# Post-harvest Management and Processing of Fruits and Vegetables

भाकृअनुप
ICAR

N S Rathore • G K Mathur • S S Chasta

Indian Council of Agricultural Research
New Delhi

# Post-harvest Management and Processing of Fruits and Vegetables

**Dr N S Rathore**
Dean
Maharana Pratap University of Agriculture and Technology
Udaipur (Rajasthan) 313 001

**Dr G K Mathur**
Associate Professor
College of Dairy and Food Science Technology
Udaipur (Rajasthan) 313 001

**Shri S S Chasta**
Assistant Professor
College of Dairy and Food Science Technology
Udaipur (Rajasthan) 313 001

भाकृअनुप
ICAR

**Directorate of Knowledge Management in Agriculture**
**Indian Council of Agricultural Research**
Krishi Anusandhan Bhavan, New Delhi 110 012

Printed : July 2012
*First Reprint* : October 2016
*Second Reprint* : May 2018

*Project Director (DKMA)* : Dr S.K. Singh

*Incharge, English Editorial Unit* : Dr Aruna T Kumar

*Chief Production Officer* : Dr V K Bharti
*Assistant Chief Technical Officer* : Punit Bhasin



**ISBN : 978-81-7164-115-4**

**Price : ₹300**

Published by Dr S.K. Singh, Project Director, Directorate of Knowledge Management in Agriculture, Indian Council of Agricultural Research, Krishi Anusandhan Bhavan I, Pusa, New Delhi 110 012 and printed at M/s Chandu Press, 63, Patparganj Industrial Estate, Delhi 110 092.

# Preface

Fruits and vegetables are rich reservoirs of important nutrients that improve food quality and are also necessary for maintaining good health. India is one of the largest producers of fruits and vegetables, after Brazil and China. It has been observed that about 30-35% of the total production of fruits and vegetables in India goes waste from harvesting to consumption. The problem is severe during "glut" period of fruits and vegetables because of the inadequate availability of the post-harvest management technologies. The need of the present situation is to make fruits and vegetables available for consumption throughout the year in the processed or preserved form. This necessitates development of an effective value-chain, starting from production to consumption, that in turn will give higher returns to growers and entrepreneurs also. Since fruits and vegetables are highly perishable, different types of processing and value-addition technologies are required to preserve them. So there arose a need for information on different techniques, starting from the pre-harvesting, post-harvesting, preservation, processing, value-addition and finally packaging.

There was a long-felt need for a document on the subject covering various techniques and fundamentals of the post-harvest management and processing of fruits and vegateables for farmers, growers, entrepreneurs, scientists, industrialists, students and general public. Keeping in view the importance of the post-harvest management and processing, this book has been compiled and it has vast information on the various issues of management and processing of fruits and vegetables. It covers on different aspects of processing and post-harvest technologies, including storage, packaging, advanced preservation technology and value-addition of fruits and vegetables.

This book will be of immense value to teachers, students and extension-workers for understanding post-harvest management and processing practices. And may create employment opportunities at the local level through value-addition.

**N. S. Rathore, G. K. Mathur**
**and S. S. Chasta**

# Contents

Chapter 1

# Production and Processing Scenario of Fruits and Vegetables

## 1.1 Introduction

India is one of the most important fruits and vegetables producing countries of the world. It is the second largest producer of fruits, next only to China; contributing to 10.9% of the total world's fruits production. Recently, the country has emerged as the largest producer of mango (40%), banana (24.5%), papaya (28.8%), lime and lemon (11.9%), coconut, arecanut, cashewnut, ginger, turmeric and black pepper. Among vegetables, India is the largest producer of peas (29.5%), and is the second largest producer of brinjal (28.7%), cauliflower (28.9%), onion (14.7%) and cabbage (8.8%); and ranks fourth in tomato production (7.3%). Diverse agroclimatic zones of the country make India amply suitable for cultivation of almost all varieties of fruits and vegetables— over 40 types of vegetables and 30 types of fruits. Still India's per capita availability of fruits is only 100 grams per day. It is reported that more than 30-35% of the total fruits production is lost owing to spoilage at various stages after harvesting. Thus, reducing per capita availability further to around 80 grams per day, which is almost half of the requirement for a balanced diet.

Currently, vegetables production of the country is over 105 million metric tonnes and total cultivated area under them is around 6.2 million hectares; 3% of the total cultivated area of India. It is estimated that around 20-25% of the total vegetables produced are lost due to poor post-harvest practices. And less than 2% of them are commercially processed as compared to 70% in Brazil and 65% in the USA (Khetarpaul, 2005).Herein, post-harvest management technology offers promising option for increasing production of vegetables and fruits quantity-wise and also in maintaining quality of products.

In India, a substantial percentage of foodgrains, fruits, vegetables and dairy products are lost every year due to poor post-harvest management, which results in the loss of more than Rs 50,000 crore per annum. Hence, to feed ever-increasing population, there is a need for proper post-harvest management, which will ultimately check losses in production; quality- and quantity-wise.

Post-harvest management involves all activities that are followed after production or harvesting of agricultural commodities–including procurement, removal of field heat, sorting, grading, packaging, storage, transportation, primary and secondary processing and marketing of agricultural products from farm-gate to distributors. Sequences and interactions of these activities performed after harvesting contribute to the formation of a system known as post-harvest management, which is required for increasing production and maintaining quality; that would otherwise generate waste. Improved management depends on the efficiency of techniques used for handling, preservation, processing and value-addition. Post-harvest management techniques are basically for ensuring food safety and quality, and can be a source of employment generation. To meet emergent form of consumer demands, for value-addition of products for higher income and for alleviating standards of living of farmers are the main objectives for proper post-harvest management (FAO, 2003).

## 1.2 Fruits and Vegetables Production and Processing

From the eighth plan onwards, production of horticultural crops has witnessed tremendous growth in area, production and productivity. Area and production under horticultural crops were 13.43 million ha and 97.83 million tonnes, respectively, during 1991-92, and increased to 19.33 million ha and 185.86 million tonnes during 2005-06. And the increase in area, production and productivity was to the tune of 56.92, 91.86 and 28.0%, respectively, between 1991-92 and 2005-06. Changes in fruits, vegetables, flowers, spices and plantation crops during the above period have also been substantial, which were 105.2, 86.3, 89.6, 168.8 and 50.2%, respectively. Among states, West Bengal contributed maximum (14.09), followed by Maharashtra, Karnataka, Kerala and Andhra Pradesh (Table 1.1).

In India, fruits are grown on 5.51 million hectares; yielding 58.92 million tonnes of fruits. Important ones are mango, citrus, banana, apple, litchi, guava, pomegranate and sapota. And vegetables are grown on 7.49 million hectares with a production of 116.33 million tonnes. Important vegetables are potato, brinjal, tomato, onion, okra, cauliflower, cabbage and green peas. Fruits and vegetables production showed an increase from 87.13 million tonnes in 1991-92 to 174.95 million tonnes in 2006-07 (NHB, 2008). They together registered a growth of 3.97% in production, 3.06% in area and a meagre 0.89% in

**Table 1.1** Share in percentage of area, output in horticulture and of agricultural GDP of states during 2005-06

| States/ UTs | Area under horticulture* (%) | State output in horticulture (%) | In agriculture output at 1999-2000 price (%) |
|---|---|---|---|
| Andhra Pradesh | 11.41 | 7.50 (5) | 29.37 |
| Arunachal Pradesh | 40.15 | 0.17 | 49.07 |
| Asom | 14.34 | 3.67 | 55.65 |
| Bihar | 19.63 | 5.49 | 48.96 |
| Chhattisgarh | 2.75 | 2.01 | 33.83 |
| Goa | 70.85 | 0.31 | 63.93 |
| Gujarat | 8.57 | 4.96 | 22.36 |
| Haryana | 6.50 | 1.50 | 12.62 |
| Himachal Pradesh | 44.85 | 1.83 | 65.44 |
| Jammu and Kashmir | 34.13 | 1.46 | 53.65 |
| Jharkhand | 4.73 | 1.53 | 51.33 |
| Karnataka | 12.73 | 9.48 (3) | 42.70 |
| Kerala | 73.33 | 9.09 (4) | 74.15 |
| Madhya Pradesh | 4.61 | 2.27 | 13.86 |
| Maharashtra | 10.23 | 12.41 (2) | 30.54 |
| Manipur | 57.21 | 0.29 | 48.55 |
| Meghalaya | 31.25 | 0.31 | 66.18 |
| Mizoram | 18.00 | 0.07 | 39.09 |
| Nagaland | 7.20 | 0.17 | 35.86 |
| Odisha | 20.91 | 4.58 | 45.25 |
| Punjab | 4.85 | 1.42 | 7.86 |
| Rajasthan | 14.80 | 1.43 | 8.01 |
| Sikkim | 58.80 | 0.29 | 80.81 |
| Tamil Nadu | 16.86 | 4.97 | 38.04 |
| Tripura | 28.47 | 0.71 | 59.33 |
| Uttarakhand | 15.20 | 0.88 | 40.14 |
| Uttar Pradesh | 6.41 | 6.79 (6) | 15.78 |
| West Bengal | 25.89 | 14.09 (1) | 50.96 |
| Andaman and Nicobar | 100.00 | 0.06 | 56.50 |
| | 10.00 | 0.00 | 50.39 |
| Chandigarh | 9.17 | 0.01 | 17.42 |
| Dadar and Nagar Haveli | 12.50 | 0.00 | 9.00 |
| | 83.32 | 0.20 | 71.00 |
| Daman and Diu | 100.00 | 0.00 | 5.30 |
| Delhi | 31.24 | 0.04 | 35.71 |
| Lakshadweep | 13.08 | 100.0 | 31.25 |
| Puducherry | | | |

