much sharper and more acidic than that of hot pulped juice.
- The cold pulped juice need to be processed immediately to avoid the chances of microbial spoilage.

b) Hot pulping: It is also known as hot break process. The tomatoes after slicing or crushing in a fruit grater are boiled in pressure cooker/ steam jacketed stainless steel kettle or aluminum pans till softening to facilitate pulp extraction in pulper. The merits of hot pulping are as under:

- Hot pulping destroys the inherent enzymes (pectinase) which otherwise hydrolyze the pectin, to make the extracted juice thin in consistency.
- Heating results in release of natural lycopene (red colour) present in the skin into the juice.
- It also causes partial sterilization of juice to check the growth of micro-organism.
- It helps in inactivation of oxidative enzymes which otherwise cause destruction of ascorbic acid in the juice.
- The yield of juice in hot pulping is higher than cold pulping.

4. Equipment for juice/pulp extraction: Tomato juice/pulp is extracted either by passing the crushed tomatoes through a continuous spiral press or pulper.

a) Continuous spiral press: It consists of a long spiral screw which presses the tomatoes against a tapered screen of fine mesh. The juice passes through the screen while seeds and peel are removed from the lower end of the sieve.

b) Pulper: The pulper consists of a horizontal cylinder made of fine stainless steel. The heavy paddles inside the cylinder rotates rapidly, forcing the fine pulp to pass through the screen/sieves which is collected separately while the pieces of skin, seeds, fibre etc pass out through another end of the machine. However, at home scale, the crushed tomatoes after heating can be strained manually through stainless steel sieves.

5. Finishing and homogenization: After extraction, edible common salt (0.4-0.6 %) and sugar (1%) are added to the extracted pulp/juice to improve the taste and flavour of the finished product. For commercial production, the juice is homogenized for separation of liquid from the pulp and to impart a thick consistency and uniform appearance. For homogenization, the juice is heated to 66^{o}C and forced under high pressure (70 kg/cm 2) to shear the particles and bring them to almost same size.

6. Filling: The finished juice is heated to 82-88^{0}C and filled hot in pre-sterilized glass bottles. The bottles are then hermetically sealed using crown corks and sterilized in boiling water (100^{0}C) for about 25-30 minutes. Hot tomato juice (82-88^{0}C) can also be packed into plain or lacquered tin cans of appropriate size. The cans are then double seamed in a seamer and processed in boiling water for varying period of time depending upon the can size. Generally, the sterilization time at 100^{0}C for different sizes of can is 25 minutes (A2 can), 30 minutes (A21/2 can) and 40 minutes (A10 can).

7. Labeling and storage: After sterilization, the cans are cooled and stored in a cool dry place. Glass bottles are allowed to air cool. Both bottles and cans are labeled before sending them to market/sale.

FPO specification: According to FPO specifications, tomato juice shall be a liquid product derived from sound, fresh and fully ripe tomatoes practically free from insect and fungal attack or other blemishes affecting quality of the fruit and may contain finely divided insoluble solids from the flesh of tomatoes.

- It shall be free from pieces of skin, seeds, bits of coarse tissue and extraneous matter.
- The only substances that may be added are salt (1.5% w/w), sugar, dextrose, malic acid, ascorbic acid, citric acid and permitted colour.
- The minimum total soluble solids free of salt shall be 5% (w/w).
- The finished product shall have good flavour characteristic of tomato and be free from burnt or any other objectionable flavour.
- It shall be of good keeping quality and shall show no sign of fermentation when incubated at 37^{0}C for 7 days.

- The mould count shall not exceed 30% of the field examined.
- Harmful poisonous metals in tomato juice shall not be more than 1 ppm (lead) 100 ppm (copper on the dried tomato solids basis). 2 ppm (arsenic), 250 ppm (tin) and 19 ppm (zinc).

II. TOMATO PUREE

Tomato puree is prepared from tomato pulp after evaporation/concentration of the juice or pulp to desired total soluble solids with or without addition of salt. According to FPO specification, tomato puree shall contain minimum of 9 % total soluble solids excluding salt. The percentage of total soluble solids is required to be declared on the level of the product. Method for preparation of tomato puree: For preparation of puree the tomato pulp is prepared from ripe tomatoes either by hot pulping or by using cold pulping method. The pulp/juice is then concentrated either by using open cooking method in steam jacketed kettle or cooking by using vacuum pan. However, cooking under vacuum is desirable as the juice/pulp boils at much lower temperature (71^{0}C) which results in retention of original red colour and flavour with natural vitamin C. The pulp is concentrated to desired solids (9 to 12% solids), packaged in pre-sterilized bottles, crown corked and processed in boiling water for 25-30 minutes. Tomato puree can also be preserved by adding sodium benzoate (250 ppm benzoic acid). For packing in tin cans, the tomato puree is filled hot at 82-88^{o}C and then the cans are closed and processed for 20 minutes at 100^{o}C.

III. Tomato paste

A concentrated tomato juice or pulp without skin and seeds and containing not less than 25% of tomato solids is known as tomato paste. Depending on the degree of concentration, tomato paste can be further grouped into three groups:

a. Light tomato paste containing 25-29% of salt free tomatoes.
b. Medium tomato paste containing 29-33% of salt free tomatoes.
c. Heavy tomato paste containing not less than 33% of salt free tomatoes.

Method for preparation of tomato paste: Tomato pulp or juice is concentrated to 14-15% soluble solids in open pans followed by concentration in vacuum pans and packing in pre-sterilized bottles while still hot. In large scale processing units, the tomato paste is manufactured by using vacuum evaporators and packed either in tin can or in bulk aseptic packages. The tomato paste is utilized for manufacture of different tomato products like ketchup, soup and sauce etc.

FPO specification for tomato puree and paste: According to FPO specifications, the tomato paste shall be derived from sound, fresh and fully ripe tomatoes practically free from insect or fungal attack or any other blemish affecting the quality of the fruit.

- Properly prepared and strained tomatoes shall be free from skin and seeds.
- The only substances that may be added are common salt, citric acid, ascorbic acid, spices, permitted colour and preservatives.

- The finished product shall have good flavour of the tomato and must be free from any other objectionable flavour.
- It shall be of good keeping quality and shall show no sign of fermentation, when incubated at $37^{0}C$ for seven days.
- The mould count in the finished product shall not exceed 60% of the field examined.
- The minimum percentage of soluble solids (w/w) free of salt in tomato paste and tomato puree should be 25% and 9% respectively.

IV. Tomato ketchup

Tomato ketchup is the commercial product made either from fresh tomato by converting them into juice/pulp or by using tomato puree or tomato paste. It is made by concentrating tomato juice or pulp without seeds and skin. Spices, salt, sugar, vinegar, onion, garlic etc. are added to the extent that the ketchup contains not less than 12% tomato solids and minimum of 25 % total soluble solids (w/w). The juice or puree prepared earlier can be used for preparation of tomato ketchup. Generalized recipe for preparation of tomato ketchup is as under:

Ingredient	**Quantity**
Tomato juice	1 litre
Onion (chopped)	35-40 g
Garlic (Chopped)	5-10 g
Red chillies powder	2-3 g
Spices (Cloves, cardamom, black pepper, cinnamon)	4 g (each)
Glacial acetic acid	2-3 ml
Sugar	20-30g
Salt	10 g
Benzoic acid	750 ppm

Recipe for ketchup

Method for preparation of tomato ketchup: The tomato juice is concentrated with spices, salt, sugar etc. About 1/3 of the sugar is added initially at the time of commencing the boiling and the balance is added a little before the ketchup is ready. The sugar added initially helps to intensify and fix the red tomato colour. However if whole sugar is added initially with the pulp, it will require the boiling of pulp for longer duration, which will adversely affect the colour of the ketchup. Salt is added towards the end of boiling, as otherwise, it bleaches the tomato colour. Spices are placed in the muslin cloth and cloth is placed in boiling mixture. At the end cloth bag is pressed to squeeze the spices and cloth is taken out. Vinegar should be added when the ketchup has thickened sufficiently, so that the acid does not volatize away. Tomato ketchup generally contains 1.25-1.50% acid. The tomato ketchup is generally concentrated to 25-30% solids, out of which 12% solids are tomato solids. The ketchup is filled hot ($88^{o}C$) into pre-sterilized glass bottles, crown corked and processed for 30 minutes and cooled at room temperature. Tomato ketchup may also contain benzoic acid as preservative.

V. Tomato soup

Tomato soup is a fairly popular product now a day. It can be prepared either from pulp or tomato juice. Butter or cream, spices, starch etc are used for preparation of soup. These are added in different proportions on the basis of desired taste. There are several recipes which give tomato soup a good quality.

Recipe for soup

Ingredient	**Quantity**
Tomato juice/pulp	1 litre
Salt	20 g
Sugar	20 g
Spices (Cardamom, black pepper, cinnamon, cumin)	1 g (each)
Onion (Chopped)	20 g
Red chillies	2 g
Cream or butter	20 g
Arraroot starch	10 g
Garlic (chopped)	5 g
Water	350 ml

Method for preparation of tomato soup: The juice is boiled in pans for concentration. Add spices in a cloth bag as in case of tomato ketchup, while it is being concentrated. In the mean time arrowroot and butter with small amount of juice are mixed to form smooth paste and added to the whole lot. Boiling is continued to the desired consistency by stirring it continuously. At the end, sugar and salt are added and mixture is boiled for about 2 minutes to dissolve them. The soup is filled hot (88^{o}C) into cans and is processed at 100-110^{o}C for 20-45 minutes depending on the size of cans and cooled quickly after processing.

VI. Tomato powder

The tomato juice is converted into a free flowing, highly hygroscopic powder by using different drying methods. Sometimes the natural tomato flavour in powder form is incorporated to compensate any loss of flavour to yield full strength juice powder. Juice can be converted to powder by using different methods like spray drying, roller drying and foam mat drying.

VII. Tomato cocktail

The tomato cocktail contains tomato juice to which common salt, vinegar, Worcestershire sauce, lemon or lime juice etc are added in different proportions to suit the palate. It is prepared just before use or sometimes also served from the stock. The general recipe for tomato cocktail is as under:

Recipe for cocktail

Ingredient	Quantity
Tomato juice	5 litre
Common salt	100 g
Spices (Cumin, cardamom, coriander seed, cinnamon, black pepper)	2 g (each)
Cloves (Headless)	5 numbers
Red chilli powder	5 g
Vinegar	300 ml

Method for preparation of tomato cocktail: Simmer the tomato juice, with the spices loosely tied in cloth bag for about 20 minutes in a covered vessel. Then add vinegar and common salt. After mixing all the ingredients the cocktail is ready, it is filled hot at the temperature of 82-88oC in pre-sterilized bottles. The bottles are closed and kept immersed in boiling water for 30 minutes and cooled.

Mushroom and Mushroom Products

Mushroom

Mushroom, a form of fleshy edible fungi is a rich source of high quality protein, minerals, folic acid and vitamins. Because of pleasant flavour, taste and freshness, mushroom are considered as an important delicacy in human diet. They are praised for their characteristic meaty biting texture and flavour.

White button mushroom (Agaricus bisporus), oyster mushroom or dhingri (Pleurotus sajorcaju) and paddy straw mushroom (Volvariella volvacea) are commercially cultivated in India. White button mushroom contributes more than 90% of the total production. However owing to high moisture content and delicate nature, mushroom are highly perishable and cannot be stored for more than 24 hours at ambient temperature. The deterioration is mainly caused due to their high metabolic activity, respiration rate and susceptibility to enzymatic browning. Drying, canning and freezing are the accepted methods for preservation of mushrooms and by converting into different products like pickle, chutney, soup etc their availability can be increased.

I. Canning of mushroom

White button mushrooms (Agaricus bisporus) are preferred over other types of mushroom for canning. Commercially mushrooms are canned in brine. Different unit operations used in canning are given in Fig-12.1.

1. Sorting and grading: Diseased, damaged, bruised, shriveled and browned mushroom are discarded. Only the healthy white and tight buttons are selected and separated into two grades i.e. cap diameter up to 2.5cm with compact head as 'A' and cap diameter beyond 2.5 cm as 'B' grade.

2. Washing: Graded mushrooms are thoroughly washed 3-4 times in cold running water to remove dirt, soil etc without damaging or rubbing them excessively.

3. Blanching: To inhibit enzymes activity blanching in necessary. It also removes the air from the tissues of raw material to enable a satisfactory and uniform pack. Mushrooms are blanched in boiling water for 2-3 minutes followed by immediate cooling in water. The steam blanching is preferred because the blanching losses in boiling water have been estimated to be about 30 percent.

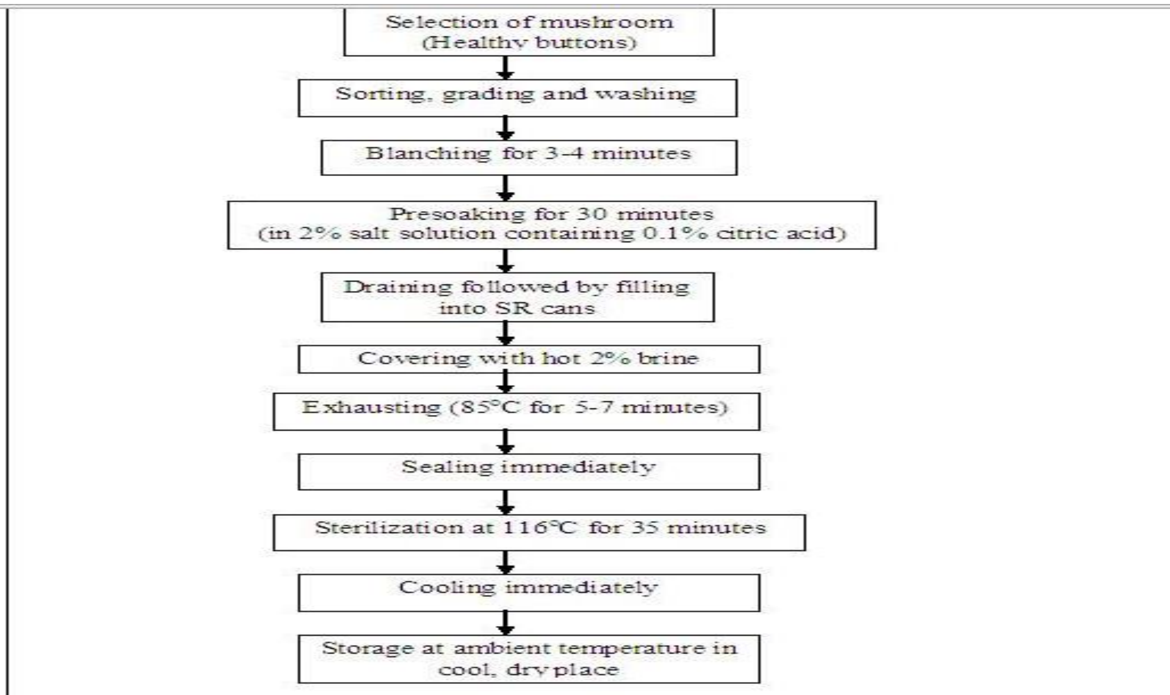

Figure 12.1: Flow sheet for mushroom canning

4. Filling of cans: For mushroom canning, lacquered cans (sulphur resistant) are recommended in order to avoid sulphur staining of canned mushroom. The blanched mushrooms are filled into cans to its declared drained weight i.e. 230 g in A 1 tall can and 430gm in A2½ can size.

5. Brining: After filling mushroom in cans, add hot brine solution having a ratio of 2% common salt, 1% sugar and 0.05 % citric acid. Fill upto the brim of the can. Brining adds flavour to the product, reduces processing time and helps in increasing the shelf-life of canned mushroom.

6. Exhausting: After brining, cans are exhausted to remove any entrapped air and other occluded gases from the product to ensure longer shelf-life. Cans filled with brine solution are fed to the exhaust box for a specified period of time depending upon the length of exhaust tunnel and size of can. Exhausting can also be performed by placing the filled cans in boiling water till temperature of the centre of can reaches 85-900C for 1-2 minutes.

7. Double Seaming /can closing: Immediately after exhausting cans are sealed with the help of double seamer to get the hermetic seam. Sealed cans are then placed in upside down position to sterilize the coded lids.

8. Processing/sterilization: Processing is also designated as sterilization is an indispensable unit operation in canning. 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 the can and altitude of processing place. However for A1 tall and A21/2 size cans, processing is required for 35 and 45 minute respectively.

9. Cooling: 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.

10. Labeling and storage: The cooled cans are stored in a cool and dry place and smeared with grease to remove any adhering moisture from the can body to avoid rusting. Cans are kept at ambient temperature for 8-10 days to check any swell, leakage, puffing and other disorders before labeling. Before the cans are exposed for sale, proper labeling is done to meet statutory requirements of Indian Food Laws.

II. Mushroom pickle in oil

Recipe for pickle

Ingredient	**Quantity**
Mushroom	1kg
Salt	100 g
Red chillies Powder	10 g
Turmeric powder	10 g
Coriander powder	10 g
Aniseed and cumin powder	5 g (each)
Spices (fenugreek, black pepper, cinnamon powder)	2 g (each)
Garlic chopped/paste	20 g
Onion chopped	100 g
Vinegar	80-100 ml
Mustard oil	200 g

Method for mushroom pickling: Wash and cut mushroom into pieces. Blanch by holding the pieces in muslin cloth in boiling water containing salt for 3-4 minutes followed by immersing in cold water.

Remove excessive moisture by spreading the pieces on a muslin cloth. Fry onion garlic and ginger in oil, mix other ingredients and mushrooms except vinegar and mix thoroughly. Add vinegar and pack in a clean jar. **III. Mushroom soup**

Recipe for soup

Ingredient	**Quantity**
Mushroom	1kg
Salt	30 g
Red chillies powder, cardamom, fenugreek, black pepper, cinnamon powder	5 g (each)
Butter	100 g
Wheat flour (maida)	12 g (each)
Vinegar	20-30 ml
Milk	200 ml

Preparation of mushroom soup: Take fresh mushroom and wash in water and mash in blender. Pass slurry through an aluminum or plastic sieve to remove the fibrous portion. Melt the butter in a pan and fry the slurry till it is just brown. Add wheat flour, spices and milk to the mixture. Boil the whole mass to a reasonable consistency. After this process, the soup is ready for use. Fill boiling hot soup into the cans and process in a similar way as explained under canning of mushroom.

IV. Mushroom sauce

Recipe

Ingredient	**Quantity**
Mushroom	1kg
Salt	20 g
Red chillies powder	10 g
Cardamom powder	5 g
Dry ginger powder	5 g
Garlic paste	2 g
Mace	4 g
Vinegar	100 ml

Preparation of mushroom sauce (Fig 12.2)

- 1. Wash the mushroom thoroughly. Keep them in porcelain or an enameled can for 12hr after sprinkling with salt, alternatively dip the mushroom in vinegar.
- 2. Blend the soaked or salted mushroom into fine slurry.
- 3. Add vinegar and spices.
- 4. Heat the mass till it thickens to the consistency of sauce.
- 5. Fill hot in sauce bottles and seal with crown corks.
- 6. Sterilize for 30 minutes at 82-85^{0}C.
- 7. Store in cool and dry place.