*,Data for 2003-04

productivity. In fruits, production registered a growth of 3.62%, which was mostly area-led (-0.37%). In vegetables, production grew at 4.16%, and here also it was area-led; area grew at a rate of 2.44% and yield registered growth of only 1.68% (Table 1.2).

**Table 1.2** Production of fruits and vegetables in India

| | As on 1 January | | | | | |
|---|---|---|---|---|---|---|
| | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** |
| Capacity (lakh tonnes) | 11.08 | 12.60 | 14.02 | 17.60 | 19.10 | 20.40 |
| Production (lakh tonnes) | 4.69 | 5.59 | 6.76 | 8.50 | 9.60 | 9.10 |
| Growth in production over the previous years (%) | 30.28 | 20.00 | 20.93 | 25.74 | 12.94 | 5.20 |
| | **As on 1 January** | | | | | |
| | **1999** | **2000** | **2001** | **2002** | **2003** | **2004** |
| Capacity (lakh tonnes) | 21.0 | 20.08 | 21.00 | 21.1 | 21.98 | 23.28 |
| Production (lakh tonnes) | 9.80 | 9.40 | 9.80 | 9.90 | 10.30 | 10.72 |
| Growth in production over the previous years (%) | 4.26 | 3.30 | 4.26 | 1.00 | 4.04 | 4.08 |

**Source:** Ministry of Food Processing Industries (2003-04). *Annual Report.*

Among fruits, average productivity is much lower in India compared to other fruit-producing countries in the world. Excepting grapes and banana, productivity is much below as compared to other countries. And as regards to vegetables, average productivity is not only the lowest in India but productivity of individual vegetables is also the lowest among major vegetable-producing countries in the world.

### 1.2.1 Fruits Production

India is the only country to have production and availability of one or more fruits at any point of year—with about 10.4% of all fruits and nearly 40% of tropical fruits of the world. Major fruit-growing Indian states are—Uttar Pradesh, Karnataka, Tamil Nadu, Maharashtra and Gujarat. India ranks second in the world in fruits production. Fruits production increased from 36 to 47 million tonnes at an average annual growth rate of 3% between 1995 and 2004, and harvested area and yields increased by 2.4 and 1.5%. It contributes 10% on an average to gross value of total agricultural output in India and about 13% of the total export earnings from the major agricultural products.

The main tropical fruits produced in the country are banana, mango, guava, pineapple, papaya, *litchi* and to a lesser extent are sapota, jackfruit, *phalsa*, annona and *ber.*

The three major tropical fruits (mango, pineapple and guava) accounted for 33% of the total fruits production in 2004—mango output was 10.8 million tonnes, a 6.2% increase over 1998/2000; and production of papaya and pineapple was 700,000 tonnes, and 1.3 million tonnes,and percentage increase in production of papaya was 4.3% and of pineapple was 2.3% from1995 to 2004 (Table 1.3).

**Table 1.3** Major fruits production in India ('000 tonnes)

| | Average (1992/1994) | 2002 | 2003 | 2004 |
|---|---|---|---|---|
| Bananas | 9,718 | 16,820 | 16,820 | 16,820 |
| Mangoes | 10,108 | 10,640 | 10,640 | 10,800 |
| Oranges | 1,743 | 3,120 | 3,070 | 3,070 |
| Apples | 1,205 | 1,160 | 1,470 | 1,470 |
| Lemons and Limes | 863 | 1,440 | 1,420 | 1,420 |
| Pineapples | 956 | 1,180 | 1,310 | 1,300 |
| Grapes | 684 | 1,210 | 1,150 | 1,200 |
| Papayas | 470 | 700 | 700 | 700 |
| Pears | 127 | 200 | 200 | 200 |
| Peaches and Nectarines | 83 | 150 | 150 | 150 |
| Grapefruits and Pomeloes | 83 | 140 | 142 | 142 |
| Plums | 55 | 80 | 80 | 80 |
| Figs | 6 | 11 | 11 | 11 |
| Apricots | 7 | 10 | 10 | 10 |
| Cherries | 4 | 8 | 8 | 8 |

Most of the fruits produced in India are consumed domestically; and export volume represents only less than 1% of world's exports.

Total apparent consumption of fruits was estimated at 39 million tonnes in 2002, about 8 million tonnes higher than that in 1995; with consumption of fresh tropical fruits estimated at 16.3 million tonnes. Annual per capita consumption of fruits was evaluated at 37 kilograms in 2002, a 12% increase over 1995; with major tropical fruits at 13.3 kg, temperate fruits at 4.2 kg and other fruits at 5.9 kg.

Major fruit-consuming states are Kerala, Tamil Nadu in south and Goa in the west, followed by Punjab, Haryana, Delhi, Chandigarh, Bihar, Odisha, Rajasthan and Madhya Pradesh.

Banana (*Musa* sp.) is the fourth most important food in the world after rice, wheat and milk and milk products for human consumption.

It is grown worldwide in 130 countries, more than any other fruit-crop. Banana-crop is native to tropical south eastern Asia, and is widely cultivated in tropical regions. In India, total area under this crop is 3.70 lakh ha,and production is next only to mango, with a total annual production of 16.91 million tonnes (37% of the total fruits production in India). Among states, Maharashtra has the maximum area of about 90,000 ha with a productivity of 60 tonnes/ha. Other important states are Kerala, Tamil Nadu, Asom and Andhra Pradesh.

In India, grape cultivators are concentrated mainly in Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, Madhya Pradesh, Uttar Pradesh, Punjab, Haryana, Delhi and Rajasthan. Area under grapes cultivation is 34,000 ha with an annual production of 1 million tonnes. Approximately 8.5% of its total production, irrespective of the variety, is consumed fresh. Varieties Tas-A-Ganesh, Sonaka and Manik Chaman are dried for raisins.

In India, Jammu and Kashmir and Himachal Pradesh are the two major apple-producing states; and apple-based industries form the backbone of economy of the these states. Apple is also grown in Sikkim and Nagaland. Although there has been 5-6 fold increase in apple production during the last 50 years, but productivity level of it is still very low (5.56 tonnes/ha). Presently a small quantity of apple produced is exported to Bangladesh and Srilanka.

### 1.2.2 Vegetables Production

About 175 types of vegetables are grown in India, including 82 leafy vegetables, 41 root (tuber and bulb) crops; a prime enterprise in modern horticulture. India is the second largest producer of vegetables in the world, next only to China; with an estimated production of about 50.09 million tonnes from 4.5 million hectares at an average yield of 11.3 tonnes /ha. India shares about 12% of the world's output from about 2.0% of cropped area (Tables 1.4, 1.5).

West Bengal, Uttar Pradesh, Bihar, Odisha and Karnataka are the leading vegetable-producing states, and potato, brinjal, tomato, chilli, cabbage, onion, cauliflower, okra and peas are grown on commercial scale. Vegetables production increased from 58.5 million tonnes during 1991-92 to 90.83 million tonnes during 1999-2000. However, their productivity is still lower compared to world average productivity of 15.7 tonnes/ha. Experimental productivity in vegetables is, however, much higher; meaning thereby that there is still scope for increasing production of vegetables. Per capita availability of vegetables is estimated at about 175 g /day after deducting quantity exported (about 0.5 million tonnes) and post-harvest losses of about 280 g/capita/day for a balanced

**Table 1.4** Area, production and productivity of vegetable crops on the all-India basis

| Year | Area (m ha) | Production (m tonnes) | Productivity (tonnes/ha) |
|---|---|---|---|
| 1991-92 | 5.593 | 58.532 | 10.5 |
| 1992-93 | 5.045 | 63.806 | 12.6 |
| 1993-94 | 4.876 | 65.787 | 13.5 |
| 1994-95 | 5.013 | 67.286 | 13.4 |
| 1995-96 | 5.335 | 71.594 | 13.4 |
| 1996-97 | 5.515 | 75.074 | 13.6 |
| 1997-98 | 5.607 | 72.683 | 13.0 |
| 1998-99 | 5.873 | 87.536 | 14.9 |
| 1999-2000 | 5.991 | 90.823 | 15.2 |
| 2000-01 | 6.250 | 93.849 | 15.0 |
| 2001-02 | 6.156 | 88.622 | 14.4 |

diet. And vegetables requirement in India is estimated to be 220 million tonnes by 2020. The average productivity of tomato in India is merely 15.71tonnes/ha compared to 58.76 tonnes/ha in the USA, 49.86 tonnes/ha in Greece, 46.5 tonnes/ha in Italy and 46.62 tonnes/ha in Spain.

Tubers and bulbs account for 45% of the country's total area under vegetables, and include tapioca, potato and onion. All leafy and flower crops share only 12% of the total area; cabbage and cauliflower are the main vegetables of this group. And the fruit group contributes about

**Table 1.5** Area, production and productivity of major vegetable crops in India (2002-03)

| Crops | Area (m ha) | Production (m tonnes) | Productivity (tonnes/ha) |
|---|---|---|---|
| Brinjal | 507.3 | 8,001.2 | 15.8 |
| Cabbage | 233.8 | 5,392.0 | 23.1 |
| Cauliflower | 254.6 | 4,444.1 | 17.5 |
| Okra | 329.2 | 3,244.5 | 9.9 |
| Onion | 424.7 | 4,209.5 | 9.9 |
| Peas | 305.2 | 2,061.8 | 6.8 |
| Potato | 1,337.2 | 23,161.4 | 17.3 |
| Sweet-potato | 131.9 | 1,130.3 | 8.6 |
| Tapioca | 207.0 | 5,426.2 | 26.2 |
| Tomato | 478.8 | 7,616.7 | 15.9 |
| Others | 1882.0 | 20,127.6 | |
| **Total** | **6,091.7** | **84,815.3** | **151** |

28%; with egg-plant at 8%, and lady's finger, tomato, peas and beans with 5% share. Vegetables occupy an important place in diversification of agriculture and play a pivotal role in food and nutritional security of our country.

Onion (*Allium cepa*) is a popular vegetable, grown for its pungent bulbs and flavoured leaves, and it is grown in Maharashtra, Gujarat, Uttar Pradesh, Odisha, Karnataka, Tamil Nadu, Madhya Pradesh, Andhra Pradesh and Bihar. Area, production, productivity and per capita availability of onion in India have shown marked improvement during the past decade, by about 50, 11, 239 and 66% respectively. At present, India ranks first in area under onions (4.21 lakh hectares); second in production (5.97 million tonnes) after China; and third in exports after Netherlands and Spain.

Garlic (*Allium sativum*), an important bulb crop, is used throughout India primarily as a spice or as a condiment. It is mainly grown in Gujarat, Madhya Pradesh, Odisha, Maharashtra, Uttar Pradesh and Rajasthan. Small quantity of good quality garlic produced in Ootakamund and Kodaikanal (Tamil Nadu) is consumed only locally. Recently, a few farmers in Punjab and Haryana have started cultivating garlic and the yield recorded in the states has been found higher than that from traditional growing areas.

India is the world's fourth largest producer of potato (1.50 million ha). However, despite significant increase in production per hectare from 6.59 tonnes (in 1949) to 16.71 tonnes (in 2005), its productivity is lower than that in Europe and the USA. Potato-crop is extensively grown in North Indian Plains, 85% of the total acreage; and the remaining lies in hills and plateau.

Cabbage is the fourth most widely grown crop of the country. Area under its cultivation is 0.23 million ha with production of 5.62 million tonnes. West Bengal produces 1.84 million tonnes, and is the largest grower, followed by Odisha and Bihar. Other major grower states are Asom, Karnataka, Maharashtra and Gujarat.

*Bhindi (*okra, lady's finger and grumbo) *Abelmoschus essculentus*, is a vegetable of the tropical and subtropical countries.And its seeds form nutritious ingredient of cattle-feed and are source of vegetable oil.Major okra-producing states are Uttar Pradesh, Bihar, West Bengal, Odisha, Asom, Andhra Pradesh and Karnataka.

Fruits of cucurbits, warm-season vegetables, are used as salad, (cucumber), cooked vegetable (gourds), desert fruits (watermelon, muskmelon) or in confectionary (ash gourd). Most of the cucurbits are seed propagated. Bittergourd(*Momordica charatia*) fruits are rich in iron (1.8 mg/100 g), calcium (20 mg/100 g), phosphorus (55 mg/100 g), vitamin A 210 IU/100 g and vitamin C (88 mg/100 g) and form an ideal diet for diabetic patients. Maharashtra, Kerala, Karnataka and Tamil Nadu are the major bittergourd-growing states. Bottlegourd(*Lagenaria siceraria*) is grown throughout India. It is diametric and has cardiotonic properties. It is cultivated extensively in Uttar Pradesh, Punjab, Asom, Meghalaya and Rajasthan. Cucumber (*Cucumin sativus*) fruit is used as salad and for pickling. Muskmelon (*Cucumis melo*) is a plant for dry cool climate, and cannot tolerate frost. For it well-drained loamy soil is suitable. Watermelon (*Citrullus Iannatus*) is grown in Maharashtra, Karnataka, Tamil Nadu, Madhya Pradesh and Uttar Pradesh.

### 1.2.3 Processed Vegetable Products

Home-scale processing and preservation of different vegetables by sun-drying and pickling is being practised in India. And types of processes and methods adopted for vegetables processing vary from region to region. Vegetables have mostly been canned and dehydrated. But recently products like frozen vegetables, vegetable curries in retortable pouches, canned mushrooms and mushroom products are also in vogue.

**Table 1.6** Vegetable-based processed products

| Crop | Processed products |
|---|---|
| Tomato | Tomato powder, Canned tomato pulp, Tomato juice, Tomato puree, Tomato ketchup, Tomato sauce |
| Brinjal | Dried brinjal, Canned brinjal |
| Chilli | Chilli powder, Canned chilli, Frozen chilli, Chilli sauce, Chilli pickle |
| Cowpea | Dried cowpea, Canned cowpea, Frozen cowpea |
| Carrot | Dried carrot, Canned carrot, Carrot pickle |
| Pea | Dried pea, Canned pea, Frozen pea |
| Okra | Dried okra, Canned okra, Frozen okra, Pickle okra |
| Cucurbits | Dried cucurbits, Canned cucurbits, Frozen cucurbits, Preserved cucurbits |
| Cauliflower | Dried cauliflower, Canned cauliflower, Frozen cauliflower, Cauliflower pickle |
| Broccoli | Dried broccoli, Canned broccoli, Frozen broccoli |
| Cabbage | Canned cabbage, Fermented cabbage |
| Onion | Dried onion, Canned onion, Onion pickle |

## 1.3 Scope of Fruits and Vegetables Preservation Industry

The scenario of this industry in India is fast changing. Since nineties there has been a constant flow of funds into this sector as a foreign exchange direct investment (FDI).At present, the new industrial policy has placed fruits and vegetables processing in the list of high priority area. The Food Processing Industry is now identified as a "SUNRISE INDUSTRY" owing to its enormous input potential and its significance in the development of the country. The number of fruits and vegetables processing units, their installed capacity and production have grown up steadily in the last six years.

There were over 4,000 fruit processing units in India with an aggregate capacity of fruits and vegetables processing increased from 11.8 lakh tonnes in January 1993 to 23.28 lakh tonnes in January 2004. The estimated installed capacity of the industries increased from 20.8 lakh tonnes in 1998 to 23.28 lakh tonnes in 2003-04.And production of processed fruits and vegetables increased from 9.4 lakh tonnes in 1998 to 10.72 lakh tonnes in 2003-04.

The utilization of fruits and vegetables for processing in the organized and the unorganized sectors is estimated at around 2% of the total production of various products; fruit juices and fruit pulp account for 27%, followed by ready-to-serve beverages and pickles, being between 12 and 13%, jams and jellies 10%, and synthetics 8%.

Over the last few years there has been a positive growth in ready-to-serve beverages, fruit juices and pulps, dehydrated- and- frozen fruit and vegetable products, tomato products, pickles, convenience vegetables spices pastes, processed mushrooms and curried vegetables (Khetarpaul, 2005).