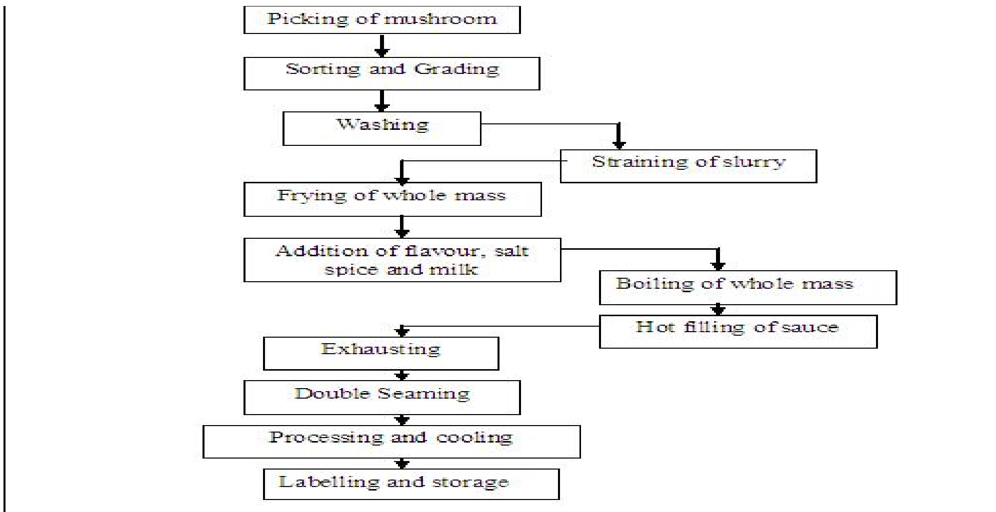

Figure 12.2: Flow sheet for preparation of mushroom sauce

Figure 12.2: Flow sheet for preparation of mushroom sauce

V. Mushroom chutney

Recipe

Ingredient	**Quantity**
Mushroom Sugar	1kg 250 g
Salt	100 g
Red chillies Powder	5 g
Ginger chopped	75 g
Aniseed and cumin powder	5 g (each)
Spices (fenugreek, black pepper, cinnamon powder)	2 g (each)
Garlic chopped/paste	25 g
Onion chopped	100 g

Vinegar	10-15 ml
Mustard oil	100 g

Preparation of mushroom chutney: The mushrooms are thoroughly washed in water and cut into small pieces and cooked with a small quantity (100-150ml/kg) of water in a pressure cooker for 15-20 minute. Chopped onion, garlic and ginger are fried in oil and mixed with mushrooms, cook until the whole mass thickness (30-45 minutes). Now add spices and cook for 2-3 minutes. Finally, add sodium benzoate (dissolved in small amount of water) and acetic acid. Final TSS should be in the range of 55-58^{o}Brix. Pack the material in clean glass container while still hot.

VI. Dehydration of mushroom (Fig. 12.3)

Material required

Ingredient	Quantity
Mushroom	10kg
Potassium meta-bi-sulphite	150gm
Citric acid	20gm

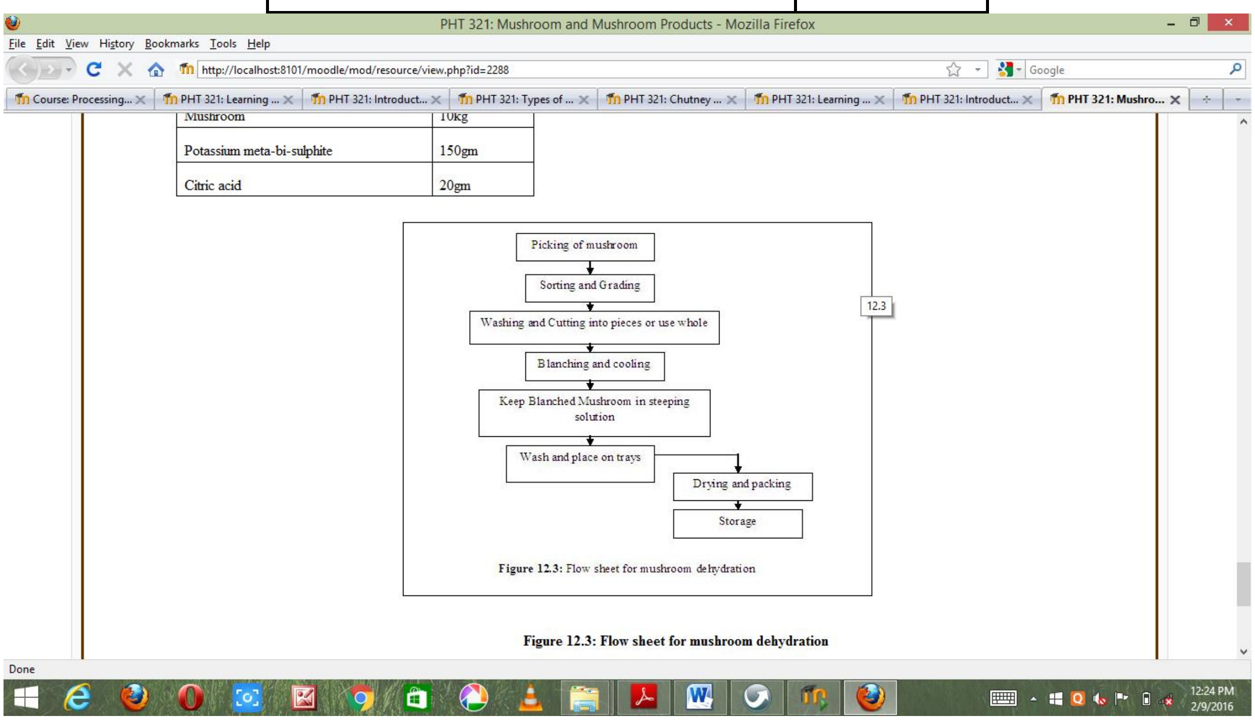

Figure 12.3: Flow sheet for mushroom dehydration

Method for mushroom dehydration

1. Select sound white button mushroom and wash the fresh produce thoroughly in running cold water and then in salt and 0.1% KMS.

2. Cut into two equal halves longitudinally and wash again quickly in running cold water. If desired these can also be kept as such without cutting into halves. Keep the mushroom in 2 % salt water to check browning.
3. Blanch in boiling water for 4-5 minutes.
4. Cool immediately in cold water.
5. Steep the blanched mushrooms in water containing 1.5% potassium meta-bi-sulphite + 0.2% citric acid for 30 to 45 minutes.
6. Drain the mushroom and wash with water thoroughly.
7. Dry the product by placing over trays.
8. Place the loaded trays in dehydrator maintaining 60^{o}C temperature for 6-8 hours.
9. Pack in polyethylene bag.

Note: Dhingri can also be dried by using this method.

Lecture 13 - Freezing of fruits and Vegetables

Objective: This chapter includes freezing theory, history of freezing, freezing process and freezing point of foods. Freezing time, freezing rate, energy requirements, refrigeration process are also discussed in this chapter. Different freezing equipments with figures, mechanical freezers like cooled air freezer, cooled liquid freezer, cooled surface freezer are also discussed along with types of freezing. Dehydro-freezing and freeze-drying are also the most important methods of freezing. Packaging and storage of frozen foods, quality changes and storage life of frozen foods, legal standards for frozen foods are also included with complete procedure for freezing of fruits and vegetables. Flow sheets, curves and tables are also included in the chapter to elaborate the freezing process in simple and well defined manner. Further, to judge the ability of the students to grasp the subject; frequently asked questions and multiple choice questions are also included in the end of the chapter.

Introduction

Introduction

Freezing is one of the oldest and most widely used methods of food preservation, which allows preservation of taste, texture, and nutritional quality in foods better than any other method. It is a process of bringing down the temperature of food below its freezing point and the frozen storage generally refers to storage at temperature below -18^{0}C.

Theory of Freezing

The freezing process is a combination of the beneficial effects of low temperatures at which micro-organisms cannot grow, chemical reactions are reduced, and cellular metabolic reactions are delayed. Freezing is generally referred to as a unit operation in which the temperature of food is reduced below freezing point and a proportion of water undergoes a change in state to form ice-crystals. Immobilisation of water to ice and the resulting concentration of dissolved solutes in unfrozen water cause lowering of water activity of the food. Thus reduction in water activity and use of low temperature coupled with some pre- treatments like blanching is the basis for food preservation by freezing. Fruits such as strawberries, oranges, raspberries, black currants and vegetables like green pea, green beans, sweet corn, spinach, sprouts and potatoes are examples of commercially frozen products.

History of Freezing: The frozen food market is one of the largest and most dynamic sectors of the food industry. In spite of considerable competition between the frozen food industry and other sectors, extensive quantities of frozen foods are being consumed all over the world. In 1920, Clarence Birdseye introduced commercial freezing and storage equipments and soon the cold chain marketing system was evolved. The frozen vegetable industry mostly grew after the development of scientific methods for blanching and processing in the 1940s. The commercial freezing of small fruits and berries began in the eastern part of the US in about 1905. The main advantage of freezing preservation of fruits is the extended usage of frozen fruits during off-season. Additionally, frozen fruits can be transported to remote markets that could not be accessed with fresh fruit. Also, freezing preservation makes year-round further processing of fruit products possible, such as jams, juice, and syrups from frozen whole fruit, slices, or pulps. Thus, the preservation of fruits by freezing has become one the most important preservation methods.

Freezing process: The material to be frozen first cools down to the temperature at which nucleation starts. Common frozen storage temperature is -18^{0}C or 0^{0}F. Once the first crystal appears in the solution, a phase change occurs from liquid to solid with further crystal growth. Therefore, nucleation serves as the initial process of freezing and can be considered as the critical step that results in a complete phase change.
The freezing process involves lowering the product temperature generally to -18 °C or below. During freezing, sensible heat is first removed to lower temperature of a food to the freezing point. In case of fresh produce, heat produced by respiration (heat load) is also removed. Latent heat of crystallization is then removed to allow formation of ice crystals and hence to freeze the food. Besides, latent heat of other components of food like fat must also be removed before they can solidify. Usually in most of fruit and vegetables these components are present in smaller amounts and thus the removal of a relatively small amount of heat is needed for crystallisation to take place. However, since most fruit and vegetables containing a large proportion of water (78-95%), possess high specific heat (4200 J/kg/k) and high latent heat of crystallisation (335kJ/kg), as such considerable amount of energy is needed for freezing processes.

Freezing point of foods

Freezing point is defined as the temperature at which the first ice crystal appears and the liquid at that temperature is in equilibrium with the solid. The freezing point of pure water at normal temperature and pressure is 0°C (273°K). However, when food systems are frozen, the process becomes more complex due to the existence of both free and bound water. The presence of solutes in water alters both the boiling and freezing point of water. Bound water does not freeze even at very low temperature. Un-freezable water contains soluble solids, which cause a decrease in the freezing point of water lower than 0°C. During the freezing process, the concentration of soluble solids increases in the unfrozen water, resulting in a variation in freezing temperature. Therefore, the temperature at which the first ice crystal appears is commonly regarded as the initial freezing temperature.

The freezing point depression is given by the relation: ccording to International Institute of Refrigeration (IIR), the freezing process is divided into three stages based on major temperature changes in a particular location in the product, as shown in Figures 13.2 and 13.3 for pure water and food respectively. In pre-freezing stage, the food is subjected to the freezing process until the appearance of the first crystal. For pure water, the freezing temperature will be 0°C and up to this temperature, there will be a sub-cooling until the ice formation begins.
In case of foods during first stage, the temperature decreases below the freezing temperature and with the formation of the first ice crystal, temperature again increases to freezing temperature. The second stage is the freezing period; a phase change occurs, transforming water into ice. For pure water, temperature at this stage is constant however; it decreases slightly in foods due to the increasing concentration of solutes in the unfrozen water portion. The last stage starts when the product temperature reaches the point where most freezable water has been converted to ice, and ends when the temperature is reduced to storage temperature.

The initial freezing point of some of the foods is given along with water contents in Table-13.1. Most of the foods have a freezing point in the range of 28-30^{0}F or -1 to -2^{0}C. The freezing time and freezing rate are the most important parameters in designing freezing systems.

Table 13.1: Average freezing point and water contents in some of commodities and products.

Commodities and products	**Water contents (%)**	**Initial freezing point (^{0}C)**
Apple juice	87.2	- 1.44
Apple juice concentrate	49.9	- 11.3
Asparagus	92.6	- 0.67
Carrots	87.5	- 1.11
Grape juice	84.7	- 1.78
Orange juice	89.0	- 1.17
Peaches	85.1	- 1.56
Pears	83.8	- 1.61
Raspberries	82.7	- 1.22
Strawberries	89.3	- 0.89
Sweet cherries	77.0	- 2.69
Tomato pulp	92.9	- 0.72

Freezing time: Freezing time is defined as time required to lowers the product temperature from its initial temperature to a pre-determined temperature of -10 or -18^{0}C at its thermal centre. Since the temperature distribution within the product varies during freezing process, the thermal centre is generally taken as reference. Freezing time depends on various factors including the initial and final temperatures of the product, the quantity of heat removed, dimensions (especially thickness) and shape of product, difference in freezing point and rate of ice crystal formation, heat transfer process and temperature. The freezing time for food cubes is calculated by:

Freezing rate: The freezing rate (°C/h) for a product or package is defined as the ratio of difference between initial and final temperature of product to freezing time. The quality of frozen products is largely dependent on the rate of freezing. Generally, rapid freezing results in better quality frozen products when compared with slow freezing.

- If freezing is instantaneous, there will be more locations within the food where crystallization begins.
- Large ice crystals are known to cause mechanical damage to cell walls in addition to cell dehydration.
- Rapid freezing is advantageous for freezing of many foods; however some products are susceptible to cracking when exposed to extremely low temperature for long periods.
- Several mechanisms, including volume expansion, contraction and expansion, and building of internal pressure, are responsible for product damage during freezing.

Several methods for estimation of freezing time and rate exist as:

- Use of analytical solution to heat transfer equation involving phase change problems under appropriate boundary conditions.
- Use of empirical equation based on assumptions and approximations that can give estimates of freezing time.

Energy requirements: For fruits and vegetables, the amount of energy required for freezing is calculated based on the enthalpy change and the amount of product to be frozen. Refrigeration requirements for fruits and vegetables can be calculated from the following equation:

Refrigeration

Refrigeration is defined as the elimination of heat from a material at a temperature higher than the temperature of its surroundings. The main elements in a closed mechanical refrigeration system are the condenser, compressor, evaporator and the expansion valve. Hydro-chlorofluorocarbon (HCFC) and ammonia are used as refrigerants in mechanical refrigeration systems. A simple scheme for the closed mechanical refrigeration system is shown in Fig 13.4.

Fig 13.4: Closed mechanical refrigeration system (one-stage).

Starting at the suction point of the compressor, fluid in a vapour state is compressed into the compressor where an increase in temperature and pressure takes place. The fluid then flows through the condenser where it decreases in energy by giving off heat and converting to a liquid state. After the phase, a change occurs inside the condenser, the fluid flows through the expansion valve where the pressure decreases to convert liquid into a form of liquid-gas mixture. Finally, the mixture flows through the evaporator and is converted into a saturated vapour state and removes heat from the environment in the process of cooling.

Refrigerants: A refrigerant can be selected on the basis of physical, thermodynamic and chemical properties of the fluid. Environmental considerations are also important in refrigerant selection, since leaks within the system produce deleterious effects on the atmospheric ozone layer. Ammonia is commonly used for industrial applications whereas; chloro-fluoro-methane and tetra-fluoro-ethane are also recommended as refrigerants.

Freezing capacity: Freezing capacity (tonnes per hour) is defined as the ratio of the product quantity that can be loaded into the freezer to the holding time of the product in that particular freezer. The amount of food product loaded into the freezer is affected by both the dimensions of the product and the mechanical constraints of the freezer. The holding time of the product has an important role in freezing systems and is based on the calculation of the amount of heat removed from the product per hour, which varies on the type of product.

Freezing equipment

Freezing equipment: The equipment for freezing can be categorized in different ways, namely as equipment used for batch or in-line operation, heat transfer systems (air, contact, cryogenic), and product stability. Mechanical freezers use cooled air, liquid or cooled surfaces to remove heat from foods. On the basis of heat transfer system, freezers are categorised as:

A. Mechanical Freezers

1) Cooled air freezer: Mechanical refrigerator which evaporate and compress a refrigerant in a continuous cycle and use cooled air to remove heat from foods. It includes chest freezer, air blast freezer, fluidized bed freezer etc. Mechanical refrigeration generally refers to any system that uses electrical power to produce chilled air. The chilled air is passed over food continuously and it removes the heat.

2) Cooled liquid freezer: These are similar to cooled air freezers but they use cooled liquid to remove heat from foods and include Immersion freezers.

3) Cooled surface freezer: In this type, the surface of freezer is cooled by the refrigerant on which the food is placed for removal of heat. For example Plate freezer, Scraped surface freezer etc.

Types of freezing: On the basis of rate of formation of ice front, the freezers are classified into following types:
1) Slow freezer and sharp freezer: In this type, the rate of ice front formation is very slow i.e. 0.2 cm/h-1 (e.g., Still air freezers and cold stores) (Fig 13.5).

Fig 13.5: Quick versus slow freezing

2) Quick freezers having rate of ice front formation as 0.5-3 cm/h-1 (e.g., air blast and plate freezers).

3) Rapid freezers having rate of ice front formation as 5-10 cm/h-1 (e.g., fluidized bed freezer).

4) Ultra rapid freezers having rate of ice front formation as 10-100 cm/h-1 (e.g., cryogenic freezer).
All freezers are insulated with materials which have low thermal conductivity such as expanded polystyrene, polyurethane etc. Basic principle of operation of different freezers is discussed as under:

A. Cooled air freezers
1. Chest freezer: In chest freezer, the food is frozen in naturally circulated stationery air at temperature between -20^{o}C to -30^{o}C. Chest freezer takes longer time (3-72 h) for freezing; resulting in loss of product quality. These are not used as such for commercial freezing owing to low freezing rates. Cold stores can be regulated as large chest freezers. These are used to store foods that are frozen by other methods and as hardening rooms for ice cream. Air is circulated by fans for uniform distribution of temperature; however the heat transfer coefficients are low. The major problem in cold stores is the formation of ice on the floor, walls and evaporator coils, caused by moisture from the air or from unpackaged products in the store.