There have been fluctuations in production of canned and bottled fruits and vegetables products and fruit-juices concentrates. Domestic consumption of value-added fruits and vegetables products is less as compared to primary processed foods, in general, and fresh fruits and vegetables, in particular, which is attributed to higher tax and duties, including that on packaging material, lower capacity utilization, non-adoption of cost-effective technology, high cost of finance, infra-structural constraints, inadequate farmers-processors linkage leading to dependence upon intermediaries.

India's share in the world trade in this sector is only around 1%. It is estimated that around 20% of the production of procured fruits is meant for exports, the rest caters to defense, institutional sectors and household consumption. Mango and mango-pulp- based products constitute 50% of exports. In 1997-98, processed fruits and vegetables exported were valued at ₹ 5,240 million. Major exports are of fruit pulps, pickles, chutneys, canned fruits and vegetables, concentrated pulps and juices, dehydrated vegetables and frozen fruits and vegetables.

Modern fruits and vegetables preservation industry is by-and- large employing sophisticated machinery, equipment and efficient techniques of production on a large scale to reduce cost and minimize wastage. There is still considerable scope in this context.

In India, traditionally fruits and vegetables processing has been practised as household or cottage-scale activity by small-scale artisans as a family profession. Despite lack of basic training in food processing operations, excellent quality pickles, *murabbas*, fried, roasted and puffed products could be prepared and marketed by these artisans for local consumption.

While Indian agriculture sector has witnessed several heights of innovations and technological advancements, processing sector is still in its infancy. Even though installed capacity of processing industries of fruits and vegetables has increased, their utilization for processing in organized and unorganized sectors is estimated at 2% of the total production. Ever since the withdrawal of excise duty on the processed products, there has been significant rise in growth of the industry. Most fruits and vegetables are seasonal crops and are perishable in nature. In a good season, there may be a local glut, particularly of fruits, but because of insufficient transport facilities, lack of cold chain, lack of roads and poor availability of packaging materials, surplus cannot be taken quickly enough to natural market in urban areas. Moreover, surplus often cannot be stored for sale in off-season because of inadequate local cold-storage facilities. Besides their careless and improper handling reduce market value and keeping quality, ultimately causing enormous losses and depriving rightful benefits to both growers and consumers. At present, more than 25% of fruits and vegetables valued at ₹ 67,500 million are reported as wastage annually. Although R & D efforts on the development of post-harvest handling have helped in reducing spoilage, considerable losses continue to occur. If 10% of the spoilage could be prevented during glut by converting them into new categories of processed products, there will be a saving of ₹ 6,750 million. It has also been observed that with increasing urbanization, there is a rise in middle class purchasing power, change in food habits and drying out of practice of marketing demand for factory-made jams, jellies, fruit beverages, dehydrated foods and pickles in the domestic market.

In spite of all this, fruits and vegetables preservation industry at present is able to utilize less than 2% as against 40-60% in the developed countries. Thus, there is a considerable scope for expansion of this industry, which in turn would give a fillip to development of horticulture, especially in hilly areas.

## 1.4 Constraints in Popularization of Food-processing Technology

The present-day fruits and vegetables preservation industry is plugged with lots of constraints. Land ceiling is a major deterrent for large-scale cultivation of fruits and vegetables, especially in organized sectors. And small-captive orchards are insufficient to meet requirements of the processing industry. In India, vegetables are typically grown in fields; contray to cultivation of vegetables in greenhouses, practised in the developed countries for higher yields. Vegetables sector also suffers from lack of availability of good quality planting material and low use of hybrid seeds, besides poor farm management and manual harvesting practices. The industry also faces following constraints.

- Lack of funds for marketing of products.
- Lack of modern machinery and equipment for storage and transportation.
- Lack of modern management and professional enterprises for adopting present state-of-art of equipment.
- Lack of proper infrastructuring to manufacturing international quality goods.
- Lack of information for competitive leverage.

The above constraints have often resulted in a glut situation for farmers, and it has not been uncommon to come across incidents when farmers could get only ₹ 1 for a kilo of tomatoes or ₹ 3 per kilo of grapes. Lack of preservation infrastructure and other facilities leave farmers with no option then to sell their produce at lower prices during peak season. In India, when tomatoes are sold for ₹ 3/kg, value-added tomato ketchup is sold at ₹ 70/kg. In the dairy sector, farmers get 66% of what consumers pay for milk, and fruits and vegetables farmers get less than 20% of what consumers pay. This has resulted in stunted growth of this sector.

## 1.5 Future of Fruits and Vegetables Processing

There has been no major focused project like "operation flood" in vegetables' and fruits' production, processing and marketing. Drip irrigation has emerged as a useful technology for conservation of water used for irrigating crops. Fruits and vegetables sector is ideal for drip irrigation. The expert opinion survey inferred following trends in the future for fruits and vegetables sector.

- Fruits and vegetables would continue to be harvested manually.
- While small land holdings and non-availability of good quality seeds have been major concerns, it is expected that quality of planting materials would improve in a long run due to hybridization and tissue-culture techniques.

- Farmers and farm-women would be educated through extension education and trainings to produce better quality material and processing of the produce.
- Co-operative and contract farming may resolve problems of small land holdings towards improved yield and quality.
- Controlled atmosphere/modified atmosphere (CA/MA) technologies and irradiation technologies are expected to emerge for preservation and extension of shelf-life.
- Most of the food materials are perishable in nature and need to be preserved using proper techniques. Cold chains have been a boon for fruits and vegetables industry for reaching of food materials to consumer in the natural form. In the coming years, the cold chain service will be able to satisfy desire of everyone, from a primary seller to a consumer.
- Marketing of fruits and vegetables is expected to be dominated by co-operatives and by middle man for short term; organized direct soaring supermarkets are likely to emerge.
- Dehydrated products, fruit-juices, pickles and other forms of preserves are likely to emerge as processed products.
- Changes in consumer taste, food habits and life style, convenience, nutritional value and purchasing power are likely reasons for preference of processed products.
- While level of processing will be around 5-10% in the next 10 years; 15-20% of fruits and vegetables may be processed for long term.
- The share of sectoral consumption for processed fruits and vegetables in the long term would be —domestic 30%, institutional 40% (including defense) and export 30%.
- While small-scale processing units would dominate for short-term; an advent of large-, medium- scale units are likely to run on the long-term basis.

## 1.6 Post-harvest Management Technology

Post-harvest losses mean a measurable quantitative and qualitative loss in a given product after harvesting and during transportation, storage and handling. These losses can occur during any of the various phases of post-harvest system. The direct causes of post-harvest losses are premature harvesting, poor threshing, insufficient drying, insufficient cleaning, bird attack, rodent attack, insect attack, microorganism attack, biochemical change, leakage or waste, incorrect moisture content for storage, inadequate storage and faulty transport techniques.

Post-harvest operations of fruits and vegetables are shown in Fig. 1.1. The management during these operations is important in maintaining quality as well as in reducing losses.