2. Air blast freezer: Air blast freezing refers to freezing of products in a powerful blast of circulating cold air at a temperature from -18 to -400C under forced circulation. The air blast freezer is one of the oldest and commonly used freezing equipment due to its temperature stability and versatility for several product types. Air is used as the freezing medium in the freezing design, either as still air or forced air. The air is re-circulated over food at a velocity of 1.5-6.0 m/s. The high air velocity reduces the thickness of boundary films surrounding food and thus improves the surface heat transfer co-efficient. For freezing in batch system the foods is stacked on trays in rooms or cabinets. While continuous system consists of trolleys stacked with trays of food or on conveyor belts which carry the food through an insulated tunnel. Multi-pass tunnels contain a number of belts and products falls from one to another. This action breaks up any clumps of foods and allows control over the product depth (for example a 25-50 mm bed is initially frozen for 5-10 minutes and then repiled to 100-125 mm on second belt). Air flow is either parallel or perpendicular to the food and is directed to pass evenly over all food pieces. Blast freezing is economical and highly flexible for different shapes and sizes of the food. The equipment is compact and has a relatively low capital cost and high throughput (200-1500 kg h-1).

3. Tunnel freezer: In tunnel freezers, the products on trays are placed in racks or trolleys and frozen with cold air circulation inside the tunnel. In order to allow air circulation, optimum space is provided between layers of trolley, which can be moved continuously in and out of the freezer manually or by forklift trucks. This freezing system is suitable for all types of products, although there are some mechanical constraints including the requirement of high manpower for handling, cleaning, and transportation of trays. A trolley for a tunnel freezer is shown in Figure 13.6.

The freezer is generally used for the individual quick freezing (IQF) of small products with particle size of 0.5 to 5cm in diameter like peas, beans, mushrooms, small fruits etc. It has low operation costs as compare to other liquid nitrogen freezers.

4. Belt freezers: Belt freezers were first designed to provide continuous product flow with the help of a wire mesh conveyor inside the blast rooms. These are also called as spiral freezer as they have a continuous flexible mesh belt which is formed into spiral tiers. The food is carried up through a refrigerated chamber on the belt. Cold air or sprays of liquid nitrogen is directed down through the belt stack in a counter current flow, which reduces weight losses due to evaporation of moisture. Airflow has good contact with the product only when the entire product is evenly distributed over the conveyor belt. Belt freezers require relatively small floor space and have high capacity. Other features include automatic loading and unloading, low maintenance cost and flexibility to freeze different products. Both packed and unpacked products with variable freezing times (10 min to 3 hr) can be frozen in spiral belt freezers due to the flexibility of the equipment.

5. Fluidized bed freezer: These are modified blast freezers in which air between -25^{o}C and -35^{o}C is passed at a high velocity (2-6m/s) through a 2-13 cm bed of food, contained on a perforated tray or conveyor belt. The shape and size of food pieces determines thickness of fluidized bed and air velocity needed for fluidization. The foodstuff is fluidized to form a bed of particle followed by freezing. Air is forced upward through belt o suspend the particles. In fluidized bed freezer, the food comes in to greater contact with the air than in blast freezer and thus all surfaces are frozen simultaneously and uniformly. The use of high air velocity is very effective for freezing unpacked foods, especially when they can be completely surrounded by flowing air, as in the case of fluidized bed freezers. The product zone in the freezer is constructed with stainless steel and food grade plastic for easier maintenance. In some cases, the freezing is done in two stages; firstly the initial rapid freezing to produce ice glaze on food surface, followed by freezing on second belt in beds 10-15cm deep. Small vegetables, french-fried potatoes and fruits like strawberries are some of the products now frozen with this technology. A typical fluidized-bed freezer is shown in Figure 13.7.

B. Cooled liquid freezer

Immersion freezer: In immersion freezer, the food comes in direct contact with the refrigerant. For freezing, the food is passed through a bath of refrigerated propylene glycol, brine, glycerol or calcium chloride solution on a submerged mesh conveyor. In contrast with cryogenic freezing, the liquid in immersions freezer remains fluid throughout the freezing operation and change of state does not occur. Immersion freezer involves less capital cost and offers high rates of heat transfer. They are used commercially for concentrated orange juice in laminated polyethylene cans. Freezing of orange juice in cans and peas to -18^{0}C in immersion freezing generally takes 10-15 minutes and 30 seconds respectively. Direct immersion of a product into a liquid refrigerant is the most rapid way of freezing since liquids have better heat conducting properties than air. The solute used in the freezing system should be safe without taste, odour, colour or flavour and for successful freezing; products should be greater in density than the solution. A simple illustration of the immersion freezer is shown in Figure 13.8.

C. Cooled surface freezer: These include plate freezer and scraped-surface freezer.

1. Plate freezer: These freezers consist of a vertical or horizontal series of hollow plates, through which refrigerant is pumped at -40oC temperature. In this case, the product is pressed between hallow metal plates, either horizontally or vertically, with a refrigerant circulating inside the plates. Vertical plate freezers are suitable for the viscous products like orange juice whereas, horizontal plate freezers are suitable for packaged products like vegetable or fish fillets. For freezing, flat and relatively thin foods are placed in single layers between plates and a slight pressure is applied by moving plates together. This improves contact between the food and plates and thus increases the rate of heat transfer.

Advantages: Plate freezers include advantages like good economy and space utilization, low operating costs, minimum defrosting of condenser and high rate of heat transfer.

Disadvantages: High capital costs and suitability only for flat and thin foods are the major disadvantages.
A typical plate freezer is shown in Figure 13.9. Plate freezers may be batch, semi-continuous or continuous in operation.

Fig 13.9: Plate freezer with a two-stage compressor and sea water condenser

2. Scraped surface freezer: These are used for liquid as well as for semi-solid foods like ice cream. They consist of a jacket (freezer barrel) surrounding a high speed rotor, fitted with short blades. In ice-cream manufacture, the rotor scrapes frozen food from the wall of the freezer barrel and incorporates air. In scraped surface freezers, the freezing is very fast and up to 50% of the water is frozen within a few seconds. This results in very small crystals which are not detectable in the mouth and thus given a smooth creamy consistency to the product. The temperature is reduced between -4^{o}C and -7^{o}C. The frozen aerated mixture is then pumped into containers and finally the freezing is completed in hardening room.

3. Contact freezers: Contact freezing is one of the most efficient ways of freezing in terms of heat transfer mechanism. In contact freezing process, the product can be directly or indirectly contact with the freezing medium.

a) For direct contact freezers, the product being frozen is fully surrounded by the freezing medium, the refrigerant, maximizing the heat transfer efficiency. A schematic illustration is given in Figure-13.10.
b) In case of indirect contact freezers, the product is indirectly exposed to the freezing medium while in contact freezers; the product is directly in contact with the belt or plate, which is in contact with the freezing medium. The material is being frozen is separated from the refrigerant by a conducting material, usually a steel plate. The mechanism of indirect contact freezer is shown in Figure 13.11. Indirect contact freezers generally provide an efficient medium for heat transfer, although the system has some limitations, especially when used for packaged foods due to resistance of package to heat transfer.

Fig 13.10: Direct contact freezer. Fig 13.11: Indirect contact freezer.

B. Cryogenic Freezers

The Cryogenic freezers use solid or liquid carbon dioxide, liquid nitrogen directly in contact with the food and refrigeration is obtained as a pre-cooled substances. Cryogenic freezers used are carbon dioxide, liquid nitrogen or Freon. Cryogenic freezers are characterized by a change of state in the refrigerant (Cryogen) as heat is absorbed from the freezing food. The food is exposed to an atmosphere below -60°C through direct contact with liquefied gases such as nitrogen or carbon dioxide. The heat from the food provides the latent heat of vaporization or sublimation of the cryogen. The cryogen is in intimate contact with the food and rapidly removes heat from all surfaces co-efficient and rapid freezing. Liquid nitrogen and solid on liquid carbon dioxide are the commonly used refrigerants. Low initial investment and rather high operating costs are typical for cryogenic freezers. The limitation cryogenic freezer is the rate of excess cryogen residue in foods.

1. Liquid nitrogen freezers: Liquid nitrogen refrigerants are colourless and odourless. In these freezers, the packaged or unpackaged food travels on a perforated belt through a tunnel where product is cooled by gaseous nitrogen and frozen by liquid nitrogen spray. Liquid nitrogen, with a boiling temperature of -196°C at atmospheric pressure, is a by-product of oxygen manufacture. The refrigerant is sprayed into the freezer and evaporates both on leaving the spray nozzles and on contact with the products. Typical food products used in this system are fish fillets, seafood and fruits like berries. The temperature is either allowed to equilibrate at the required storage temperature (18-30^{o}C) before the food is removed from the freezers or alternatively food is passed to a mechanical freezer to complete the freezing process. The use of gaseous nitrogen reduces the thermal shock to the food and recirculation fans increases the rate of heat transfer.

2. Liquid carbon dioxide freezers: Liquid carbon dioxide exists either as a solid or gas when stored at an atmospheric pressure. When the gas is released to the atmosphere at -70°C, half of the gas becomes dry-ice snow and the other half stays in the form of vapour. This unusual property of liquid carbon dioxide is used in a variety of freezing systems, one of which is a pre-freezing treatment before the product is exposed to nitrogen spray.

C.Dehydro-Freezing

In this method of freezing, the freezing of food is preceded by the partial dehydration. The moisture of fruits and vegetables is removed up to 50% by dehydration, prior to freezing. The products which are dehydro-frozen are more stable and are better in quality.

D.Freeze-drying

Freeze drying is also known as sublimation-drying or lyophilisation. The method involves freezing of the material by exposing to cold air followed by sublimation of ice in vacuum from frozen state to produce a dried product. The food is firstly frozen at -18^{o}C on trays in lower chamber of the freeze drier and the frozen material is then dried initially at 30^{o}C for 24 hours and then at 20^{o}C under high vacuum of 0.1mm Hg in the upper chamber. In freeze drying process, the food material is composed of a frozen core and as the ice sublimes the plane of sublimation recedes from outer surface leaving a porous shell of the foodstuff. The heat supplied for latent heat of sublimation of about 2838 kJ/kg ice is conducted inward through layer of dried material. Water vapour also transferred through dried material and heat or mass transfer occurs simultaneously during freeze drying.

Packaging and Storage of frozen foods

Packaging of frozen foods

There are three types of packaging used for frozen foods: primary, secondary, and tertiary. The primary package is in direct contact with the food and the food is kept inside the package up to the time of use. Secondary packaging is a form of multiple packaging used to handle packages together for sale. Tertiary packaging is used for bulk transportation of products.

- Packaging materials should be moisture-vapour-proof (e.g. glass and rigid plastic) to prevent evaporation, thus retaining the highest quality in frozen foods.
- Oxygen should also be completely evacuated from the package using a vacuum or gas-flush system to prevent migration of moisture and oxygen.
- Most bags, wrapping materials and waxed cartons used in freezing packaging are moisture-vapour-resistant.
- The containers should be leakage free while easy to seal.
- Durability of the material is another important factor to consider, since the packaging material must not become brittle at low temperatures and crack.
- Glass, plastic, tin and heavily waxed cardboard materials are rigid containers used for packaging of liquid food products.
- Non-rigid containers include bags and sheets made of moisture-vapour-resistant heavy aluminium foil, polyethylene or laminated papers.
- Bags are the most commonly used packaging materials for frozen fruits and vegetables due to their flexibility during processing and handling. They can be used with or without outer cardboard cartons to protect against tearing.

Storage of frozen foods

Frozen products should be kept at the lowest possible temperature during frozen storage, transport, and distribution in achieving a high-quality product and to check deteriorative changes. The storage life of frozen foods at -18^{o}C is given in Table-13.2. The lower the product temperature is, the slower the speed of reaction is leading to loss of quality. The temperatures of supply chains in freezing applications from the factory to the retail cabinet should be carefully monitored. The temperature regime covering the freezing process, the cold-store temperatures (-18°C), distribution temperatures (-15°C) and retail (-12°C) are generally recommended.

Quality changes in freeze foods: The major effect of freezing on quality of food is the damage caused to cells by ice crystal growth. In fruits and vegetables, more rigid cell structure may be damaged by ice crystals. Extent of damage depends on size of crystals, and hence rate of heat transfer. During slow freezing, ice crystals grow in intercellular spaces and deform and rupture adjacent cell walls. Cells become dehydrated and permanently damaged by increased solute concentration. In case of fast freezing, smaller ice crystals form within both cells and intercellular spaces. Texture of food is thus retained in fast freezing compared to slow freezing.

Table 13.2: Storage life of frozen food at -18^{o}C.

Storage time	Type of food	Products
3 months or less	Meat	Liver, heart, brain, precooked bacon, precooked sausages
	Bakery products	Sponge cake, spice cake
3-6 months	Meat	Porks, beef, lamb kidney, tongue etc
	Poultry	Precooked turkey
6-12 months	Meats	Beef, veal, lamb, pork, smoked and roasted meat, processed pies
	Poultry	Raw and fried chicken
	Fish	Fatty fish, raw and cooked
	Vegetables	Asparagus, beans, Brussels sprout, corn
More than 12 months	Meat	Beef, lamb roasted
	Eggs	Whole, white yolk
	Fruits	Raspberries, strawberries, peach, apricot etc
	Vegetables	Lima bean, broccoli, cauliflower, green peas, spinach

Freezing causes negligible changes to pigments, flavours, nutritionally important components, although these may be lost in preparation procedures or deteriorate later during frozen storage. Main changes to frozen foods during storage are degradation of pigments, loss of water soluble vitamins at sub freezing temperatures, residual enzyme activity by polyphenoloxidase, lipoxygenase and off flavour developed due to oxidation of lipids.

1. **Recrystallization:** It is a physical change where small ice crystals combine to form large crystals.
2. **Sublimation:** It is a condition when water goes from solid to gaseous state without passing through liquid phase as opposed to way ice would normally melt if placed in glass of water is called sublimation.
3. **Freezer burn:** One of the most common forms of quality degradation due to moisture migration (sublimation) in frozen foods is freezer burn, a condition defined as the glassy appearance in some frozen products produced by ice crystals evaporating on the surface area of a product. This quality defect can be prevented by using heavyweight, moisture proof packaging during the freezing process.
4. **Chemical changes:** Maillard and enzymatic browning, flavour deterioration, protein insoluble and degradation of chlorophyll and vitamins. Chemical changes like insolubilization or gelation of proteins, lipid oxidation and degradation of

vitamins occurs at fairly slow rate at 0^0F (-18^0C) but at fast rate as temperature is increased.

Legal standards for frozen foods: Several agencies exist that establish regulatory standards for frozen fruits and vegetables based on import-export regulations of countries around the world. Some of the general regulations for consideration in the freezing of fruits and vegetables are summarized by the Canadian Food Inspection Agency, Liaison.

A) Frozen fruit products
a. Shall be prepared from fresh or previously frozen fruit that is preserved by freezing.
b. Shall be packed

- with or without a sweetening ingredient in dry form
- in a packing medium consisting of water, with/without a sweetening agent
- one or more fruit juices, concentrated and reconstituted fruit juices, fruit purees or fruit nectars, with or without a sweetening agent.
- May contain citric acid or ascorbic acid, in accordance with good manufacturing practice (GMP's).
- May contain any other substance the addition of which to frozen fruit is in accordance with GMP's and is generally recognized as safe.

B) Frozen vegetable products

- Shall be prepared from fresh vegetables or a mixture of frozen vegetables.
- May contain salt.
- May contain any other substance the addition of which to frozen vegetables is in accordance with GMP's and is generally recognized as safe.

Labelling of frozen foods
Most regulatory agencies depending on the location of production require some specific information to be included on the label of the frozen food package. Several basic requirements are recommended for labelling of frozen products is:

1. The common or usual name of the ingredients.
2. The form/style of vegetables or fruits like whole, slices or halves. If the form is visible through the package, it needs not to be mention.
3. The variety or colour in case of some fruits and vegetables.
4. Total contents (net weight) must be stated in grams for containers holding 1 kilogram or less.

Other information required on the label, although not on the front panel

a) Ingredients like spices, flavouring, colouring or special sweetener, if used
b) Any special type of treatment

c) The packer/distributor name and place of business
d) Nutritional information
e) Expiration date
f) Storage requirements
g) Heating instructions

Labels may also give the quality or grade, count, size and maturity of the vegetables, cooking directions and recipes or serving ideas. If the label lists the number of servings per container, the law requires that the size of the serving be given in common measures such as ounces or cups.

I. Freezing of fruits

The method for freezing of fruits depends upon the intended use. If the fruit is to be eaten without any further processing after thawing, texture characteristics are more important. In general, conventional methods of freezing tend to destroy the turgidity of living cells in fruit tissue. Different from vegetables, fruits do not have a fibrous structure that can resist this destructive effect. Additionally, fruits to be frozen are harvested in a fully ripe state and are soft in texture. On the contrary, most vegetables are frozen in an immature state. Fruits have delicate flavours that are easily damaged or changed by heat, indicating they are best eaten when raw and decrease in quality with processing.
Further, attractive colour is important for frozen fruits. Chemical treatments or additives are often used to inactivate the deteriorative enzymes in fruits. Therefore, proper processing is essential for all steps involved from harvesting to packaging and distribution. A process variable for freezing of different fruits given in Table 13.3 and flow chart for freezing process discussed in Fig 13.12.

Harvesting: The characteristics of raw materials for freezing include ability to withstand rough handling, uniformity in ripening, free from diseases, insect attack and bruises. The use of mechanical harvesting generally causes bruising of fruits and results in a wide range of maturity levels for fruits. In contrast, hand-picking provides gentler handling and sorting of fruits. For assessment of optimum maturity a combination of colour and pressure tests are generally used.

Table 13.3: Process variables for freezing of different fruits

Fruit	Preparation	Type of Pack followed by freezing
Apples	Wash, peel, slice and immerse in solution containing citric acid/salt/ascorbic acid to check browning. Drain prior to use.	Pack in 30-40% syrup containing 0.02% ascorbic acid
Apricots	Wash, halve and remove pit. Peel and slice if desired. If peeling is not possible, heat apricots in boiling water for half minute, cool and drain.	Pack in 40% syrup containing 0.02% ascorbic acid
Avocados	Peel soft and ripe avocados. Cut in half, remove pit and mash pulp.	Add 0.05% ascorbic acid to puree.
Berries	Select firm, fully ripe berries. Sort, wash and drain.	Use 30% syrup, dry unsweetened pack, dry sugar pack or tray pack.

Cherries (sour/ sweet)	Select healthy, well ripened and coloured cherries. Sort, wash thoroughly and remove pit.	Pack in 30-40% syrup containing 0.02% ascorbic acid. For pies, pack in dry sugar.
Citrus fruits, (sections or slices)	Select firm fruit, free of soft spots. Wash and peel.	Pack in 40% syrup or in fruit juice. Use 0.02% ascorbic acid in syrup or juice.
Grapes	Select firm and ripe grapes. Wash and remove stems. Cut grapes with seeds in half and remove seeds.	Pack in 20% syrup or pack without sugar. Use dry pack for halved and tray pack for whole grapes.
Melons (cantaloupe, watermelon)	Select firm-fleshed, well-coloured, ripe melons. Wash rinds well. Slice or cut into chunks.	Pack in 30% syrup or pack dry using no sugar. Pulp also may be crushed (except watermelon), adding 0.5% sugar. Freeze in recipe-size containers.