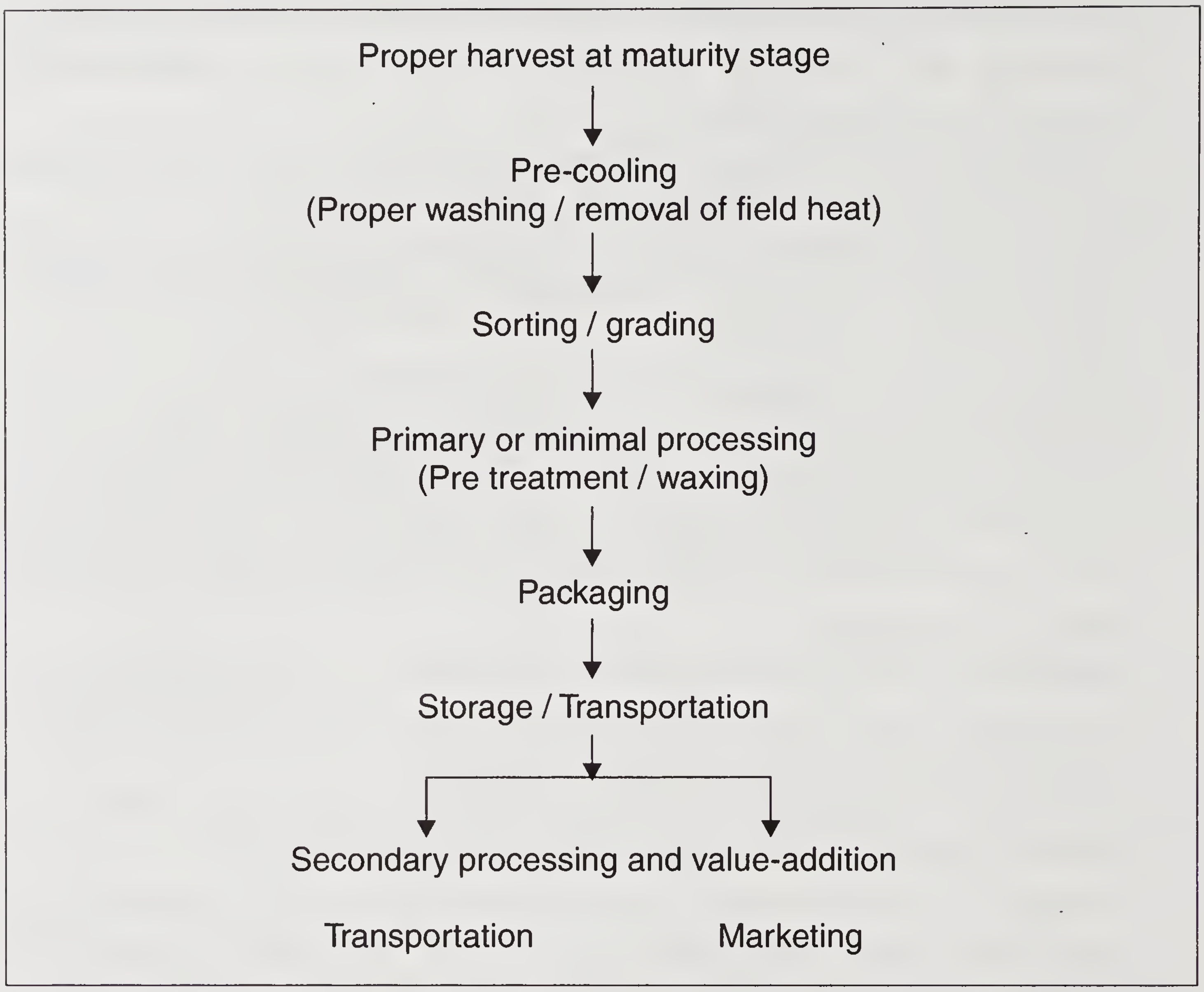


**Fig. 1.1** Post-harvest management of fruits and vegetables

## 1.7 Post-harvest Management

The post-harvest management includes number of unit operations—washing (removing field heat), sorting and grading, pretreatment or other minimal processing techniques, packaging, storage and transportation, secondary processing and value-addition and finally packaging, transportation and marketing (Fig. 1.1).

Chapter 2

# Post-harvest Management Technology for Fruits and Vegetables

## 2.1 Introduction

Post-harvest management activities start immediately after harvesting of fruits and vegetables at the proper maturity stage. These include minimal or primary processing at the field level — removing field heat, sorting, grading and packaging for transportation— and secondary processing for value-addition, and finally for packaging and marketing. Fruits and vegetables after-harvest management depends on the practices adopted for their cultivation and production, pre-harvesting and harvesting practices, quantity and quality of fruits obtained, farm and orchard size, expected returns and on the scope of the nearby value-addition, if any. Production practices have tremendous effect on the quality of fruits and vegetables at harvest and post-harvest and on the shelf-life of products; some cultivars have a longer shelf-life (Satin, 1996). In addition, environmental factors— soil type, temperature, relative humidity, air-flow rate, frost and rainy weather—affect storage life and quality. Management practices can also affect post-harvest quality, which varies according to the quality of the product obtained after harvesting. Crop produced under too much or with too little water, high rate of nitrogen or mechanical injury (scrapes, bruises, abrasions) is particularly susceptible to post-harvest diseases. Thus, handling of products during pre-harvesting and processing is important for their overall output; it is observed that pre-harvesting operations affect considerably post-harvest operations.

## 2.2 Harvesting and Handling

It is important to harvest fruits, vegetables and flowers at a proper stage and at a proper size, and when their peak quality is available. Immature or over-mature produce in storage may not last as long as that is picked at the proper maturity. Harvesting should be done during the coolest time of the day; usually in the early mornings or later evenings, and produce should be kept under shade in the field. Field heat should be removed immediately after harvesting, and crops destined for storage should be as free as possible from skin breaks, bruises, spots, rots, decay and any other deterioration. Bruises and other mechanical damages not only affect appearance of the product but can be a facilitator for entry of harmful organisms. In majority of the fruits, primary processing techniques are to be performed at the field (Ryall and Lipton, 1973).

Post-harvest rots are more prevalent in bruised or otherwise damaged fruits and vegetables. Mechanical damage increases moisture loss also. Moisture loss may increase by as much as 400% by a single bad bruise on an apple; and non-skinned potatoes may lose 3-4 times as much weight as skinned ones. Damage can be prevented by handling crop gently, harvesting it at a proper maturity, avoiding injury during harvesting and transportation, harvesting dry, whenever possible, handling fruits or vegetables individually, installing padding inside the bulk-bins, avoiding over or under-packing of containers, and safe-handling and transportation. Harvest-handling processes include placing fruits in the right container immediately after harvest, washing or removing field heat through clean-water supply, sorting/ grading and removing spoiled and damaged fruits from bulk and pre-treating (waxing etc.) according to the grade of the fruits.

## 2.3 Storage Management

This is for creating artificial environment around the products for increasing their shelf-life, and thus leading to higher returns. Depending upon the crop type, temperature, humidity, air-flow rate and aeration are to be maintained. Storage management is basically giving adequate attention to all factors causing spoilage of products.

### 2.3.1 Temperature

This is a single most important factor in maintaining quality of the products after harvesting. Therefore, maintaining it as per the need of the crop for maintaining crop quality is an important aspect in post-harvest handling. Refrigerated storage is required for checking of the following.

- Ripening and softening during primary processing, transit and storage.
- Ageing and textural/colour changes due to ripening and softening during storage and transportation.
- Undesirable metabolic changes and respiratory heat production during storage and transportation.
- Moisture loss and wilting due to high temperature.

- Spoilage due to bacteria, fungi and yeasts.
- One of the most important functions of refrigeration or building an enclosure of low temperature for storage is to control crop's respiration rate. Respiration generates heat as sugars, fats and proteins in the crop cells oxidize. Loss of these food reserves through respiration means decreased food value, loss of flavour, loss of saleable weight and faster deterioration. The respiration rate of a product strongly determines its transit and post-harvest life. Higher storage temperature means higher respiration rate, and thus higher spoilage.

To be effective in postponing deterioration, temperature in the cold storage rooms should be kept as constant as possible. Exposure to alternate cold and warm temperatures may result in moisture accumulation on the surface of the produce (sweating), which may hasten decay. Storage rooms should be well insulated and adequately refrigerated and should have appropriate air circulation to prevent temperature variation. Designing of the right type of refrigeration system, specific to the types of fruits and vegetables, is also very important.

### 2.3.2 Pre-cooling

This in fact is the primary step in maintaining temperature. It is a process of removing field-heat of products. Field-heat of freshly harvested crops (the heat a product holds from sun and ambient temperature) is usually high and should be removed as quickly as possible before shipping, processing or storage. Refrigerated trucks are not designed to cool fresh commodities but are only for maintaining temperature of pre-cooled produce. Likewise, most refrigerated storage rooms have neither refrigeration capacity nor air movement needed for rapid cooling. Therefore, pre-cooling is generally a separate operation; which requires special equipment and rooms. Rapid pre-cooling to product's lowest safe temperature is the most critical for crops with inherently high respiration rate (Putturaj and Reddy, 1997).

*Methods for Pre-cooling.* Pre-cooling is accomplished commercially by: (i) Room cooling, (ii) Forced air cooling, (iii) Hydro-cooling, (iv) Package icing, (v) Vacuum cooling and (vi) Cryogenic cooling.

In general, most of the cooling is done at packing houses or under central cooling facilities. Some of the products may be pre-cooled by any of these methods, others may be affected adversely with the cooling technique applied. For example, cantaloupe may be successfully pre-cooled by several methods but not by vacuum cooling. And iceberg lettuce can be cooled effectively only by vacuum cooling.

Choice of pre-cooling method depends upon the fruit and the vegetable type, their stage of harvesting, quantity of material harvested, cost of pre-cooling factors of the area (Brosnan and Sun, 2001).

### 2.3.3 Chilling Injury

Low temperature during transportation and storage may cause discolouration and textural changes on the surface of the fruits and vegetables; this is known as chilling injury. Right cooling temperature is important for storage of products and for preventing chilling injury. Many vegetables and fruits store best just above freezing, while others are injured by low temperature and store well at 7 to 13 °C. Chilling injury effects are cumulative in some crops. Low temperatures in transit or even in field shortly before harvest, add to the total effects of chilling that may occur in storage. Keeping grapes in freezer may affect their surface and texture due to chilling injury. Basil, cucumber, eggplant, pumpkin, summer squash, okra and sweet-potato are highly sensitive to chilling injury. And moderately sensitive are snap-bean, muskmelon, pepper, winter-squash, tomato and watermelon. These may appear absolutely fine when removed from low temperature storage, but after a few days of warm temperature, chilling symptoms may become apparent such as pitting or other skin blemishes, internal discolouration or failure to ripen. Tomato, squash and pepper that have been over-chilled may particularly be susceptible to decay.