Pre-process handling (peeling, slicing/cutting)
Quality of the raw materials prior to freezing is the major consideration for successful freezing. Washing and cutting generally results in losses when applied after thawing. Thus, fruits should be prepared prior to the freezing process in terms of peeling, slicing or cutting. Peeling is done by scalding the fruit in hot water, steam or hot lye solutions in case of fruits that require peeling. Banana, tomato, mango and kiwi fruits are cut into smaller cubes or slices prior to freezing.

Blanching: The objective of blanching is to inactivate the enzymes causing detrimental changes in colour, odour, flavour and nutritive value, but heat treatment causes loss of such characteristics in fruits. Therefore, only a few types of fruits are blanched for inactivation of enzymes prior to freezing. The loss of water-soluble minerals and vitamins during blanching should also be minimized by keeping optimum blanching temperature and time.

Addition of sugar syrup: Addition of sugar is an important pre-treatment for fruits prior to freezing since the treatment has the effect of excluding oxygen from the fruit, which helps to retaining colour and appearance. Sugars when dissolved in solutions act by withdrawing water from cells by osmosis, resulting in very concentrated solutions inside the cells. The high concentration of solutes depresses the freezing point and therefore reduces the freezing within the cells, which inhibits excessive structural damage. Sugar syrups (30-60%) are commonly used to cover the fruit completely. It acts as a barrier to oxygen transmission and browning. Addition of syrup has a protective effect on flavour, odour, colour and nutritive value during freezing, especially for frozen berries.

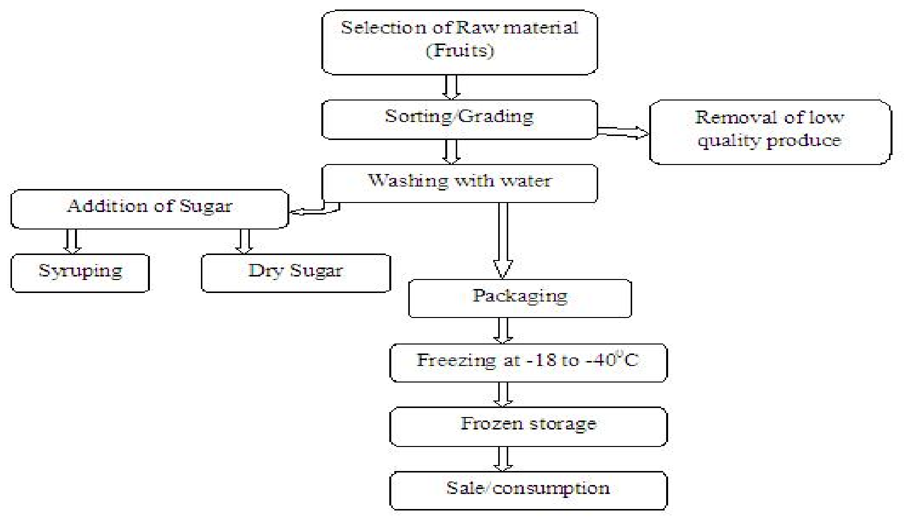

Fig 13.12: Flow chart for freezing of fruits

Packaging

Packaging of frozen fruits is done to exclude air from the fruit tissues. Replacement of oxygen with sugar solution or inert gas consuming the oxygen by glucose-oxidase and/or the use of vacuum and oxygen-impermeable films is used for packaging frozen fruits. Plastic bags, plastic pots, paper bags and cans are some of the most commonly used packaging materials (with or without oxygen removal) selected on basis of penetration properties and thickness. There are several types of fruit packs suitable for freezing: syrup pack, sugar pack, unsweetened pack, tray pack and sugar replacement pack. The type of pack is usually selected according to the intended use for the fruit.

1. Syrup pack: For most fruits, 40 percent sugar syrup is recommended. Lighter syrups are lower in calories and mostly desirable for mild-flavoured fruits to prevent masking the flavour, while heavier syrups may be used for very sour fruits. Cooled syrup is used to cover the prepared fruits. Pectin can also be used in the syrup to reduce sugar content in syrups when freezing berries, cherries and peaches.

2. Sugar packs: In preparing a sugar pack, sugar is first sprinkled over the fruit and the container is agitated gently until the juice is drawn out and the sugar is dissolved. This type of pack is generally used for soft sliced fruits such as peaches, strawberries, plums and cherries to cover the fruit with syrup. Some whole fruits may also be coated with sugar prior to freezing.

3. Unsweetened packs: Unsweetened packs can be prepared in several ways, either dry-packed, covered with water containing ascorbic acid, or packed in unsweetened juice. When water or juice is used in syrup and sugar packs, fruit is submerged by using a small piece of crumpled water-resistant material. Generally, unsweetened packs yield a lower quality product when compared with sugar packs, with the exception that some fruits such as raspberries, blueberries, scalded apples, gooseberries, currants, and cranberries maintain good quality without sugar.

4. Tray packs: Unsweetened packs are generally prepared by using tray packs in which a single layer of prepared fruit is spread on shallow trays, frozen and packaged in freezer bags promptly.

5. Sugar replacement packs: Artificial sweeteners can be used instead of sugar in the form of sugar substitutes. The sweet taste of sugar can be replaced by using these kinds of sweeteners, however the beneficial effects of sugar like colour protection and thick syrup cannot be replaced.

II. Freezing of vegetables

Freezing is often considered the simplest and most natural way of preservation used for vegetables. Frozen vegetables form a significant proportion of the market in terms of frozen food consumption. The quality of frozen vegetables depends on the quality of fresh products, since freezing does not improve product quality. Pre-process handling from the picking of vegetables until its ultimate use, is the important factor affecting quality of finished product. A process variable for freezing of different vegetables given in Table 13.4 and flow chart for freezing process discussed in Fig 13.13.

Table 13.4: Process variables for preparation of vegetables for freezing

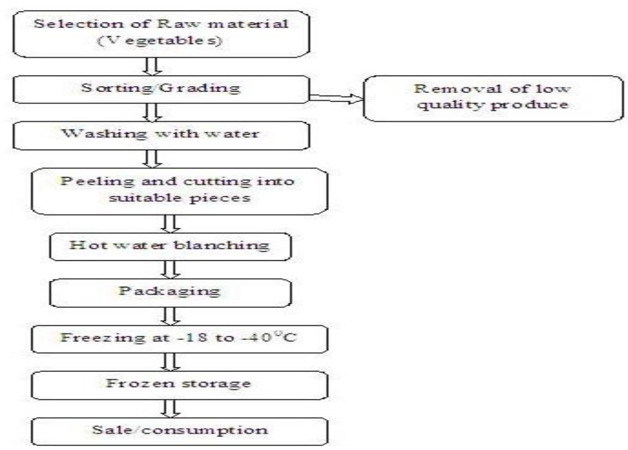

Figure 13.13: Flow chart for freezing of vegetables

2. Pre-process handling: Vegetables at peak flavour and texture are used for freezing. Post harvest delays in handling vegetables are known to produce deterioration in flavour, texture, colour and nutrients. Therefore, the delay between harvest and processing should be reduced to retain fresh quality prior to freezing. Cooling vegetables by cold water, air blasting or ice will often reduce the rate of post-harvest losses sufficiently, providing extra hours of high quality retention for transporting raw material to considerable distances from the field to the processing plant. Vegetables are sorted and graded to discard any diseased, bruised and non uniform ripened part.

3. Blanching: Blanching is the exposure of the vegetables to boiling water or steam for a brief period of time to inactivate enzymes. All vegetables (except herbs and green peppers) need to be blanched and promptly cooled prior to freezing, since heating slows or stops the enzyme action. After maturation, however the enzymes can cause loss in quality, flavour, colour, texture and nutrients. If vegetables are not heated sufficiently, the enzymes will continue to be active during frozen storage and may cause the vegetables to toughen or develop off-flavours and colours. Blanching is usually carried out between 75 and 95°C for 1 to 10 minutes, depending on the size of individual vegetable pieces. Blanched vegetables should be promptly cooled down to control and minimize the degradation of soluble and heat-labile nutrients. Vegetables can be blanched in hot water, steam, and in the microwave.

- Hot water blanching is the most common way of processing vegetables. For water blanching, vegetables are put in a basket and then placed in a kettle of boiling water covered with a lid.
- Steam blanching takes longer than the water blanching method, but helps retain water-soluble nutrients such as water-soluble vitamins. For steam blanching, a single layer of vegetables is placed on a rack or in a basket at 3-5 cm above water boiling in a kettle. A tightly fitted lid is placed on the kettle and timing is started.
- Microwave blanching is usually recommended for small quantities of vegetables prior to freezing.

4. Packaging: There are several factors to consider in packaging frozen vegetables, which include protection from atmospheric oxygen, prevention of moisture loss, retention of flavour and rate of heat transfer through the package. Vegetables for freezing are packed either as dry pack or tray pack.

Dry-pack method: In the dry pack method, the blanched and drained vegetables are put into meal-sized freezer bags and packed tightly to cut down on the amount of air in the package. Proper headspace (approximately 2 cm) is left at the top of rigid containers before closing. For freezer bags, the headspace is larger. However, provision for headspace is not necessary for vegetables such as broccoli, asparagus and brussels sprouts as they do not pack tightly in containers.

Tray-pack method: In the tray pack method, the chilled, well-drained vegetables are placed in a single layer on shallow trays or pans. Trays are placed in a freezer until the vegetables become firm and then removed.

Lecture 14 - Spoilage of processed products

Objective: This chapter deals with various causes of food spoilage, identification of spoiled products from external appearance, chemical and biological spoilage, discolouration of canned products and classification of spoilage on the basis of acidity of food. In the end frequently asked questions pertaining to food spoilage are also given.

Introduction

Introduction

Spoiled food is defined as the food that has been damaged or has undergone changes so as to render it undesirable/unacceptable/unfit for human consumption. Spoilage of processed products is mainly caused by the action of micro-organisms and due to the physical or chemical changes. The reasons for microbial spoilage include under- processing, inadequate cooling, contamination from leakage through can seams and pre-process spoilage. In under-processed cans (receiving low heat treatment) large number of micro-organisms is expected to be involved in spoilage.

Causes of food spoilage

Food spoilage or deterioration may be described as loss of weight, softening, souring, rotting, wilting, moulding or a combination of one or more forms. The major causes of food deterioration are: biotic and abiotic factors.

A. Biotic factors

- Microbial spoilage (yeast, mould, bacteria)
- Enzyme action (activation of enzymes present in foods)
- Insect and rodent damage (attack of insects, rodents and parasites)

B. Abiotic factors

- Factors like temperature, moisture, light, oxygen etc.

A. Biotic factors

1) Microbial spoilage: Micro-organisms like yeast, mould and bacteria spoil food after harvesting, during handling, processing and storage. Some of these micro-organisms can be used to produce desirable changes in foods under controlled conditions such as lactic acid producing bacteria in making cheese and fermented dairy products, yeast as leavening agent and for production of beer and wine, citric acid production by using Aspergillus sp etc.

a) Yeast: Yeasts are those fungi which are not filamentous but unicellular, ovoid or spheroid in shape and reproduce by budding or fusion. Yeasts are both useful as well as harmful in foods. Yeast fermentations are involved in the manufacture of foods such as bread, beer, wines and surface ripened cheese as well as for production of enzymes. Foods are often contaminated by yeasts as they cause spoilage by converting sugar to alcohol and carbon dioxide. Common foods spoiled by yeasts include fruit juices, syrups, molasses, honey, jam, jellies, sauerkraut, wine etc. Most common yeasts grow in high to low available moisture, but generally require less moisture than majority of bacteria and comparatively more moisture than moulds. The optimum temperature for growth of yeasts is 25-30^{o}C with maximum limit up to 35-47^{o}C. Many types of yeast grow best in acidic (pH 4.0-4.5) but not in alkaline medium.

b) Moulds: Moulds are multi-cellular, filamentous fungi whose growth on foods is recognized by its fuzzy appearance. The growth may appear to be white, coloured, dark or smoky. They are strictly aerobes and require oxygen for their growth and multiplication. Moulds grow on almost all kinds of foods ranging from simple to complex. They require less free moisture than yeasts and bacteria. They grow over a wide range of pH (2.0 to 8.5) but majority of them favour acidic pH. Most moulds are able to grow at ordinary temperatures i.e. mesophilic. The optimal temperature for most moulds is 25-30^{o}C but some can grow at 37^{o}C or above like Aspergillus sp., while few moulds are psychotropic as they grow well at refrigeration temperature or even below freezing temperature. Most moulds are not harmful. Some moulds in foods are capable of producing toxic materials called mycotoxins. Examples of mycotoxins are aflatoxins produced by moulds growing on groundnut, patulin from Penicillium expansum on apple and other agricultural products such as wheat, millet and rye if they are not dried properly.

c) Bacteria: Bacteria are unicellular micro-organisms and are much smaller in size than yeasts or moulds. They occur in different sizes and shapes and are classified as coccus (spheroidal), bacilli (rod shape or cylindrical) or spirillae and vibrios (spiral shape). They can penetrate the smallest opening, as many can pass through the natural pores of an egg shell. Bacterial growth on the food make it unattractive in appearance, cause discolouration on the food surface, make surfaces slimy or results in undesirable cloudiness or sedimentation. In contrast to yeast and moulds, most bacteria cannot grow in acidic media (pH $<$4.5). Some bacteria require oxygen for their growth (aerobes) and some cannot tolerate oxygen (anaerobes) while some can grow in an atmosphere devoid of oxygen but can also manage in air (facultative anaerobes). Bacteria can grow and develop rapidly between 20-53^{o}C. On the basis of temperature requirement, bacteria are categorized as thermophiles (requiring temperature higher than 45^{o}C), mesophiles (requiring temperature between 20-25^{o}C) and psychrophiles (requiring temperature less than 20^{o}C). Bacteria usually cause spoilage in foods which are neutral or low acidic such as vegetables, milk, eggs, meat and fish.
Thus micro-organisms like bacteria, yeast and moulds are the main causes of food spoilage.

2) Enzyme action: Enzymes are the polypeptides that catalyze a reaction with certain degree of specificity. Many reactions in plant and animal tissues are activated by enzymes. The changes in food during storage can be produced by the enzymes present in the food or by the micro-organisms that contaminate the food. They are responsible for bringing many changes during storage like change in colour, texture and flavour in fresh produce after harvest. Through some of these changes are desirable like ripening of fruits but these changes can also result in food deterioration if they are not halted at appropriate time. Thus, enzymes responsible for deteriorative changes should be inactivated by using a suitable method to prevent food deterioration. The enzymes are proteinaceous in nature and can be denatured by heat. Enzymes can act from 0oC to 60oC, however, 37oC is optimum temperature and the rate of reaction varies directly with temperature. Generally, most enzymes are inactivated by temperature above 80oC.

Important enzymes involved in food deterioration include polyphenol oxidase, lipoxygenase, amylase, pectin methyl esterase and poly galacturonase.

3) Insects, parasites and rodents: Insects like worms, bugs, weevils, fruit flies and moths damage the food and reduce its nutrient content and render it unfit for human consumption. Insect eggs may persist in foods even after processing as in flour. Insects in grains, dried fruits and spices are generally controlled by fumigation with fumigants like methyl bromide, ethylene oxide, propylene oxide etc besides eating loss; the insects cause greater damage by making bruises and cuts in the fruits thus exposing the food to microbial attack and resulting in total decay.

Parasitic spoilage occurs in some foods. Parasitic nematode penetrates the hog's intestine when uncooked food is eaten by the hog's and finds its way into pork. Rodents like rats cause extensive damage of food grains. Urine and droppings of rodents harbour several kinds of disease producing bacteria and rats spread many human diseases like typhus fever, plague, typhoid fever etc.

B. Abiotic factors

1) Temperature: Low or high temperature apart from its role in food preservation also brings deterioration of foods. The rate of chemical reaction doubles with every 10oC rise in temperature. Excessive heat causes protein denaturation, destroys vitamins, breaks emulsions and dries out food by removing moisture. Similarly, low temperature cause deterioration like freezing and thawing of fruit and vegetables destroy their structure. Many fruits and vegetables are damaged even at refrigeration temperatures (4oC). The deterioration includes off-colour development, surface biting and various forms of decay. Thus banana, tomato, lemons etc are stored above 10oC to avoid chilling injury.

2) Moisture: The presence of water is the most important factor controlling the rate of deterioration of food either by micro-organisms, enzymes or other chemical reactions. Moisture is required for chemical and enzymic reactions and for microbial growth. Foods with high moisture contents deteriorate fast. Perishable foods with high water content like leafy vegetables, juicy fruits, meats and milk deteriorate rapidly. Changes in surface moisture with change in relative humidity cause caking, surface defects, crystallization and stickiness in foods. Condensation of moisture results in multiplication of bacteria and yeasts. Fruit and vegetables give off moisture from respiration and transpiration even when packaged in moisture free packages. Thus control of moisture in foods is necessary to ensure preservation. The shelf-life of a food can also be measured by the water activity of food. Water activity (aw) is defined as the ratio of the vapour pressure of water in food to the saturated vapour pressure of pure water at the same temperature.

aw = p where, p = vapour pressure of water in food, Pa
p0 p0 = vapour pressure of pure water, Pa

Water activity can also be defined according to Raoult's law of mole fractions, which refers water activity as the ratio of number of moles of water in a solution to the total number of moles of water and solute in the solution as under:-

$$a_w = \frac{n_2 \text{ (moles of water)}}{n_2 \text{ (moles of water)} + n_1 \text{ (moles of solute)}}$$

Assuming that water is pure, the a_w can be calculated as

$$a_w = \frac{n_2}{n_2+n_1} = \frac{55.5}{55.5+0} = 1.0$$

(1 litre of water contains 55.5 moles)

In case, even if one mole of sucrose or salt is added, the water activity shall consequently be lowered down.

$$a_w = \frac{55.5}{55.5+1.0} = 0.98$$

This equation can be used to get desired water activity in the food by increasing the number of moles of solute and reducing the mole of solvent either by using drying, concentration, addition of sugar, salt, freezing etc. Thus most of the methods of preservation like drying, concentration, salting, sugar preservation etc are based on management of water activity. Most of micro-organisms fail to grow at reduced water activity and hence aids in preservation. The interaction of aw with temperature, pH, oxygen and carbon dioxide or chemical preservatives influence the microbial growth. Thus, water activity can be used as an important tool in food preservation.

3.) Oxygen and Light: Air and oxygen bring about a number of destructive changes in food components such as destruction of food colour, flavour, vitamin A, C and E and other food constituents. As oxygen is required for growth of moulds, its removal from the food by deaeration, vacuum packing or flushing containers with nitrogen or carbon dioxide or by using oxygen absorbing chemicals like antioxidants helps in food preservation.
Vitamins like B2, A, C and food colours in the food are deteriorated in the presence of light. Foods can be protected from light by using impervious packing or keeping them in containers that screen out specific wavelengths. Further, all the food deteriorative factors are time dependent. The longer the time, the greater the destructive influences. Therefore, optimum time of storage for food commodities need to be worked out.