## 2.4 Preventing Moisture Losses

While temperature is the primary concern in storage of fruits and vegetables, air-flow rate and relative humidity are equally important. Relative humidity of storage unit directly influences water loss in produce. Water loss can severely degrade quality—wilted greens may require excessive trimming, and grapes may loosen from clusters if their stems dry-out. Water loss means saleable weight loss and so it reduces profit. Most fruits and vegetables are stored at high relative humidity (80 to 95%); but at this humidity, disease outbreak can be more. Crops that can tolerate direct contact with water may be sprinkled water to promote high relative humidity. It has been observed that high temperature with even low flow rate and low relative humidity increases moisture loss from the product and low temperature at high air flow rate coupled with low relative humidity also increases moisture loss. It is desirable to keep products at low temperature, with low flow rate and moderately high relative humidity.

## 2.5 Sanitation for Maintaining Quality

Proper sanitation and hygiene during handling, transportation, processing and storage increases shelf-life, maintains quality and finally fetches higher remuneration from products. Proper sanitation of produce-handlers protects products against post-harvest diseases, and also protects consumers from food-borne illnesses. Use of a disinfectant in the wash water can help prevent both post-harvest diseases and food-borne diseases.

## 2.6 Ethylene for Ripening

Ethylene, a natural hormone produced by some fruits as they ripen, promotes ripening of the produce exposed to it. Damaged or diseased apples produce high level of ethylene, and fasten ripening of other apples; thereby, one bad apple spoils the whole bushel. Ethylene producers should not be stored with fruits, vegetables or flowers that are sensitive to ethylene. Ethylene producers are apples, apricots, avocados, ripe bananas, cantaloupes, honeydew melons, ripe kiwifruits, nectarines, papayas, passion-fruits, peaches, pears, persimmons, plantains, plums, prunes, quinces and tomatoes.

Thus, post-harvest handling is the final stage in producing high-quality fresh produce. Being able to maintain a level of freshness from field to dinner table is full of challenges. A grower, who can meet these challenges, will be able to expand his marketing opportunities and will be able to compete in the market. Improvement in post-harvest management depends on the quality and efficiency of handling, processing and preservation techniques used. Increased agricultural production may be nullified owing to inappropriate and unreliable post-harvest management employed. In nutshell, post-harvest management is for reducing post-harvest losses by devising better storage and processing technologies and by improving transit of goods from producers to consumers.

## 2.7 Post-harvest Physiological Disorders

Fruits' and vegetables' physiological activities continue even after harvesting. Rate of respiration, gaseous exchange and transpiration are observed to hasten, and these occur owing to mineral deficiency, low or high temperature injury or undesirable atmospheric conditions such as high humidity. Major physiological disorder is tissue damage or breakdown that is not related to pathogen insects or mechanical damage, freezing injury or chilling injury, low $O_2$ or elevated $CO_2$ level etc. Respiration and microbial decay influence development and ripening of horticultural produce and are known as post-harvest physiological disorders (Stanely, 1991).

### 2.7.1 Respiration

Respiration increases temperature during storage, and thereby quality of products deteriorates rapidly. It is basically an oxidation reaction in which starch, sugars, organic acids and other food reserves are utilized and converted into molecules like carbon-dioxide and water accompanied by release of energy. For each milligram carbon-dioxide produced by respiration, 2.25 calories of heat is generated (1 calorie = 4.187 Joules, thus 1 milligram of carbon-dioxide generates 10.67 Joules of energy, which is considerable quantity for increasing rate of respiration further). The chemical reaction of this change is as follows.

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Energy}$$

$CO_2$ thus formed escapes, leading to weight loss, and energy released tends to raise temperature of the product. For every 10 °C rise in temperature, rate of respiration roughly doubles or triples; as the rate of most chemical and biological reactions increases 2 to 3 times. Therefore, the rate of respiration is often considered a good index of anticipated storage life of horticultural produce. Higher is the respiration rate, shorter is the life of the product and quality of the product, and the *vice versa.*

*Factors Affecting Respiration.* **Temperature.** Respiration itself increases temperature of fruits and vegetables that ultimately increases respiration rate and destroys rapidly quality of produce. The influence of temperature on the degraded reactions is indicated by $Q_{10}$ value (temperature quotient), which represents ratio of change in the rate of reaction to 10°C change in temperature.

**Ethylene.** It is a natural plant hormone which plays an important role in fruits and vegetables ripening. Ethylene generation varies greatly among fruits. Fruits generating moderate to very high quantities are being classified as climacteric (apples, pears, peaches, bananas, mangoes). Ethylene production is always accompanied by increase in respiration rate. Consequently, high respiration rate stimulates production of ethylene, which induces early ripening of fruits leading to reduced shelf-life. Artificially addition of ethylene during storage for ripening of fruits is also common, which provides sufficient time for ripening to pre-ripened fruits during transit.

**Oxygen and Carbon-Dioxide Concentration**. Oxygen and carbon-dioxide concentration influences rate of respiration and ripening during storage. Reduction of $O_2$ concentration to less than 10% slows down respiration rate. But adequate $O_2$ must be available to maintain aerobic respiration. Elevated levels of $CO_2$ can inhibit ethylene action and thus delay fruit ripening. At $CO_2$ concentration above 20%, a significant increase in anaerobic respiration occurs, which can damage plant tissue.

**Transpiration.** Through this, all fruits and vegetables continue to lose water even after harvesting, and this water loss affects mainly their commercial and physiological value. Transpiration causes wilting, shrinkage, loss of firmness, crispiness and leads to loss of succulence. In other words, because of transpiration, fresh appearance, texture and flavour of fruits and vegetables are lost. If humidity is lesser than 70%, loss of moisture due to transpiration becomes faster than loss of solids by respiration. Water loss of 3-7% is generally enough to cause a noticeable loss of quality and value. Factors affecting transpiration are surface area to volume ratio, nature of surface coating, relative humidity, atmospheric temperature and pressure, extent of any mechanical injury/ damage and other climatic factors. Respiration generates heat, which raises temperature of tissues, and hence increases transpiration. Thus, to minimize transpiration, produce should be kept at a lower temperature, and efforts should be made to reduce respiration and ripening process during storage.

### 2.7.2 Microbial Decay

Mechanical damages like bruising or irregular detaching of fruits from the stem can be potential precursor for microbial activity. High temperature and high humidity favour this post-harvest decay. Produce also stores and absorbs heat from its environment, therefore, proper temperature management is essential to preserve quality and to prolong shelf-life of fresh produce.

## 2.8 Effect on the Quality of Fruits and Vegetables of Delayed Cooling

Temperature is the single most important factor that influences respiration rate, ripening, transpiration and attack by microbial agents. Therefore, it is a prime requirement to control temperature of the chamber, where fruits and vegetables are kept for storage. Quality loss after harvesting occurs as the result of physiological and biological processes (rates of which are influenced primarily by product temperature or temperature of the room where product is stored). The product should be cooled as quickly as possible after harvesting to slow down changes associated with ripening. This is known as removing field heat of the products; this gives more time to market product. A few hours just after harvesting are very critical for product quality and shelf-life. Each hour delay between harvesting and cooling results into loss of a day of shelf-life. Much deterioration occurs during the first hour after harvest at 25°C than during a week at 1°C. Perishable products should be brought to their final storage temperature within 24 hours. These underlining facts highlight necessity of pre-cooling. Pre-cooling is essentially required for removing field heat from products, which otherwise destroys product quality.

Shrivelling and loss of fresh appearance are noticeable effects of cooling-delays particularly for commodities that loose water quickly and show visible symptoms even at low levels of water loss, e.g. green leafy vegetables and carrots often loose their crispiness, broccoli and peppers loose their firmness, and green onions loose their texture. In fact, pre-cooling retards rate of losing water from products.

Cooling-delays are not always detrimental, can be indirectly beneficial sometimes; they delay scale development in apples and reduce cracking in carrots. Commodities like peaches, plums, pears and tomatoes are intentionally kept at 16-24 °C after packing to promote ripening. If kept at a relative humidity above 85%, these commodities will actually improve in quality in a controlled ripening process. But they must be cooled after ripening has started to reduce mechanical damage during transportation. Similarly, water loss is not always detrimental. Products like carrots need to lose some turgidity to reduce mechanical damage in handling and fresh-cut processing. In green onions, slight water loss reduces curvature problem.