Spoilage of canned food products: The spoilage of canned products during storage may be caused due to two main reasons:

- Chemical reaction on the can producing hydrogen swells or perforations, and
- Chemical action on the fruit or vegetable resulting in discolouration or loss of flavour etc.

The appearance and smell (odour) of the spoiled can is different from that of normal unspoiled can and such cans should never be tasted. It is therefore, essential to identify the can from the external appearance and diagnose the cause of the spoilage.

I. Identification of spoilage on the basis of external appearance of cans

The extent of spoilage of heat processed product can be identified by observing the external appearance of the unopened can. The ends of a normal can of food after processing are flat or slightly concave having partial vacuum inside. With the development of pressure inside the can, the can goes through a series of distortions due to increasing pressures. The conditions of such cans are designated by following terms:

1. Flipper: A can with a mild positive pressure having both ends flat. One end of this can will become convex when the side of the can is struck sharply or when the temperature of the contents is increased.

2. Springer: It is the can with both ends bulged, but one or both ends will stay concave. If swollen end of can is pushed in, an opposite flat end will pop out. Both Flipper and Springer indicates the initial stage of hydrogen swell but may also be caused by insufficient exhausting or over filling of the can. Later on it results in denting of can with change in temperature.

3. Soft swell: It refers to a can with both ends bulged, but the gas pressure is low enough to permit the ends to be dented by manual pressure.

4. Hard swell: The can with hard swell has both ends bulged. It contains such a high gas pressure that neither end could be dented by hand. Oftenly, the high gas pressure distorts the ends or side seam of the cans and finally the can bursts from side seam or through the seal at ends. The decomposed food in the can has an offensive and sour odour and the product is generally discoloured. It is not fit for consumption and may contain toxins produced by Clostridium botulinum.

5. Breather: A breather is a can with a minute leakage that permits air to move in or out but does not necessarily allow micro-organisms to enter. In these cans, there is no vacuum and the pressure inside the can is equal to that of the atmosphere. The food remains fit for consumption.

6. Leaker: A very small leakage in the can may be due to faulty seam, or pin hole as a result of corrosion inside the can or rusting of can from outside.

7. Flat sour: It may be caused by under-sterilization. The product has a sour odour and its acidity is much greater than that of the normal product.

8. Bursting of can: Bursting of cans is due to excess of pressure caused by the gases inside, produced by decomposition of food by micro-organisms, or by hydrogen gas formed by chemical action of acids of the food on the tinplate. The canned product becomes a total loss.

II. Identification of spoilage on the basis of appearance of glass containers
The glass containers like bottle, jar, carboys etc of food under gas pressure may have its closure bulged or popped off or may show leakage of food through the broken seal. The microbial growth can also be seen through the glass container in the form of gas bubbles, cloudiness and films of growth.

Causes of spoilage of canned/bottled products

III Causes of spoilage of canned/bottled products
Food is mostly subjected to physical, chemical and biological changes which lead to quality deterioration and ultimately spoilage.
1. Chemical spoilage: Hydrogen swell is the important type of chemical spoilage of canned food. The hydrogen gas formed inside the can, by the action of food acid on the iron of the can

causes the can to swell which is termed as Hydrogen swell. Major causes of hydrogen swell are:

- Presence of high acid in the can.
- Storage at high temperature.
- Imperfections in tinning and lacquering inside of the can.
- Insufficient exhausting during canning.
- Presence of soluble sulphur and phosphorus in the can contents.
- Interaction between steel base of can and contents of the food leading to chemical spoilage and may also cause following defects:
  - discolouration of the food
  - discolouration inside the can
  - production of off flavour in the food
  - cloudiness of liquors or syrups or brines
  - corrosion or perforation of the metal and loss of nutritive quality.

2. Biological spoilage: Biological spoilage in the canned food is caused by either survival of organisms after heat treatment or entry of micro-organisms through leakage of the container after heat processing. The types of micro-organisms involved in spoilage of canned foods are thermophilic bacteria and mesophilic micro-organism and kind of spoilage brought about by these groups is characterized and discussed further in this chapter.

A) Spoilage by mesophilic organisms: This type of spoilage is caused by spore forming bacteria of genera Bacillus and Clostridium growing in the food as a result of under processing. Besides, spoilage of lightly heated food like acidic foods can also be caused by non-spore forming bacteria or even yeasts or moulds. Spoilage by mesophilic Clostridium & Bacillus sp. and sugar fermenting species of Clostridium like Clostridium butyricum and Clostridium pasteurianum cause the butyric acid type of fermentation in acid or medium-acid foods. This lead to swelling of container due to the production of hydrogen gas and carbon-dioxide gas. The mesophilic organisms responsible for spoilage are as under:

- Putrefactive anaerobes
- Butyric anaerobes
- Aciduric Flat sour and Lactobacilli
- Yeast
- Moulds

i) Putrefactive anaerobes: The species of Clostridium like C. sporogenes, C. putrefaciens and C. botulinum are proteolytic or putrefactive causing decomposition of proteins with the production of off odorous compounds such as hydrogen sulphide, and ammonia. Besides, putrefactive anaerobes also produce carbon dioxide and hydrogen gas, thus causing the can to swell. The spores of some putrefactive anaerobes are very heat resistant thus putrefaction along with flat sour and TA (thermophilic anaerobes) spoilage constitutes the major type of biological spoilage of canned foods resulting from under processing. Putrefactive anaerobes grow best in the low acid canned foods like peas, corn, meats, fish and poultry. C. botulinum is main putrifier causing food poisoning.

ii) Butyric anaerobes: The spores of saccharolytic Clostridia commonly called as butyrics having comparatively low heat resistance, cause spoilage of canned foods which have been processed at 100^{o}C or less such as commercially canned acid foods processed by hot water or steam. Canned acid foods such as pineapple, tomato and pears are generally spoiled by Clostridium pasteurianum. The spoilage by Saccharolytic bacteria is characterized by the production of butyric acid, carbon dioxide and hydrogen. Similarly, canned peas, asparagus, spinach, peach and tomatoes can be spoiled by aerobacilli or gas forming Bacillus species (B. polymyxa and B. macerans) by entering possibly through the leakage in the container. The heat resistance of Bacillus sp. is same as that of Clostridium pasteurianum.

iii) Aciduric flat sour and Lactobacilli: It is also referred as spoilage by non-spore forming bacteria. The presence of viable non-spore forming bacteria in the canned food indicates that the product has received either a very mild heat treatment or the bacteria entered through a leakage in the container. Common micro-organisms found in under processed fruit products such as tomato and pear includes acid forming Lactobacillus and Leuconostoc species. Some thermoduric bacteria which can withstand pasteurization are Streptococcus thermophillus, some species of Micrococcus, Lactobacillus and Microbacterium. An important bacterium found in cooling water is coliform bacteria, which produce gas and cause the can to swell. However, spore forming bacteria can also enter the can through the leakage. Further non-spore forming and non-gas forming bacteria that may enter the can through leakage include those in the genera Pseudomonas, Alcaligenes, Micrococcus, Flavobacterium, Proteus etc.

iv) Spoilage by yeast: Detection of yeasts and their spores in the canned foods is the result of either gross under processing or leakage as the yeasts and their spores are readily killed by most heat processing methods. Canned fruits, jams, jellies, fruit juices, syrups etc are generally spoiled by fermentative yeasts, with swelling of the cans owing to the production of carbon dioxide. Presence and growth of film yeasts on the pickles, olives etc. indicates contamination, lack of heat processing and poor evacuation.

v) Spoilage by moulds: Growth of moulds is the common cause of spoilage of high sugar containing processed and canned foods as they enter through a leak in seal of the container. Though jams, jellies and marmalade having sugar concentration as high as 70% with normal acidity of 0.8 to 1.0%, practically removes the risk of mould spoilage yet sometimes mould growth can be seen on the surface of the product. Strains of Aspergillus, Penicillium and Citromyces found growing in jellies and canned fruits are able to grow in sugar concentration up to 67.5 percent but can be killed by heating the food at 90^{o}C for 1 minute. Some moulds are fairly resistant to heat like Byssochlamus fulva, a pectin fermenting moulds which resist the heat processing.

B) Spoilage by thermophilic organisms

Major cause of spoilage of heat processed foods by thermophilic spore is due to under processing as their spores are more heat resistant than those of mesophilic bacteria. Spoilage by thermophiles includes flat sour, TA spoilage and sulphide spoilage.

i) Flat sour spoilage: In this kind of spoilage, the ends of the can of food remain flat during souring or during the development of lactic acid in the food by the flat sour bacteria. Due to normal appearance of the can, this type of spoilage can not be detected by the examination of the unopened can. Flat sour spoilage occurs in low-acid foods such as peas, lima bean and corn etc and is caused by species of Bacillus which form acid without production of gas. They include mesophiles, facultative thermophiles or obligate thermophiles. In acidic foods like tomato and tomato juice, flat sour is caused by facultative thermophilic species such as Bacillus coagulans. The spores of mesophiles being least heat resistant are killed by heat processing and are therefore not involved in flat sour spoilage of low acid foods, but the spores of thermophiles are considerably more heat resistant and survive the heat process to cause flat sour spoilage.

ii) TA spoilage: TA is a nick name for the bacterium thermophillic anaerobe not producing hydrogen sulphide or for Clostridium thermo-saccharolyticum causing this type of spoilage. This bacterium is a thermophilic spore-forming anaerobe that forms acid and gas in foods. The gas (mixture of CO_2 and H2) developing inside the container cause the can to swell and when cans are stored for too long at high temperature they may result in bursting. The spoiled food has sour or cheesy odour. The source of bacteria for both flat sour and TA spoilage is starchy/sugary foods.

iii) Sulphide spoilage: TA spoilage producing H2S and cause sulphide spoilage. The micro-organism responsible for sulphide spoilage is Desulfotomaculum nigrificans and is found in low acid foods like peas and corn. The spores of this bacterium are less heat resistant than those of flat sour and TA bacteria; as such the appearance of sulphide spoilage in canned food is the indication of gross under-processing.

C). Classification of microbial spoilage on the basis of acidity

The low acid food with pH above 5.3 is subject to flat sour spoilage and putrefaction. Medium acid foods with pH between 5.3 and 4.5 are likely to undergo TA spoilage. Acid food with pH between 4.5 and 3.7 are spoiled by special flat sour bacterium or by saccharolytic anaerobe. However, high acid food with a pH below 3.7 generally does not undergo spoilage by bacteria, but in the cans it may result in hydrogen swell. The type of the spoilage in the canned food can be classified on the basis of acidity of the food (Table 14.1).

Table 14.1: Classification of microbial spoilage based on acidity of the food

Type of food	Foods involved	Type of spoilage
Low acid pH $\geq$ 5.4 Medium acid pH 5.3-4.6	Meat and fish products milk, vegetables like corn, lima beans, peas, meat and vegetable mixers.	i) Thermophilic flat sour group. (*Bacillus sterothermophilus, B. coagulans*). ii) Sulphide spoilage (*Clostridium nigrificans, C. bifermentans*). iii) Gas formers (*Clostridium*

		thermosaccharolyticum). iv) Mesophilic spoilage like putrefactive anaerobe. v) Spoilage and toxin production by *Clostridium botulinum*.
Acid food pH 3.7-4.6	Fruits, pears, figs, tomato etc.	i) Thermophilic spoiler *Bacillus coagulans* ii) Mesophilic spoiler *B. polymyxa, Clostridium pasteurianum, C. butyricum, Lactobacilli* etc.
High acid pH<3.7	Fruits like grape fruit, citrus, rhubarb etc and products like sauerkraut, pickles etc.	Non-spore forming mesophiles, yeast, mould and/or lactic acid bacteria.

Discolouration of fruit products

Besides microbial spoilage, the processed products may experience discolouration, which may be caused by various reactions brought by the action of enzymes, metallic contamination or through the reaction between different components.

i) Enzymatic browning: Browning of cut and peeled apples, potatoes and pears is caused by the oxidation of phenolic compounds brought about by the action of oxidase enzyme (Polyphenol oxidase) in the presence of air. The browning can be checked by placing the cut and peeled fruit in 2-3% NaCl solution until used for canning.

ii) Non-enzymatic browning: Browning of fruit products brought out by the reactions other than enzymes is called as non-enzymatic browning. The changes in colour of fruit products may be caused by reactions between i) nitrogenous matter and sugar ii) nitrogenous matter and organic acids iii) sugar and organic acids and iv) organic acids among themselves like ascorbic acid degradation and sugar degradation. The browning reactions between nitrogenous matter and sugar are known as Maillard reactions.

iii) Metallic contamination: The browning of canned fruit products is generally caused by the presence of iron and copper salts. Important metallic contaminations in fruit products include ferric tannate, iron sulphide, copper sulphide etc.

a) Ferric tannate: The natural tannins present in fruit and vegetables react with the iron of the tinplate of can to form ferric tannate which make the product black and spoils the appearance of the canned product.

b) Iron sulphide: Sulphur dioxide may be formed inside the can due to decomposition of protein in the product or it may come from the sulphited sugar used in canning. The SO_2 may react with hydrogen formed by the fruit acid acting on the tin plate and get reduced to H_2S, which in turn may react with the iron of the can and form the black iron sulphide. Ferrous sulphide releases obnoxious smell of H_2S, besides spoiling the appearance of product.

c) Copper sulphide: The copper from the plant and equipment made of copper or brass may find its entry into the product and such product when comes in contact with H_2S formed inside the can may form black copper sulphide, which causes discolouration of the product.

d) Black deposit in canned pumpkin. The amino compounds present in the pumpkin react with the iron of the can forming deposits in the canned product.

e) Discoloration in canned corn. Canned corn turns grey in colour. This is due to the formation of sulphides of iron and copper as a result of corrosion of the tin plate and tarnishing of the metal of the equipment, respectively. To prevent it only 'C-enamel' cans should be used.

f) Black deposit in canned fruits. In the case of fruits canned in syrups prepared from sugar, which sometimes contain sulphur dioxide, cause blackening of the tin plate due to the formation of iron sulphide.

g) Pink discoloration in canned pears, guava and peaches. Pears, peaches and guava turn pink, if the cans are not cooled properly after sterilization.

Thus major cause of spoilage of canned products are under processing, cooling of cans in contaminated water, defects in seaming operation, use of non-lacquered cans in some products etc which may be avoided during processing of canned products.

Lecture 15 - Processing of plantation crops

Objective: This chapter covers processing techniques and methods for major plantation crops like tea, coffee, rubber, coconut, arecanut, oil palm, cashewnut and cocoa. CTC and orthodox method for tea processing, different types of tea, dry and wet method of coffee processing, drying, roasting, grinding, blending steps in coffee processing are also discussed alongwith different types of coffee. Cocoa processing, chocolate processing from cocoa, processing of arecanut into dried nuts, kalipak, scented supari; cashewnut processing, cashew by-products; products from coconut like edible copra, ball copra, coconut milk, coconut oil, shell based and wood based products are discussed in this chapter. Multiple choice quick answer questions are also included at last in this chapter.

Introduction

Introduction

Plantation crops are high value industrial crops grown in the tropics having great economic importance. They have great potential for utilization of waste land like rainfed dry land, hilly, arid and coastal areas to provide nutritional security, earn foreign exchange and to ensure livelihood security. The major plantation crops grown in India are tea (Camellia sinensis L), coffee (Coffea arabica L.), rubber (Hevea brasiliensis), coconut (Cocos nucifera), arecanut (Areca catechu L.), oilpalm (Elaeis guinensis), cashewnut (Anacardium occidentale L.) and cocoa (Theobroma cacao L.). India is the leading producer of most of these plantation crops. Among all fruit crops, the processing plays an important role in plantation crops as they are generally consumed only after processing. Coconut, arecanut, cashewnut, black pepper and cardamom are known as small holder plantations whereas, crops like rubber, tea and coffee are known as estate crops or conventional plantation crop.

A. TEA (Camellia sinensis L)

Tea is an evergreen woody perennial grown in many Asian countries including China, Japan, Java, Sumatra and India. Tea belongs to family Camelliaceae. The plant produces dark green, small shiny leaves with white blossom. In post harvest and manufacturing practices for tea, only mechanical and physical processes are followed with natural fermentation. It can be manufactured by orthodox, CTC (crush, tear and curl) processing.

Processing of tea

Tea processing is the method in which the leaves from the tea plant (Camellia sinensis L) are transformed into dried leaves for brewing. Processing steps broadly involves picking, withering, rolling, oxidation/fermentation, drying and curing/ageing. The steps involved are as follow:

1. Picking: Tea leaves and flushes, which include a terminal bud and two young leaves, are plucked from Camellia sinensis bushes twice a year during early spring and early summer or late spring. Generally hand picking is preferred for picking of tea leaves. Hand picking is done by pulling flush with a snap of wrist and does not involve twisting or pinching of flush, as twisting generally reduce the quality of leaves. Machine picking results in more broken leaves and is not suitable on mountain slopes where tea is grown.

2. Withering: Withering is used to remove excess water from the leaves and sometimes loose more than a quarter of their weight. Newly picked leaves are thinly spread in the sun or left in a cool breezy room to pull moisture out from the leaves. Heated air is sometimes forced over the leaves if the climate is not suitable. By the end of this process, the leaves become pliable enough for rolling. In order to quicken the oxidation process, the leaves may be bruised by tumbling in baskets or rolled-over by heavy wheels. The main purpose of this process is the partial expulsion of moisture and thus saving fuel consumed in drying operation and allows a very light oxidation.

3. Rolling: From the withering racks, the leaves are twisted and rolled to allow breaking of leaf cells. During rolling process, some of leaf juices and oils are released, that gives the tea its distinctive aroma and may aid in oxidation. The leaves can be rolled with rolling machine or by hand.

a) CTC processing: The CTC (crush, tear, curl) machine consists of two cylindrical rollers (61 or 91 cm long and 20 cm in diameter) having stainless steel segment having fine tooth like sharp ridges (3-4 ridges/cm in lengthwise and 50-60 ridges over circumference). The rollers are having marginal clearance and rotate in opposite direction at different speed in the ratio of 1:10 between slow: high speed rollers. The speed of 70:700 and 100:1000 rpm have good effects. The crush, tear and curl (CTC) maceration takes only few minutes.

b) Orthodox processing: The rolling is done normally in 36" or 46" diameter rollers. A tea roller consists of 3 main parts; a table fitted with cones and battens, a bottomless jacket and pressure cup fitted with adjusting screw to enable pressure to be applied to a desired extent. The roller may be table or jacket moving, normally rotates at 45 rpm speed. The battens are provided to form obstruction in the leaf path. It increases frictional effect of roller table and breaks the leaf at the same time. Battens help in cutting the leaves in roller. The cone fitted at centre of table intensifies leaf circulation by causing a greater turning action provided by batten alone. With each turn of roller, the leaf caught between cone and roller jacket subjects to heavy pressure and this result in greater extraction of sap. The withered leaf is then charged into the jacket.