Following are some reasons for pre-cooling of products, which are essentially required for retarding respiration rate, ripening and transpiration of products.

- Reduction in respiratory activity and degradation by enzymes.
- Reduction in internal water loss and wilting.
- To slow down or inhibit growth of decay-producing micro-organisms.
- Reduction in production of natural ripening agents.
- To provide market flexibility by allowing grower to sell produce at appropriate time.

## 2.9 Packaging

It is required for proper transportation and for maintaining quality of product during storage. Packaging improves aesthetic appearance as well as maintains quality during transportation. Packaging in the present context is the deciding factor for net returns to growers and processors. Good packaging not only increases shelf-life of products but also gives higher income to growers. Packaging should be for attracting attention, reducing storage requirement and lessening loss during transportation (Barmore, 1987). An ideal package of fruits and vegetables should (a) protect fruits from mechanical injury, (b) keep fruits in clean and hygienic manner, (c) serve as an efficient handling unit for the consumer and the producer, (d) be convenient for transportation, (e) serve as a convenient warehouse or storage unit, (f) reduce wastage, (g) provide adequate ventilation to the product to avoid storage and transport loss, (h) have height adjustment in a way that products of lower stack do not get pressed by the upper stack, (i) be attractive and have retailer acceptance, (j) fulfill government rules and regulations, if any and (k) be economical. The outer surface of the package should be easily printable to specify name of the product, company and quantity (Dhillon, 1988).

Chapter 3

# Post-harvest Losses and Control Measures

## 3.1 Introduction

Post-harvest losses of fruits and vegetables are defined as "that weight of wholesome edible product (exclusive of moisture) that is normally consumed by humans and that has been separated from the medium of its immediate growth and production by deliberate human action with the intention of using it for human feeding but which for any reason fails to be consumed by human" (Sudheer and Indira, 2007).

**Physical losses.** Fruits and vegetables with high water content and with relatively thin peel are susceptible to mechanical damage throughout the post-harvest period. Losses due to injury on the product surface are called physical losses. Faulty harvesting, poor handling, unsuitable containers, improper packaging and transportation can easily cause bruising, distortion and other forms of injuries on the surface of the fruits and vegetables. Mechanical damage like bruising or cracking will reduce not only the appeal of the produce but also its potential storage life; directly through enhanced water loss and physiological changes and indirectly through entry of pathogens.

**Physiological losses.** Harvested fruits and vegetables are living, and they continue to respire and transpire. There is utilization of energy reserves through respiration, and changes in biochemical composition and texture and through increased ethylene production associated with ripening of climacteric fruits (Mitra, 2001).

**Biological losses.** These losses are due to growth of pests and insects. Control of post-harvest decay is becoming difficult because the number of pesticides available for control are declining rapidly as regards for food safety concerns of consumers. Presently, emphasis is more on the organic farming. The grave situation of the post-harvest losses can be realized from the findings of the Ministry of Food Processing Industries, Govt of India, that indicates we waste more fruits and vegetables than that are consumed by the UK every year. Post-harvest losses can be considered a social evil, which is eating away grower's margin and is escalating cost of produce for consumers. The losses are mainly due to improper and unscientific handling and packaging followed in India.

The fruit or the vegetable, fresh or ripe, is a valuable commodity as food for the people and as a cash crop for the producer. Though utmost care is taken till harvest, less care and importance has been often given to quantity as well as to quality after harvest. It is not possible to improve produce quality after harvest, but it is possible to slow down rate of undesirable changes. Post-harvest handling system must aim to ensure that the fruit reaches market in the exact condition as is required by the importer; and it is not necessarily be fully ripe ready-to-eat fruit; as some climacteric fruits like avocado, banana, guava, mango, passion-fruit and papaya may be ripened after transportation in a mature but unripe state.

The rate at which changes occur in harvested fruit may be influenced by temperature, humidity and atmospheric composition. All these may be manipulated by careful management of the post-harvest handling system to obtain best possible results (quality and storage life) for the produce.

Harvesting at the proper maturity, employing careful harvesting techniques, proper handling, reducing field heat, adequate transportation, proper packaging and storage can reduce losses to a great extent.

## 3.2 Harvesting of Fruits and Vegetables

The way harvested fruits are handled determines their condition in which they will reach market. Harvesting, therefore, is an important operation in horticultural crops production and any insufficiency during this time may lead to losses of the whole year's work. During harvesting, delicacy of crop, maturity criteria, time and method of harvesting, mode of packaging and transportation, economy of operations and need for harvesting method to fulfill market requirement should be taken into consideration.

### 3.2.1 Harvesting Time

Harvesting of the produce needs to be done during early hours of the day or late in the evening to avoid damage by high temperature. If market is nearby, we can harvest early in the morning, and for distant market, late in the evening harvesting is desirable, so to be transported during night.

### 3.2.2 Method of Harvest

This can have significant impact upon the composition and post-harvest quality of fruits and vegetables. Following are common harvesting methods for fruits and vegetables.

*Manual Harvesting.* It is commonly practised in developing countries like India where knife-and-spade clippers are used for fruit-picking. Most commonly fruits are collected in small holders such as picking aprons, buckets, baskets or bags.

*Mechanical Harvesting.* Mechanical harvesting employs direct contact methods like combing, cutting, pulling, snapping, twisting, stripping and compacting.

Selection of the right type of harvesting tool that reduces damage and impact of high distance falling is one of the critical factors for maintaining shelf-life of fruits and vegetables after harvest. Mechanical aids to harvested vegetables such as lettuce, cauliflower and cabbage involve cutting vegetables and placing them on a conveyor in a mobile packing, which is slowly conveyed across the field. Telescopic type of poles are used for harvesting mangoes or through a person standing on the hydraulic lift-net attached to poles may be used for harvesting mangoes, which can reduce impact shock while harvesting. A prototype hand-held mango harvester is also available. It consists of an adaptation of the commonly used pole with an attachment bag.

## 3.3 Maturity for Harvesting

Maturity is defined as the stage of development of fruits and vegetables that gives their minimum acceptable quality to ultimate consumers. Harvesting maturity is the point at which fruit has reached a minimum level of development such that it has sufficient life to withstand transportation and ripening. Harvesting at the right stage of maturity influences overall quality of products. Depending upon the purpose of the utilization after harvest of the commodities, maturity can be classified into two stages–decided on the stage of the development of the vegetative growth and the stage of utilization by consumers (Moris, 1986).

**Physiological maturity.** Stage in the development of the fruit and the vegetable when maximum growth and maturation has occurred.

**Horticultural maturity.** Stage of development when a plant or a plant part possesses the pre-requisite for utilization by the consumer for a particular purpose.

### 3.3.1 Maturity Indices for Fruits and Vegetables

Maturity index for a commodity is a measurement or measurements that can be used to determine whether a particular commodity is at the right maturity. It depends on the (i) fruit size (ii) position of the fruit on the tree (iii) climate and season (iv) fertilizers and manures (v) soil type (vi) soil moisture (vii) pruning methods and (viii) use of hormones and other chemicals. In spite of all limitations, it is possible still to combine various indices of maturity to assess stage at which commodity may be harvested. Generally, it is decided on the basis of the total soluble solids (TSS) and acid ratio at different stages of development of fruits and vegetables.

*Maturity Indices for Fruits.* Maturity indices are objective and non-destructive; the indices used vary among fruits and often among cultivars within a specific fruit.

**Avocado.** Too immature fruits must be avoided as they tend to be inferior in flavour and texture on subsequent ripening. Depending on size, colour and shape; avocado may be harvested between 140 and180 days after flowering.

**Banana.** Its harvesting is generally decided by its expected end-use and distance of transport before the final consumption. When bananas are to be transported, they are picked slightly immature at about 75 to 80% maturity with plainly visible angles; and they generally ripen in about 3 weeks.

Bananas for inter-island shipment are harvested at about 85 to 90% maturity, when they have attained full development and fruit angles are still well-defined; these fruits ripen from 1 to 2 weeks after harvest. For local or nearby markets more mature fruits are harvested, which ripen in less than a week. For judging maturity, pulp to peel ratio, days from emergence of inflorescence, disappearance of angularity of fingers, drying of leaves, brittleness of floral ends are some of indices used in India. Angularity or fullness of fingers seems to be the standard practice. To determine proper time of harvesting, it is best to supplement "fullness of fingers" with size and number of days it takes from inflorescence to maturity.

**Grapes.** Physical characteristics like texture of pulp, peel colour, easy separation of berries from bunch and development of characteristic flavour and aroma are useful indices.