4. Oxidation/fermentation: Oxidation begins once the leaf membranes are broken down enzymatically during the rolling process. It is an important stage in black tea processing. During this stage, the most important properties of tea are produced. It is a chemical process where oxygen is absorbed and the leaves turn progressively darker. The tannins are released and transformed during this process. Oxidation causes the leaves to turn bright copper in colour. This process is the main deciding factor to prepare different types of teas like Green, Oolong or Black tea. For different types of teas, the extent of oxidation is 5-40% for light oolong tea, 60-70% for darker oolong tea and 100% for black tea. During fermentation, low temperature (20^0C) and high humidity (95%) are desirable.

5. Kill-green and shaping: After oxidation, kill-green is done to stop tea leaf oxidation at a desired level. Heating tea leaves moderately deactivate their oxidative enzymes without destroying tea flavour. The leaves after kill-green are allowed to be lightly heated in a closed container, which causes the previously green leaves to turn yellow. The damp tea leaves are then rolled to be formed into wrinkle strips.

6. Drying: The leaves are then dried evenly and thoroughly without burning. Drying of leaves stops the oxidation process. The main objective of drying is to arrest fermentation and to remove moisture and produce good quality tea. This can be done in different ways including conventional drying, fluidized bed drying and air drying or baking. Curing/ageing: Curing is not required for all types of teas however, some type of teas require additional aging or secondary fermentation to enrich their drinking potential. Flavoured teas are manufactured by spraying with aromas - and flavours or by storing them with their flavourants.

Different types of tea: On the basis of manufacturing method, commercial tea is broadly classified as black tea, green tea, oolong tea, yellow tea etc. The basic difference is in the degree of fermentation adopted during manufacturing of tea from the Camellia sinensis evergreen plant. Brief detail about type of teas is as under:

1. Black tea: Black tea is the most common form of tea in Southern Asia (Sri Lanka, India, Pakistan, Bangladesh etc.) and many African countries including Kenya, Rwanda, Malawi and Zimbabwe. The Black tea process goes through the most stages of processing like withering, leaf maceration, fermentation, drying and grading. After picking, the leaves are left to wither for several hours and allowed to oxidize completely. Rolling or maceration is done to bruise and disrupt the leaf cell structures to release the oil which aid in oxidation. The last step consists of placing the leaves in an oven with temperature reaching up to 93.3^{o}C. When the leaves are 80% dry, the leaves complete their drying over wood fires. The final product is sorted accordingly to size, the larger size is considered "leaf grade," and smaller size "broken grade" which are usually used for tea bags. Black tea is further classified as either orthodox or crush, tear and curl (CTC) process tea.

2. Green tea: Green tea undergoes least amount of oxidation and the oxidation process is halted by quick application of heat, either with steam or by dry cooking in hot pans. Steaming of the leaves is done to prevent the leaves changing their colour from green to black and to inactivate the enzyme. It is followed by rolling. The leaves retain much of its original green colour especially the finer leaves whereas the older leaves have a blackish gray colour. For drying, the leaves are either stacked in hot air rack driers or are exposed to natural heat of sunlight. The tea is processed within one to two days of harvesting and retains most of the chemical composition of the fresh leaves in tea if processed properly.

3. Oolong tea: It is partially fermented tea. Oxidation is stopped somewhere between the standards for green and black tea. The fermentation period is short to change the colour of the leaf completely. The processing typically takes two to three days from withering to drying with a relatively short oxidation period. It is partially blackened. In oolong tea, the outer edge of the tea leaf is fermented while heart of leaf remains unfermented. The beverage is intermediate between those produced from green and black tea. The term "oolong" is used specifically as a name for certain semi-oxidized teas.

4. White tea: White tea is produced in lesser quantities than most other styles and is therefore, more expensive than tea from the same plant processed by other methods. It is mostly produced in China and is classified as organic or premium tea. It is produced from the young leaves or new growing buds that have undergone minimal oxidation. The oxidation is halted after a slight amount of wilting with heat. Leaf buds processed into white tea are usually dried immediately after wilting/withering.

5. Yellow tea: Yellow tea is processed in a similar manner to green tea but instead of immediate drying, leaves are stacked, covered and gently heated in a humid environment. This initiates oxidation in the chlorophyll of the leaves through non-enzymatic and non-microbial means, which results in a yellowish or greenish-yellow colour. This tea is popular in Japanese tea ceremonies due to its appearance and distinctive flavour.

B. COFFEE

Coffee is an important beverage used all over the world. Brazil and Columbia are the largest coffee producers in the world. Coffea arabica accounts for 75-80% of world production. The domestic consumption of coffee in India stands at 85,000 tonnes valued at about Rs 2292 crores. Coffee is harvested during dry season when the coffee cherries are bright red, glossy and firm. Picking is done by hand or by using machine. After picking, the coffee can be prepared either by dry method which produces natural coffee or by wet method which produces washed coffee. Coffee is harvested in one of two ways:

a) Strip picked: The entire crop is harvested at one time. This can either be done by machine or by hand. In either case, all of the berries are stripped off of the branch at one time.
b) Selectively picked: In this method, only the ripe berries are picked individually by hand. Pickers rotate among the trees every 8-10 days, choosing only the cherries which are at the peak of ripeness. This method being labour intensive and costly is used primarily to harvest the finer arabica beans.

Processing of coffee

Coffee processing is the most critical activity in its production. Processing of coffee deals with the conversion of raw coffee fruit into coffee. The quality of the final product depends upon the manner of processing. The methods employed for processing of coffee includes; dry method and wet method to produce unwashed and washed coffee respectively.

1. Dry method: The harvested cherries are spread over a concrete, brick or matting surface in suitably at good raked at regular intervals to prevent fermentation. In about 7-10 days the cherries dry to about 11% moisture. The outer shells become dark brown and brittle. The dried cherries are then stored in silos, where beans continue to loose moisture.

2. Wet method: In wet method, the beans are separated from the skin and pulp using a pulping machine. The beans are stored in a fermentation tank for 12-48 hours, during which time enzymes work to naturally separate the slimy layer (parenchyma) from the parchment like covering (endocarp). When the process is complete, the endocarp has pebbly feel. Coffee processed by the wet method is called wet processed or washed coffee and is found superior in quality as compared to dry processed coffee.
Drying: The endocarp is dried in open sun or in mechanical drier to moisture content of about 11% so that beans can be stored in stable condition. In open sun drying, it takes 7-15 days for drying. The coffee is called as parchment coffee.
Hulling: In wet processed coffee, hulling is used to remove the hull or dried parchment layer surrounding the beans. In dry processed coffee, hulling refers to removal of husk or whole of dried outer covering of original cherries.

3. Roasting: Raw green coffee does not have any flavour or aroma and has an unpleasant taste. Roasting is a heat treatment which transforms the green beans into aromatic brown nuggets. Roasting is done at air temperature of 287.8°C and in this process the beans are kept moving to avoid burning. When the bean temperature reaches 209°C they start turning dark brown and oil (called coffee oil or caffeol or coffee essence) start to emerge. This process is called Pyrolysis is the heart of roasting, as it produces aroma and flavour of coffee. After roasting, beans are cooled by air or water. The cooling must be quick in order to preserve the flavour, aroma and keeping quality.

4. Grinding: The bulk of roasted beans is ground to powder and sold as ground coffee. Roasted beans are ground to three sizes namely fine, medium and coarse. Coarse ground powder retains aroma and flavour better and longer than fine ground powder. Coarse ground powder is more suitable for preparing coffee decoction by percolation. On the other hand, fine ground coffee gives a decoction with high body.

5. Blending: Two types of coffee powder are marketed namely pure coffee prepared from coffee seeds only and French coffee. Chicory strength, flavour, aroma and acidity are the chief criteria in judging the quality of coffee.

6. Packaging: For larger packs of roasted and ground coffee, gas packing under carbon dioxide or under vacuum is effective. Various flexible films like polyethylene (PE), cellulose films etc are used for packing coffee.

Different types of Coffee

1. Decaffeinated Coffee: The coffee from which caffeine is artificially removed is known as decaffeinated coffee. There is a prominent segment of consumer preferring decaffeinated coffee owing to health consciousness.

2. Estate Coffee: Production of good quality coffee by highlighting special features of estate can be classified as estate branded coffee. The estate coffee are generally more expensive and actually define the specialty coffee market.

3. Monsooned Coffee: These are prepared by the special natural process which possesses a special monsooned flavour, mellow taste and golden look. It is also produced in India. It is graded as Monsooned Malabar AA, Monsooned Basanally and Monsooned Robusta AA.

4. High Grown Coffee: The coffee grown at higher elevations more then 1250 m above mean sea level possessing distinct flavour and acidity in cup (tasting) due to slower development of beans is called high grown coffee. The coffee is of high quality with dense beans.

5. Mysore Nuggets Extra Bold: The beans are large, uniform blush green in colour with a clean polished appearance. In cup, coffee exhibits full aroma, medium to good body, good acidity and fine flavour with a tint of spice. Arabica plantation coffee (worked coffee) is grown in the Mysore, Coorag and Billigiris regions. It is a premium coffee that represents the best quality coffee in India.

6. Robusta Kaapi Royale: it is made from Robusta Parchment AB from the regions of Mysore, Coorag, Wynad, Shivaroys, Pulneys and Barbabudans. The beans are bold, round with pointed ends and gray to bluish gray in colour. This cup ensures full body, soft, smooth and mellow flavour.

C. COCOA

Cocoa (Theobroma cacao L. family Sterculiaceae) beans are the primary raw material for confectioneries, beverages, chocolates and other edible products. Cocoa powder, butter and chocolate are the major products.
The harvesting of cocoa pods is done at 7-10 days interval and the harvested pods may be kept for 2-4 days before they are opened for fermentation. Hitting pods against hard surface may be adopted for opening of pods. The main characteristics of cocoa beans are initial moisture contents (52-55%), final moisture content (6-8%), fat contents (55-58%) and acidity of 5.8 percent. The pod husk contains 6-8% crude protein and 24-56% crude fibre.

Processing of cocoa: Curing is the process by which cocoa beans are prepared for the market. Curing involves two unit operations; fermentation followed by drying. Fermentation involves keeping cocoa beans well insulated so that heat is retained whole, at the same time air is allowed to pass through the mass. The process lasts up to 7 days and immediately followed by drying. The flavour of cocoa is developed only when it undergoes fermentation.

1. Fermentation: Fermentation of cocoa beans is essential to remove mucilaginous pulp, to develop flavour and aroma precursors, reduce bitterness, kill germ of seed and to loosen the testa. The cocoa pods after harvesting are cautiously opened. The beans and the mucilage are scooped out and subjected to natural fermentation. They are piled in heaps in perforated wooden bins for a period of 3-12 days. The heat produced during fermentation raise the temperature to about 45-60^{o}C. The fermentation is complete when temperature of mass begins to fall. At the end of fermentation, the pulp breaks down and the seed colour change from pale yellow to violet to brown. For fermentation the heap, box, tray and basket methods can be followed.

2. Drying: The fermented beans contain 33% moisture. They are dried to reduce moisture to 6-8% in sun or hot air dryers. During this process, the colour of the shell changes to dark brown. The dried beans are packed in polyethylene lined gunny bags and stored in a cool and dry place. The dried beans can be used for manufacture of different products (Fig 15.1)

Chocolate from cocoa beans
Important steps used for making chocolate from dry cocoa beans include roasting, grinding, refining, conching and tempering.
1. Roasting: The dried beans are cleaned, sorted and roasted at 150-160^{o}C for 40-50 minutes. Roasting develops characteristic flavour and colour. It also causes changes in chemical structure of polyphenols producing less astringency compound.

2. Shelling: Shelling is done to remove the shells from the beans and grains become regular in size. Shelling is carried and by milling, sifting and winnowing. Shelled beans can be made into fine, smooth chocolate.

3. Milling: The roasted, shells and crushed beans are milled to reduce them to even finer particles.

4. Refining: Refining converts the milled particles into liquid cocoa mass created as cocoa butter in the beans binds dry particles.

5. Conching: Conching involves powerful machines called conches to stir the chocolate in a controlled way. It is done in two steps.

- **Dry conching:** The chocolate is slowly stirred at above 80^{o}C temperature to remove any residual moisture and improve viscosity.
- **Liquod conching:** It is followed immediately after dry conching in the same conch without stopping the machine to affect the texture and creaminess. Little quantity of cocoa butter is also added in the process.

6. Tempering: it is done to transform liquid or semisolid chocolate into a solid. Chocolate is heated to melt the cocoa butter crystals and then cooled carefully. Properly tempered chocolate is smooth and glossy and produces smooth texture in mouth with good flavour and aroma.

D. ARECANUT (Areca catechu L.)

Arecanut is one of the most important commercial crops in South East Asia and is cultivated primarily for its kernels chewed in tender, ripe or processed form. Arecanut palm belongs to family Palmae. India is the leading country in production contributing to 51% of world's total production followed by China (25%). The arecanut is used as raw or in processed form as it is an essential component of gutka and pan masala, whereas, chali supari or kalipak are some of the value added products. Kalipak is prepared from immature green nuts and chali is prepared from ripe nuts.

Preservation of arecanut: In Assam, fresh fruits are preserved in thick layer of mud and this product is known as 'Bura Tamul'. In Kerala, fresh fruits are stored by steeping in water and the product is called 'Neettadakka'. The inner core is well preserved by this method but discolouration of outer husk and foul smell due to bacterial attack are some drawbacks. Preservation of ripe nuts after initial heat blanching in a solution containing sodium benzoate (0.1%) and potassium meta-bisulphite (0.2%), acidified to a pH of 3.5 to 4.0 with HCl helps in eliminating the foul smell and improves the quality of nuts.

Processing of arecanut

1. Dried ripe nuts (Chali or kottapak): The dried whole nuts of arecanut are known as Chali or kottapak. The ripe nuts are dried in open sun for 35-40 days up to 12% moisture content and the marketing of whole nuts is done after dehusking. Dehusking can be done with manually operated dehusker developed by CPCRI, Kasargod. Depending upon the size, different grades of arecanut in decreasing order are moti, srivardhan, jamnagar and jini. Sometimes the fruits are cut longitudinally into 2 halves and are sun dried for 10 days. The kernels are scooped out and are given a final drying. The product is known as Parcha, which is popular in Kerala and Karnataka. Drying in mechanical drier takes 60-70 hours at 45-75^{0}C.

2. Kalipak: This product is famous in Kerala and Karnataka. Tender nuts are dehusked, cut in to pieces, boiled with water or a diluted extract from previous boiling, coated with kali and dried. Kali is a concentrated extract obtained after 3-4 batches of boiling of arecanut. The kalipak is known by different names depending on number, shape and size of the cuts. Api or Unde (without any cuts), batlu (transverse cut into halves), choor (several longitudinal cuts), podi (both longitudinal and transverse cuts) and erazel (transverse thin slices). Lylon is another product made from green nuts which are cut transversely into 5-6 discs without kali coatings. A well dried product with dark brown colour, glossy appearance, chewing feel and absence of over-mature nuts are rated superior.

3. Scented supari: It is made both from chali and kalipak. Chali supari is more popular. The dried nuts are broken into bits and blended with spices for flavour and packed in butter paper. Saccharin is occasionally used for sweetening. Rose essence is commonly used for flavouring of supari. The scented supari is packed in aluminum or butter paper pouches for marketing.

Last

Types of Plantation Crops

E. CASHEWNUT

Cashewnut (Anacardium occidentale L.) is a tropical evergreen fruit tree belonging to Anacardiaceae family. It is widely cultivated in tropics for its nut and is a native of Brazil. In India it was introduced in Goa from where its cultivation spreaded to other parts of country. Cashew is a versatile tree nut and its kernel contains fats, proteins, carbohydrates, minerals and vitamins. Cashew has become number one crop in the world over almond. India provides around 55% supply of cashew kernels in world. The important commercial products of this crop are nuts and apple. The cashew kernels are used in confectionary and deserts. Cashew apple is eaten fresh or mixed in salads and even a drink is prepared from its juice. Cashew can be distilled to produce alcoholic drink called as Fenny. The cashew shell contains oil known as cashew nut shell liquid (CNSL) which has wide industrial uses. In India, the cashew processing is done manually, which consists of moisture conditioning, roasting, shelling, kernel drying, peeling, grading and packing.

Processing of cashewnut

I. Processing at orchard level

The cashew processing in the orchard is mainly confined to removal of raw nuts from cashew apple and drying. The fully matured nuts are harvested and the apples are removed. The nuts are dried for 2-3 days to reduce moisture from 25% to below 9%. Drying helps the kernels to retain their quality particularly flavour.

II. Processing of raw nuts

The nuts used for processing are dried again to reduce moisture level to 7-8%. The steps involved in processing of raw nuts are as under:

1. Cleaning and grading of nuts: The nuts are cleaned and graded into three sizes, viz, small, medium and large. The grading of nuts is done on basis of nut thickness and not on the basis of its length. It helps in reducing the kernel breakage.

2. Roasting of nuts: Roasting of raw nuts is done to separate the adhering shell from kernel. There are three types of roasting viz; drum roasting, oil bath roasting and steam roasting.

a) Drum roasting: This is one of the oldest and more widely used methods. The nuts are fed into red hot rotating drum which will ignite the shell by maintaining its temperature because of burning of shell liquid. The drum is kept in rotation for 3-4 minutes and roasted nuts are discharged from lower end of drum and immediately covered by ash after sprayed with a little water, to absorb oil on surface. This facilitates removal of remaining oil on shell.

b) Oil bath roasting: The conditioned nuts are passed through CNSL (cashew nut shell liquid) bath heated to 170-200oC by conveyer buckets for 1-2 minutes. During this period the shells gets heated thus rupturing the wall and releasing oil into bath. The roasted nuts are then centrifuged to remove adhering oil, cooled and shelled by hand or leg operated shelling machines. The kernel with adhering testa is scooped out using a sharp needle. The method is followed traditionally in Kerala and Karnataka

c) Steam roasting (autoclaving): The raw nuts are steam cooked at about 120-140 psi pressure to loosen the kernels from shells. Shell oil can be extracted in later stages by crushing. The nuts are shelled by hand or leg operated shelling machines. The steamed nuts are spread on floor under natural air for 12-24 hrs for cooling.

3. Shelling of nuts (decortications): Cashew nut after roasting and cooling are shelled to remove kernels. Care should be taken to protect hands from Cashew Nut Shell Liquid (CNSL) which is highly corrosive. Hand gloves can be used while shelling. Nuts are knocked 2-3 times on long edge of wooden mallet or light hammer to release the whole kernels without any damage. Foot operated shell cutter can be used for shelling. This device consists of a pair of blade (knives) shaped in counter of half a nut. The blade cut through the shell all around the nut, leaving the kernel untouched. A hand lever is pressed to open shell into two parts. The kernel is then scooped out manually.

4. Separation of kernels: After shelling, the kernel and shell pieces are separated manually and the separated kernels are collected into containers.

5. Pre-grading: Pre-grading can be done before and after drying kernels. It can be done mechanically for large scale processing, whole kernels are separated from the broken. Sometimes the whole kernels are also separated and graded according to the kernel size.

6. Drying of kernels: After removal from the shell, the kernels are dried at about 70-80^{0}C imperforated trays for about 6-8 hrs for reducing the moisture level to 4-5 percent. Drying of these kernels is necessary to prevent fungus. In order to ensure uniform drying, the position of tray may be changed frequently. Excessive drying may result in scorched kernel. After drying kernels are kept in the moist chamber for 24 hours which facilitates easy removal of testa and minimizes broken kernels.

7. Peeling: it is done by using a sharp knife or bamboo piece to remove testa (seed coat) from the kernels

8. Grading of kernels: Kernels are graded according to the size manually. 25 different grades of cashewnut kernels are approved by Government of India. Standard specification for Indian cashew kernels are:

- **Wholes:** White wholes(WW)/scorched wholes(SW)/ dessert wholes (SWS)

- **Broken :** White broken/scorched broken/dessert broken
- **Lower grades:** Rejection etc.

Further, the classification refers to broken kernels, splits, pieces, small pieces and whether kernels are white or scorched. The cashew kernels are sold as WW 180, WW210, WW240, WW450 and WW500 which means white whole with number of kernel per pound weight. Thus WW210 means white whole with 210 kernels/ lb weight. Similarly scorched wholes are numbered as SW180-SW500. Dessert wholes (DW), white pieces as B (Butts), S (Splits), LWP (Large white pieces), SWP (Small white pieces), BB (Baby bits), Scorched pieces as SB (Scorched butts), SS (Scorched splits), Dessert pieces as SPS (Scorched pieces seconds), DP (Dessert pieces).

9. Packaging of kernels: The import trade requires packaging of kernels in 11.34 kg capacity (25 lbs) tins/airtight cans in which the kernels are kept. After filling and weighing, the tins are evacuated and filled with CO2 with help of vita pack process. This consists of removing all air from can and substituting it with CO_2 and the holes in the cans are then sealed. Cashew should be packed in impermeable packages, as they become rancid and go stale quickly.

III. By-Products from cashew

1. Cashew apple: Cashew apple is a swollen peduncle to which nut is attached. It is very juicy and sweet, it is not eaten raw because of its astringent and acidic taste. It is very rich in vitamin C and can be used for juice extraction.

2. Cashew juice: The juice can be extracted with screw press, basket press or hand press. Straining of extracted juice is done through muslin cloth which is then clarified by adding 1.4g of PVP (Poly vinyl pyrolidine) per litre juice; the mixture is stirred and again strains through muslin cloth. Add sugar to improve the taste, and boil the juice. Fill hot in pre-sterilized bottles, crown cork and process on boiling water for 20-25 minutes. On cooling, keep in cool and dry place. Sodium benzoate can be used as preservative.

3. Cashew apple jam and candy: Immerse the cashew apples in 3% salt solution for 3 days to remove astringency (tannins), followed by steaming for 15-20 minutes. Extract the pulp and prepare jam as per standard practice. In case of candy the sugar strength is kept 450Brix and is increased @ 50Brix for 4 days and then @ 100Brix for 6th and 7th day so that the final strength of syrup reaches to 700Brix. Keep in this solution for 8-10 days for complete absorption of sugar. Remove the pieces from syrup and dry.

4. Cashew kernels peel tannin: Kernel peel are a rich source of tannin (25%), which is in great demand by leather industry.

5. Cashew Nut Shell Liquor (CNSL): It is a byproduct obtained during separation of cashew kernel. It is viscous dark liquid and is extremely corrosive. It is used as raw material for phenolic resins and friction powder in automobile industry. It is also used as moulding acid resistant paints, found in any resins, varnishes and as insecticide/ fungicides etc.

6. Cashew kernels oil: Low grade kernels are processed in to kernel oil (30-40%) which is of high quality.

7. Cashew kernel butter: Kernel residue after extraction of kernel oil used to produce cashew kernel butter which is similar to peanut butter.

F. COCONUT

Coconut (Cocos nucifera L.) is most useful palm belonging to family Palmae. In India, coconut tree is called as kalpvriksha the tree of life, coconut is grown in a wide range of agro-climatic conditions. Productivity of coconut in India in terms of nuts/hectare is highest among major coconut growing area. Coconut is mainly consumed as raw nuts, copra and oil, whereas other products are coir and nuts. Coconut oil is the main commercial product. Copra obtained after drying kernel of coconut contains 65-70 % oil. Copra is used to extract coconut oil and coconut meal in the ratio of 3:2. The products like hair oil, soaps, shampoos and medicine use coconut oil as a main ingredient. In India, only 10% of the production is used for tender nut water. Traditionally, coconut industry in India is centered on copra making, coconut oil extraction and coir manufacture. The industrial products are desiccated coconut, cream milk powder, vinegar, nata-de-coco etc.

Coconut Products: following products are made from coconut on a commercial scale.

1. Copra
2. Coconut oil
3. Raw kernel
4. Coconut cake
5. Tender coconut water
6. Coconut toddy
7. Coconut shell based products
8. Coconut wood based products
9. Coconut leaves
10. Core pith

1. Copra: The dried coconut endosperm is called copra with oil content of 65% to 70% copra is the richest source of fat. The focus of copra are made in our country namely milling copra and edible copra, milky copra is made in the form of cups used for oil extraction. It is also used as a dry fruit for consumption.
Whole, edible copra is shredded and used as garnish in various dishes. Drying of copra can be carried out in open sun or in hot air driers. Even electrical and solar driers can also be used. Sun drying takes 6-8 days while hot air driers involve 20-24 hours for drying. During drying the moisture content from 50-55 % is reduced to 5-6 %. Dried copra should be packed in polyethylene lined gunny bags and stored ion cool and dry place.

- copra: it is made in the form of cups and balls.
- Ball copra: fully ripe nuts of 12-14 months are stored in upper floor of specially made store (two storied brick and mortar building). The floor and four sides of upper story and smoked by a slow fire set under the platform using coconut palm

waste. During this period, the water inside the nut dries up and kernel gets detached from shell and raffles on shaking. The process completes in 8-12 months. Small sized nuts are preferred over large sized one.

- Edible cup copra: nuts stored as above for shorter period are used for making edible cup copra. The copra balls are cut into halves and then they are sun dried for a few days.

2. Coconut oil: Coconut oil is extracted from milling copra. The pulped copra is fed continuously to the expeller from which oil and cake are expressed. Hydraulic pressing of cake also results in extraction of copra oil. Coconut oil is very low in unsaturated and polyunsaturated fatty acids, particularly linoleic acid as compared to other vegetable oils (Kumar et al. 2000). It is more resistant to oxidation than many other types of oils. It is obtained from mature meet which when dried contain 65% oil and the oil obtained from coconut milk is called as virgin coconut oil. Coconut oil is used for culinary, edible purposes and for industrial use like toiletries and soap making etc. Coconut oil processing methods are classified into two major types: dry and wet processes. When the oil is extracted from copra as raw material is termed as dry process, while use of fresh coconut as starting material is called wet process.

3. Coconut water: Water from tender coconut (7-8 month old) is a refreshing drink, effective in cases of gastroenteritis, diarrhea, vomiting and in preventing dehydration. The nut water is less nutritious from mature coconut as compared to tender coconut water. Nata-de-coco, soft drink, vinegar, food yeast etc are the products in which coconut water is main source. Coconut water can also be used to produce carbonated and non-carbonated beverages as refreshing and more nutritious drinks than other similar products.

4. Coconut meat: The kernel of seven to eight month old nut is very soft with maximum contents of protein and sugar. Kernel is as such consumed or with sweet nut water. Fresh kernel is consumed in the grated form and in the form of milk or cream obtained by squeezing the grating with or without addition of water. As the nuts turn more mature the quality decreases gradually. Fresh coconut meat contains 50-55% moisture which is to be brought down to 5-6% during drying.

5. Coconut milk or cream: Coconut milk or cream is the oil-protein-water emulsion obtained by freezing grated fresh coconut kernel. It is the processed milk extracted from fresh matured coconuts. It is the processed milk extracted from fresh matured coconuts. It is used either directly or diluted with water to make various preparations like curries, sweets, puddings and many bakery preparations. Processed and packed coconut cream has a shelf life up to three months.

6. Instant coconut milk powder: It is a spray dried product similar to dairy milk powder. The spray dried coconut milk powder if dissolved in water, results in coconut milk which can be used in place of fresh coconut milk for food preparation.

7. Desiccated coconut (DC): Desiccated coconut is the white kernel of fresh coconuts, shelled and dried to about 2.5% moisture content with high nutritional value. The common grade of desiccated coconut has particle size less than 5 mm. It is an important commercial product with a wide demand in confectionary and other industries, like chocolate and liquorice. The desiccated coconut contains moisture 2.5%, oil 67.5%, protein 5.9%, carbohydrates 5.9%, ash 9.3% and fibre 2.4 percent.

8. Coconut husk products: The coconut husk usually forms 35-45% of the whole nut weight at ripening. About 30% of husk is fibre and 70% is the coir dust. Coir pith is used as manure, as mulch or in making briquettes with good export potential. Coconut husk is the basic raw material for coir industry. The fibres extracted from coir is used for spinning into yarn for making mats, ropes, rugs, carpets, bleaching, dyeing, printing, poly coir, coir matting decorated boards, husk particle boards etc.

9. Coconut shell powder: it is made from matured coconut shells and is used in plywood and laminated board industry as a phenolic extruder and as filler in synthetic resin ghees, mosquito coils and agarbatis.

10. Other products: Coconut sap, coconut syrup and sugar, fermented coconut sap, coconut vinegar, coconut shell powder, coir fibre and pith are some of the important coconut products.

G. OILPALM

Oil palm (Elaeis guinensis) is monoecious, cross pollinated plant placed in the Arecaceae family along with coconut and date palms. It is native to West Africa. Oil palm is the highest oil producer among all perennial oil yielding crops. Fruit of oil palm is drupe. It consists of exocarp, mesocarp and endocarp surrounding the kernel. The kernel has a testa, a solid endosperm and an embryo. It produces two distinct oils viz palm oil (extracted from mesocarp of fresh fruits) and palm kernel oil extracted from kernels. The yield of palm oil ranges between 20-30%.

Processing of oil palm: The palm oil processing consist of threshing of bunches, heating of fruit, digestion, pressing, clarification/ drying and storage. The unit operation used in processing of oil palm for extraction of oil given in Fig 15.3 is explained as under:

1. Threshing: The fruit bunches consist of fruit embedded in spikelets growing on a main stem. For extraction of oil heating of fruit or bunches is necessary as it performs many functions. At small scale operation, bunches are threshed manually to separate the part from the spikelets and threshed fruits are cooked. While at large scale operation, bunches are heated using high pressure sterilization system which helps in loosening of fruits.

2. Sterilization of bunches: Sterilization of bunches either by using hot water or steam under pressure serves the following operations:

- To destroy oil splitting enzymes and to arrest hydrolysis and autoxidation.
- To weaken fruit stem to help in removal of fruit from bunches on shaking or tumbling in threshing machine.
- To solidify proteins to allow oil bearing cells to come together and flow more easily on application of pressure.
- To weaken pulp structure in fruit to help in easy detachment of fibrous material and

its contents during digestion process.

- Steaming breakdown gums and resins which are removed during oil clarification.
- High pressure steam cause separation of moisture in nuts. When pressure is reduced, contraction of nuts leads to detachment of kernel from shell wall, thus loosening kernels within their cells. Detachment of kernel from the shell wall facilitates nut cracking.

3. Digestion of fruit: It refers to the process of releasing palm oil in the fruit through rupture of oil bearing cells. Digestion consists of steam heated cylindrical vessel fitted with central shaft carrying better arms for stirring. Through action of rotating beater arms, the fruit is pounded. Pounding or digesting fruit at high temperature, helps to reduce viscosity of oil, destroys out covering (exocarp) of fruit and cause disruption of oil cells.

4. Pressing/extraction of oil: Oil can be extracted either by dry method or wet method. In dry method oil is extracted by using mechanical press while in wet method hot water is used for leaching out the oil from the digested material. Either batch press or screw press can be used for oil; extraction.

5. Clarification and drying of oil: Clarification is done to separate oil from impurities. The fluid coming out of press is a mixture of palm oil, water cell debris, fibrous material and non oily solids. Presence of non-oily solid make the mixture very viscous (thick). The mixture is therefore, diluted by adding hot water in 3:1 proportion. The diluted mixture is passed through a screen to remove coarse fibre. The screened mixture is boiled for 1-2 hours and then allowed to settle in large tanks. The clear oil is decanted and reheated in a cooking pot to reduce moisture content to 0.15-0.25%. Continuous clarifier consisting of three components heat the crude mixture, dry the decanted oil and hold the finished oil in an outer shell as a heat exchanger.

6. Storage of oil: The purified and dried oil is stored in plastic drums or in other suitable containers and stored at ambient temperature.

7. Palm kernel oil extraction: The residue left after extraction of palm oil from fruits contain mixture of fibre and palm nuts. The nuts are separated manually or in depreciation. The nuts are then dried and cracked in centrifugal crackers to release the kernels. Breaking of kernels should be avoided as it increases the free fatty acids in the oil. The kernels are then separated from the shells using a combination of winnowing and hydro-cyclones. The kernels are dried in silos to a moisture content of 7% before packing and use for kernel oil extraction. The palm kernel oil is extracted by using following three unit operations

(i) kernel pretreatment
(ii) screw pressing
(iii) oil clarification.

i) Kernel pre-treatment: The kernels after cleaning are broken into small fragments by using either hammer grinder or breaker rolls or combination of both. The kernel fragments are flaked

(0.25-0.4 mm thick) in a roller mill. The kernel flakes are then placed in stack cooker for steam conditioning which adjust the moisture content to optimum level, rupture cell wall, reduce viscosity of the oil and coagulates the protein in the meal to facilitate release of oil from pertinacious material. In palm kernel, the meal is cooked to a moisture content of 3% at 104-110^{o}C.

ii) Screw-pressing: Properly cooked meal is fed to screw-press, which consists of an interrupted helical thread (worm) which revolves within stationary perforated cylinder called cage or barrel. The meal is forced through the barrel by action of revolving worms. The expelled oil flows through the lining bars of barrel while de-oiled cake is discharged through annular orifice.

iii) Oil clarification: The expelled oil sometimes contains solid impurities thus the oil is drained to a reservoir. The oil is pumped to a decanter or revolving coarse screen to remove large part of impurities. After this, the oil is pumped to a filter press to remove remaining solids and fines to get clear oil. The cake from the press is collected separately.

Palm oil, olein and stearin are used worldwide in making margarine, in shortening and confectionery and in snack foods frying. Palm oil is also used in the manufacturing of soaps, detergents and other surfactants. It is good raw material for production of oleo-chemicals, fatty acids, fatty alcohols, glycerol and other formulations for cosmetics, household and industrial products.

H. RUBBER (Hevea brasiliensis)
Rubber tree is the most important source of natural rubber and meets around 98% of the global requirement. The rubber belongs to family Euphorbiaceae and its economic product rubber is a cis-poly-isoprenic molecule found in latex. Latex is found in all the plant parts like bark of trunk, roots, branches, leaves, flower, fruits and seeds. Commercially the latex present in the bark of trunk of mature tree is exploited. The latex consuming industry is virtually separate from the remainder of the rubber consuming industry. Natural rubber is a high molecular weight polymer and is used for the manufacture of medical gloves. Other products manufactured from latex include catheters and condoms (prophylactics), garment threads (used in garment manufacture) and foam (in pillows and mattresses) etc. The latex consists of 30-40% rubber, 1-2% resins, 55-65% water, 2-2.5% proteins, 1-1.5% sugars and 0.7-0.9% ash. Latex obtained from rubber tree is the basic raw material for extraction of rubber and its processing inot different forms. **Methods used commercially are discussed here under:**

Latex is obtained from the bark of rubber tree by tapping. Tapping is a process of controlled wounding during which thin shaving of bark is done. The purpose of tapping is to cut open latex vessels from the trees (used for first time) or to remove coagulum which otherwise block cut ends of latex vessels in case of trees under regular tapping. Tapping is done early in the morning when turger pressure for exudation of latex is maximum. For tapping and collection of latex knives, spout, cup hauzers, collection cups. Collection buckets and scrap buckets are used. Michie Golledge Knife and Jebong Knife are used for tapping however, for controlled upward tapping modified gauge knife is used. Different types of tapping include intensive tapping, high level tapping. Controlled upward tapping, puncture tapping, slaughter tapping etc.

Crop collection: The main crop from rubber plantation is latex, which is harvested by tapping process. 2-3 hours after tapping, latex collected in the crop is transferred to a clean bucket. About 70-80% of the crop from a rubber plantation is in the form of latex. The latex which gets solidified in tapping panel and collection cups or overflowed to the ground and gets dried up is also collected. This is collectively called as field coagulum.

Processing of latex: For long term storage and marketing the latex and field coagulum are processed in different forms such as preserved field latex, latex concentrate, sheet rubber, block rubber and crepe rubber. Field coagulum is generally processed only in the form of Crepe rubber or black rubber.

Latex can be processed into any of following forms

1. Preserved field latex: Field latex is preserved by using ammonia (1%), LATZ (low ammonia 0.2-0.3%) as preservative for long term storage. The processing of preserved latex consists of adding preservative to the sieved latex, bulking, settling, blending and packing.

2. Latex concentrate: Latex is concentrated by using either creaming or centrifugation method.

a) Concentration by creaming: In this method, creaming agents like ammonium alginate or tamarind seed powder is mixed with preserved latex and allowed to settle for some time. This treatment separates the mixture in to two layers. The upper layer contains concentrated latex while, lower layer of serum containing very little rubber. The lower layer of serum is removed, whereas, upper layer containing latex concentrate having 50-55% dry rubber contents is collected, packed and marketed.

b) Concentration by centrifugation: Centrifugation separates preserved field latex into two fractions, one containing concentrated latex (having more than 60% dry rubber) and other containing about 4-8% dry rubber. Skim latex is generally coagulated with H_2SO_4, made into crepe, dried and marketed as skim rubber, which is low grade rubber.

3. Sheet rubber: Latex is coagulated in container into thin slabs of coagulum and rolled with rollers followed by drying to get sheet rubber. On the basis of method of drying, sheet rubber is classified in to two types i.e., ribbed smoked sheets and air dried sheets.

Preparation of Sheet rubber

a) Straining and dilution of latex: For preparation of sheet rubber, the latex is processed immediately before pre-coagulation sets in. Anti-coagulation can also be added to prevent pre-coagulation of latex. The latex is strained through 40 and 60 mesh stainless steel sieves and diluted in bulking tanks to a standard consistency of 0.5kg dry rubber for every 4 litre of diluted latex (12.5% dry rubber contents). It is then allowed to stand in bulking tank for 15-20 minutes for sedimentation of heavy dirt particles. The clear diluted latex is decanted in coagulation pans.

b) Coagulation: For coagulation, diluted formic acid or acetic acid is mixed with latex. To prevent surface darkening small quantity of sodium bisulphate (1.2 kg/kg dry rubber content) dissolved in water is added to the diluted latex before coagulation. After coagulation, the coagulum is removed from the pan and washed thoroughly in running water. It is then rolled either in sheeting battery or smooth rollers to a thickness of 3mm and finally passed through grooved rollers. While sheeting, the coagulum is continuously washed in running water in a tank. To prevent mould growth on rubber sheet the freshly machined sheet is treated with dilute solution (0.05-0.1%) of para-nutrophenol (PNP). About 100 litres of 0.05-0.1% PNP solution is sufficient for treating 100 sheets. The wet sheets are then allowed to drip on reapers arranged in a well ventilated dripping shed.

c) Smoking/drying: The sheets after 2-3 hours of dripping in shade are placed in smoke house, where the temperature in maintained between 40-60^{o}C. In the smoke house, sheets are dried gradually to avoid blisters. Besides, the creostatic substances present in the smoke also prevent mould growth on smoked sheets. 4-6 days of smoking is sufficient for drying of sheets. The smoke house is a chamber in which sheets are placed on the reapers for drying. Smoke houses are of two types, those in which furnace is inside drying chamber and those in which furnace is outside the chamber. Rubber sheets can also dried by using any of the drying system such as solar cum smoke drying, sun drying or air drying.

d) Storage: Sheets after grading are packed in 50kg bales. There are six International grade descriptions for sheet rubber i.e., RSS IX, RSS 1 to RSS 5.

4. Crepe rubber: These are processed from fresh latex coagulum, field coagulum or cutting of rubber sheets (ribbed smoked sheets). The material is passed through a set of crepe making machines and a lace like rubber is obtained. This rubber on drying results in crepe rubber. Latex crepe and field coagulum crepe are two typesof crepe rubber depends upon which the raw material used.

i) Latex crepe: Latex crepe rubber is of two types i.e., Pale latex crepe (PLC) and sole crepe. The latex used for these two types shall be free from yellow pigments and enzymic discolouration.

ii) Field coagulum crepe: The unit operations used in making field coagulum is soaking of coagulum in water, crepe making, drying, grading and packing. The crepe prepared from field coagulum materials falls into five types.

a) Estate brown crepe: It is made from the cup lumps and other higher grades of field coagulum.
b) Thin brown crepe: It is made from wet slab coagulum as starting material.

c) Thick blanket crepe: it is made from wet slabs, unsmoked sheets or other high grade scraps.
d) Smoked blanket crepe: It is derived from ribbed smoked sheets or cuttings
e) Flat bark crepe: In this all types of low grade scrap including earth scrap is used.

5. Technically specified rubber (TSR): TSR is marketed with quality certification from Bureau of Indian Standards, under the name of Indian Standard Natural Rubber (ISNR). It is produced from both latex and field coagulum and available in six grades of BIS specifications. Basic unit operation involved in manufacture of TSR includes size reduction, dewatering, dirt removal, drying, blending, grading and packing. Slab cutter, coagulum crusher, prebreaker, macerator/crepe roller, hammer mill/shredder drier and baking press are important machineries used in performing these unit operations. TSR bales are generally packed in low-density polyethylene (LDPE) bags.

Last

Lecture 16 - Quality of fresh and processed products

Objective: This topic deals with different definitions, terms of quality, quality standards, methods used for determination of quality of fresh and processed products, factors affecting quality and different sequences followed to ensure quality control during processing. FAQ'S are included in this chapter.

Quality Standards

Introduction

Quality is a measure of the degree of excellence or degree of acceptability by the consumer. It is also defined as the combination of attributes or characteristics of the products that has significance in determining the degree of acceptability of the product to a user. Industry defines quality as the measure of purity, strength, flavour, colour, size, maturity, workmanship or any other distinctive attribute or characteristics of the product. The quality standards of fresh and processed fruit or vegetable products vary with their intended use. For marketing purposes; size, attractiveness, maturity, organoleptic quality and freedom from defects are to be kept in mind. While for processing, physico-chemical attributes of raw material such as presence of soluble solids, development of uniform colour, flavour, juiciness, uniform maturity, tenderness in some vegetables etc are taken into consideration. During processing of fruit or vegetables into value added products; colour, flavour and texture etc also become important.

Quality standards: Common standards used for measuring product quality are:

1. **Legal standards**
2. **Voluntary standards**
3. **Industry standards**
4. **Consumer oriented or Grade standards**

1. Legal standards: These are the standards commonly established by the central or state or local agencies like corporation, municipal committees etc and are usually mandatory. These mandatory standards are established by law or through regulations for maintaining quality. Legal standards are generally concerned with freedom from adulteration and mostly include insects, moulds, yeasts, residual pesticides and maximum limits of additives allowed or established specific condition in processing so that foods are not contaminated with extraneous matter. Examples of legal standards include Food Safety and Standards Act, 2006 (FSSA), Food Safety and Standards Rules, 2011 and Food Safety and Standards Regulations, Food and Drug Administration Act (FDA) etc. Minimum standards of quality for establishment of unit, labeling and packaging, and physico-chemical attributes for different food products are specified under FSSA, (2006) and Food Safety and Standards Regulations, (2011) which arte mandatory to be followed for any food business operations.

2. Voluntary standards: These represent the standards recommended by various segments of the food industry. Company standards generally represent the consumer image and may become trade mark or symbol of product quality. Mostly these standards are used by private firms and tend to vary depending upon the organization. Companies like pepsi, kissan and coca cola, etc sets their own standards for different products.

3. Industrial standards: These are the standards where an organized group attempts to establish certain limits of quality for any given commodity. Generally these become effective by pressure from marketing organization for specific commodities, where the legal standards are not involved.

4. Consumer oriented or grade standards: These standards represent the consumer requirement of particular product and are based on experience. For example few consumers do not prefer a product with preservatives.

Methods for determining quality

A. Objective methods
B. Subjective methods

A. Objective methods: Objective methods of quality evaluation are based on observation from which the attitude of investigator is entirely excluded. They are based on recognized standards, scientific tests and are applicable to any sample of the product without regard to its previous history or ultimate aim. They represent the modern ideas in quality control because the human element is completely excluded.

Objectives methods are of three types i.e., Physical methods;, chemical methods and microscopic methods.

1. Physical methods: These are the quicker methods and require least training for the evaluator. They include visual appearance, colour, texture, consistency, size, shape or some process variables like head space, fill, vacuum, drain weight etc. The colour of the food products can be measured using calorimeter, tintometer or Hunter colour difference meter. While texture can be determined by using texture analyser or firmness of fruit is estimated by penetrometer. On the basis of texture profile, the product can be classified as chewy, grainy, crispy, mealy etc. These methods are called as instrumental methods. Detail of common method used in fresh and processed products is shown in Table 16.1.

2. Chemical methods: These are the standard analytical methods and are used for quantitative chemical evaluation of nutritive value and quality levels. However, such analytical methods are lengthy, tedious and expensive. For routine analyses quick tests are developed like pH, acidity, TSS, jellification etc. Detail of some method used in fruit products is shown in Table 16.1.

3. Microscopic methods: They are also called as microbiological methods. They are used extensively in quality control programmes but require considerable training for proper interpretation of results. Two types of microscopic methods are:

a) To check adulteration and contamination of product with mould, yeast, bacteria, insect excreta etc.
b) Differentiate between cell type, tissue type and identification of micro-organisms in fresh and processed products.

B. Subjective method: In subjective method, the quality evaluation is based on the opinion of the investigator. It is usually a physiological reaction which is a result of past experience, training, individual preference and power of perception. These methods are subjective because an individual is required to give his opinion for quantitative and qualitative value of characteristics. These methods involve the use of sense organs and are thus called as sensory methods. Sensory perception includes colour, flavour, odour, taste, touch etc. The food is selected by making use of all physical senses like sense of sight, touch, smell, taste and even hearing. The snap of chip, crackle of a breakfast cereal, crunch of apple or celery are textural characters. Other senses are eyes, fingers, tongue, nose and ears. A guide to common methods for sensory evaluation is given in Table 16.1.

Table 16.1: Common physical, chemical and microbiological and sensory methods for fresh and processed fruit, vegetable products

Attribute	Method /equipment to be used
1. Physical test	Vernier calliper
Size	Weighing balance
Weight	Water displacement method
Volume	Specific gravity bottle, pycnometer
Specific gravity	Net weight + Tare weight
Gross weight	Weight of container
Tare weight	Gross weight – Tare weight
Net weight	Net weight – weight of syrup/ brine
Drain weight	Visual/ colour charts
Colour	Texture Analyser
Texture	Penetrometer, Pressure tester
Firmness	Ostwald viscometer
Consistency	Brookfield viscometer
Viscosity	Head space gauge
Head space	Vaccum/ pressure gauge

Vaccum/ pressure Seam measurement Can testing	Seam checking gauge/ seam micrometer Can tester
2. **Chemical test** Total soluble solids Brine strength Moisture Total solids pH Titratable acidity Sugars (Reducing, Non-reducing & total sugars) Ascorbic acid Salt Sulphur dioxide Ash Benzoic acid	Hand refractrometer, Abbe refractrometer, Hydrometer Salometer Oven drying method, infra-red moisture meter -do- pH meter Alkali titration method Lane and Eynon method 2,6 dichloro-phenol- indophenol dye titration method Silver nitrate titration using Mohr's method Modified Ripper-titration method Muffle furnace Benzoic acid is converted to water soluble sodium benzoate. Acidification of sodium benzoate to form water insoluble benzoic acid and chloroform. Removal of chloroform with evaporation. Dissolving residue containing benzoic acid in alcohol and titrate with standard alkali.
3.**Microbiological tests** Total plate count/ viable count Yeast and moulds count Coliform test Extraneous contamination	Inoculation chamber, incubator Howard's mould counting method Presumptive test, conferred test, completed test Macroscopic/microscopic examination Wildman trap flask

Insect fragments	
4. **Sensory evaluation** Colour Flavour Body Overall acceptability	Hedonic rating test Numerical scoring test Ranking test Paired comparison test; Single sample test; Multiple sample test

Objective of quality control

1. Control over raw materials by setting up specifications
2. Improvement of product quality
3. Improvement in processing methods by reducing cost of production and improving profits
4. Standardization of the finished product according to label specifications
5. Maintenance of sanitary conditions in the plant
6. Greater consumer confidence towards quality of the product

Factors affecting quality

Quality of processed fruit and vegetables is affected by the following basic factors, either individually or in combination.

(1) Cultivar: It is an important factor for producing quality product. The varieties/cultivars differ in size, shape, colour and chemical composition. High yield, attractive appearance and good shipping and keeping quality are the important characters taken in to consideration.

(2) Cultural practices: These include organic matter, moisture, fertilizer, method of cultivation, irrigation and pest control methods. Any of these factors may be the limiting factor in producing a quality processed product. The best example of a limiting quality factor is the use of insecticides that give good control of the pests, but produce or leave a residue.

(3) Maturity: The maturity of fresh produce is more important than the specific cultivar in many cases. Any recommended fruit or vegetable cultivar for processing should mature uniformly, should be resistant to insects and diseases. The crop harvested at its optimum condition need to be processed promptly otherwise the quality may drop down into the next lower grade in just a few hours.

(4) Harvesting and handling: Harvesting and handling methods of fresh fruit and vegetables go hand in hand with maturity and other quality characteristics. The fruit or vegetable should be harvested at the desired stage of maturity and should be delivered to the processing plant immediately to preserve the quality. Important post harvest factors affecting quality of the produce are given in Table-16.2.

Table-16.2: Post harvest factors affecting quality of fruit and vegetables.

Post harvest factors	Quality affected
1. Temperature	Off flavour, weight loss and wilting in leafy vegetable and reduces vitamin C content. Reduces the appearance of fruit by checking the carotenoid development.
2. Heat of respiration	Deteriorates the quality and speed up the growth of micro-organisms during storage.
3.Cleaning & washing	Cleaning (fruits) and washing (root vegetables) remove dirt and spray residue and provide good appearance
4. Grading	Processed product must be graded to maintain uniformity in size, shape and quality
5. Chemical treatment	Treatment with ethaphon and alar increases colour and reduces astringency.
6. Pre-cooling	Reduces weight loss and maintain freshness and appearance
7. Hot water treatment	Provides protection against diseases e.g. anthracnose in mango

(5) Processing: The important factors that must be carefully controlled during the processing of fruits and vegetables include efficiency of washing, trimming, cutting, inspecting and sorting, time and temperature of blanch or scald, fill weights, brine or syrup characteristics, closing machine vacuums, can seam formation and processing time (cooking and cooling times

Last

Techniques for Quality Control

Techniques for Quality Control

Following procedures are followed for quality control of processed products:

1. Identify the critical points in the process flow sheet which contributes to the major quality characteristics.
2. Sample each critical point (batch or continuous operation) and identify what is being sampled and to what extent it is critical.
3. Evaluate and relate quality at critical successive stages to costs and its application in field.
4. Relate costs to deviation from specified levels.
5. Evaluate data collected against standards and legal requirements.
6. Provide consistent system for the orderly continuous evaluation of quality from the selection of raw material through different stages of processing.

7. Diagnose problems and predict troubles before they occur.
8. Determine the extent of drifts and shifts in production and minimize or localize deficiencies.
9. Evolve a system to determine how well the quality control program is succeeding.

Quality control during processing

The sequence of operations in quality control followed during processing are as under:

1. Raw material control
2. Process control or the control of the manufacturing process
3. Production and processing inspection
4. Sensory evaluation
5. Packaging
6. Labeling and storage.

1) Raw material control: The quality of a food material is judged in terms of its nutritional value, purity, wholesomeness and palatability. If any of these properties is not optimal, the food quality is affected. Raw material examinations include test for genuineness and composition, freedom from contaminant, and conformity with official or factory standards. The manufacturing of a desired food product depends upon the close collaboration between plant breeders, agronomists, horticulturists and food technologists. After all parameters of raw materials are met, a sample batch of raw materials is put through a trial run to get a preview of the end product. All control tests are run on the sample and any adjustments as required are made in the processed product. The equipment is examined for any sign of corrosion due to the acidity or alcohol content of the materials used. Approval for processing is given only after all quality specifications on the sample run have been met.

2) Process control: During processing, attention should be given to the processing procedure. In order to get the product of desired quality, all treatments standardized such as use of correct amount of ingredients, use of accurate method of preparation, mixing, processing time and temperature etc should be followed. The quality control tests should run continuously and concurrently with a 24-hr production schedule. The intermediary samples are taken for routine tests to establish that specific targets of quality are being achieved. The desired composition, consistency, colour and concentration are checked and ensured. Where processing controls are not properly employed e.g., during dehydration, the quality of the product may be seriously impaired. Satisfactory hygienic conditions are also maintained during processing, in order to protect the product from bacterial contamination.

3) Production, processing inspection: Examination of the finished product is carried out to determine as to what extent the desired quality specifications have been achieved. Careful inspection is made of the external conditions of the can. A can where both ends are concave is said to be ‘flat’ and is said to be good while the cans which have the problem of flipper, springer or smell do not pass inspection.
In case of canned products, a sample of the passed cans is opened and the contents are inspected.

Where the product is dried, samples are examined for a blemish count. The dried product is regularly checked for its reconstitution value to enable the correct cooking instructions to be supplied on the package for the user.
Tests are also performed to check certain physical properties, such as crispiness, colour, viscosity and texture. Microbiological examinations are carried out to check whether proper hygienic procedures have been followed and whether the finished product is safe to eat or not.

4) Sensory evaluation: After physical, chemical and microbiological examination have been performed on a finished product with a satisfactory result, the product is considered ready for distribution, but only after its sensory quality has been assessed. To the processor, a palatable product ensures sales because palatability attracts consumers and to the consumer, palatability satisfies his gustatory senses.

5) Packaging: The primary purpose of manufacture is to produce a food product, to keep it in good condition and to preserve the flavour until it reaches the consumer. Therefore, it is essential that a suitable packaging material is chosen for packing a finished product. The material used for packaging must not contaminate the product and must be effective in preventing the product from deterioration. A variety of containers have also been designed to handle products that are sensitive to light, temperature, oxygen, moisture and contact with the chemicals.

6) Labeling and storage: After packing, labels are pasted on the finished products which are intended for sale. The information on the label shall include name of product, ingredients used, date of manufacture, name and address of the manufacturer, sale price, net weight or volume etc. A good and an attractive label is an aid to the successful marketing of the product. The product should be stored in a cool and dry place.

Critical control points of inspection
The critical control points of inspection followed during canning of foods in syrup are as under:

1. Raw material: The important material used is fruit sugar and citric acid. Water used in making syrup should be suitable for purpose of canning.

- Fruit: Variety, maturity, extent of spoilage or damage, pesticide residues, deterioration in handling and storage, potential contamination etc.
- Sugar and citric acid with respect to physical and chemical characteristics.

2. Tin containers

- Type of tin plate, weight of tin coating, side seam, and double seam accuracy.

3. Washing of fruits

- Quality of water

4. Preparation of fruit

- Efficiency of preparatory operations like peeling, slicing, coring, trimming and freedom from damaged or diseased portion.
- Uniformity with respect to colour, texture and maturity.

5. Preparation of syrup

- Calculation of strength of covering syrup required in relation to total soluble solids in fruit, filled weight of slices, weight of covering syrup added and cut-out degree brix required in the finished product.
- Control of weight, temperature and uniformity of strength at the time of filling.

6. Filling: The coefficient of variation in the weight of empty cans is generally about 4%. The fill-in-weight of fruit required to get the desired drained weight in the canned product should be carefully determined.

7. Exhausting: Periodic checks should be made to ensure that the cans coming out of the exhaust box have attained the desired can centre temperature. It has direct relation to ultimate vacuum and is related to shelf life and behavior at different altitudes.

8. Container closure operation

- Protection of empty containers
- Cleaning of containers before filling
- Maintenance of can seamers
- Measurement of can seams

9. Processing

- According to good manufacturing practices
- Pasting of process schedules near retorts
- Recording of retorting operation

10. Cooling Water

- Microbiological quality
- Chlorine content

11. Post process handling

- Prevention of filled containers from damage and contamination
- Cooling
- Warehousing-temperature, humidity etc.

12. Clean up and sanitation

13. Steam quality

14. Examination of finished product

15. Sanitation control

- Sampling
- Location
- Visual appearance
- Microbiological level
- Rating-good, fair or poor.

16. General inspection

- Raw material receiving department
- Product preparation area
- Packing and dispatching area
- Windows, doors, wall surfaces, floor etc.

Similarly, critical control points (CCP) for other processed products can be worked out.