**Jackfruit.** A dull, hollow sound is produced when the surface of jackfruit is tapped with a finger, the last leaf of the peduncle turns yellow, or yellowish orange, fruit spines become well developed and widespread, and with a moderate pressure, spines yield a typical aromatic odour.

**Citrus.** In India, Coorg mandarins are harvested from December to January, when rind colour changes from green to orange; then the juice has an acidity of 0.4% and TSS 12 to 14%. Sweet-oranges are harvested from September to October, when rind turns yellow; at that time acidity of the juice is 0.3% and TSS is 12%. Further, maturity standards of sweet-oranges are based on the juice yield, TSS and brix-acid ratio. Highest quality characteristics include firmness, good weight for size, skin, fresh colour and skin texture. These vary depending upon the areas of cultivation, variety and season.

The desirable characters of the mandarin group are smooth surface, thin skin, good weight in relation to size, high colour for particular size and freedom from physical damage or decay.

**Lemon.** It is harvested when surface colour is still green; actual colour develops during storage and prolonged transit. Lemons of good quality must be light to medium yellow, firm, smooth-skinned and heavy for their size.

**Limes.** Yellow to slight orange-yellow colour is the right maturity stage for harvesting lime. And fruits must be juicy and acidic (6%).

**Mango.**Four important changes associated with maturity of mangoes are (i) fullness of shoulders (ii) changes in the colour of pedicle (iii) growth of stones and (iv) development of lenticels.

Several growers wait for changes of peel from deep-green to olive-green. Specific gravity measurement is also found a reliable index for deciding right stage of maturity. The gravity between 1.01 and 1.02 is suitable for picking. It may be affected by seed cavity size, rainfall of the area and cultural practices.

Besides, days from flowering to maturity, change in colour, specific gravity, solids to acids/ sugar to solid ratio appear good indices. Starch to acid ratio (4 or more) can be used as an index for maturity in Langra variety; starch 5% at the time of harvest can be a reliable index.

**Papaya.** For papaya as soon as the streaks of yellow appear on the apex or between the ridges, fruit should be removed. It takes around 140 days normally from flowering to harvest. Other indices are TSS of 6% and one-third coloured surface.

**Pineapple.** Its harvesting depends on the ultimate destination or end-use. Fruit for home are picked at 25% yellowing. At this stage, fruits have higher TSS and low acidity. If fruits are for long distance markets, they are usually harvested, when all 'eyes' are still green and have no trace of yellow colour. Then fruits take 2-3 weeks for ripening, which is maintained during transportation period.

*Maturity Indices for Vegetables.* **Tomato.** Its harvesting depends on the purpose for which it is to be used. Three maturity stages generally recognized are: mature-green, pink or breaker red ripe stages. For long distance transport, fruit should be harvested at mature-green stage. In fruits at mature-green stage, pulp surrounding seeds is in jelly-like formation and seeds slip away from the knife.At the breaker stage, blossom ends of the tomatoes turn pinkish or reddish. Fruits for local or nearby markets and for canning should be harvested at pink or ripe stage. For canning, fruits should be medium large, smooth, of uniform rich red flesh, evenly ripened without green shoulders and be possessing large proportion of solid flesh of good flavour. For juice-making, tomatoes should be rich in colour and flavour and should be juicy rather than pulpy.

**Peas.** Fruits must be mature and uniform in size at the time of harvesting. And pods should be well-filled with young and tender peas. Their firmness increases with maturity. Instruments (Tendrometer) are generally used for measuring maturity of peas in the organized farms. With the progress of maturity and size, sugar content decreases rapidly, and starch and protein increases.

**Carrot.** Desirable characteristics of carrot are bright orange colour, absence of fibrous core, and tender, crisp and sweet flavour. For canning, carrots should have a smooth surface and be free from furrows or wrinkles. For freezing, tenderness is the most important character. When intended for use in soups, firm texture needs to be retained during canning.

**Okra.** Its fruits are harvested when pods are still young, tender and exhibiting maximum growth rate. At this stage, pods readily snap when bent. Mature pods are fibrous, tough and unfit for human consumption. Best maturity is decided by breaking tip of the fruit; it should be easily detached from the main part.

**Cabbage.** It matures between 62 and 110 days from field-setting at low elevations and 81 to 125 days at high elevations. Solidity and firmness are useful maturity standards. Colour is also used as an index for deciding maturity.

**Cauliflower.** The best maturity stage is determined by head size and condition. Desirable characteristics are white colour and compact head with smooth surface, tender texture, absence of looseness and with too thick flower-stalk.

**Cucumber.** Slicing cucumber must be medium-sized, dark-green, and immature with small seeds. Most of the varieties harvested are from 16 to 23-cm long.

**Garlic and Onions.** For green onions, harvest the crop at 45-90 days from field-setting, and for bulb variety, it should be from 90 to 150 days. Bulb matures when neck tissues begin to soften and tops are about to abscise and decolourize. Development of red pigment and characteristic pungency of the variety are also important harvest indices for onion. As far as garlic cloves are concerned, they are ready to harvest at 100 to 140 days after field-setting.

## 3.4 Pre-treatment

This is also one of the important links in post-harvest management, which is recommended to reduce rate of respiration and also for retarding process of ripening, and thus helping maintain original quality of products during transport and storage. After sorting and grading, the most important operation is pre-treatment, prior to packaging. It varies depending upon the commodity and the purpose of use. However, pre-cooling is an important pre-treatment in the protocol of any post-harvest management (Baviskar, 1995). There are a number of pre-treatments employed as common practices for fruits and vegetables to increase their shelf-life.

### 3.4.1 Curing

Many root-crops have a cork layer over the surface called periderm. This serves as a protection against the microbial infection and excessive water loss. This layer can be broken or damaged during harvesting and handling operations. So curing is essentially a wound-healing operation to replace damaged periderm, mainly in tuber crops like potato, sweet-potato, yams etc. Curing is also done for onion and garlic for proper colour development and for reduction in moisture content etc. Adequate curing helps maintaining quality of products for later use.

Blowing heated air at 43 to 46°C vertically through a grill on which onions in mesh bags are placed is one of the successful artificial methods of curing.

Curing of root, bulb and tuber vegetables offers effective means for reducing post-harvest decay. The operation is done immediately after harvest and generally performed at the farm. The process involves suberization of outer tissue, followed by development of wounded periderm, which acts as an effective barrier against infection and water loss.

### 3.4.2 Irradiation

It is a modern technique of pre-treatment of fruits and vegetables by the application of light or radiation. Irradiation of food involves controlled application of energy from ionizing radiations such as gamma rays, electrons and X-rays for food preservation. The basic application of irradiation is to maintain product quality in the post-harvest phase, which is accomplished by the following: (i)Inhibition of sprouting; (ii) Longer retention of quality through controlled respiration rate; (iii) Insect control, which ultimately protects product quality; and (iv) Delay in ripening through controlled respiration and ethylene release.

Irradiation involves exposure of food to short-wave energy to achieve extension of shelf-life by delaying ripening and by insect disinfestation and elimination of food-borne pathogens and parasites. In comparison with heat or chemical treatment, irradiation is considered effective and appropriate technology to destroy food-borne pathogens. However, there is a need to standardize quantum of entry of short-wave radiation and its exposure time(Fig. 3.1).

Harvesting
↓
Pre-cooling
↓
Sorting / grading
↓
Short-wave energy application
↓
Packaging
↓
Transportation
↓
Marketing / Storage

**Fig. 3.1** Various unit operations for irradiation process

### 3.4.3 Skin-coating with Waxes

Waxes are generally used for coating fruits and vegetables to improve their appearance, to delay their deterioration by reducing transpiration losses, respiration rate and by delaying ripening process, and thus extending their storage life. Waxes are melted and emulsifiers are added. With addition of hot-water and oil, water emulsions are prepared with continuous agitation.

Wax emulsion without fungicides in the required concentration does not protect fruits and vegetables against microbial spoilage. Hence permissible concentration of fungicides should be incorporated in the wax emulsion prior to wax application or fungicides can also be given as a wash treatment prior to skin-coating. Doses of fungicides with wax-coating are to be standardized, depending upon the types of fruits and their end-uses.

Concentration of wax emulsion required to obtain maximum benefits vary from fruit to fruit; depending upon the skin structure and the stage of harvesting. Fruits and vegetables should be dried prior to waxing, and are waxed by dipping in the emulsion for 30 to 60 seconds, then fruits are removed, allowed to drain, and are dried with the help of a fan or under the shade of a tree. Fruits prior to dipping should be free of dust, dirt and any microbial infection. Emulsions can be reused, are stable up to one year (Fig.3.2).

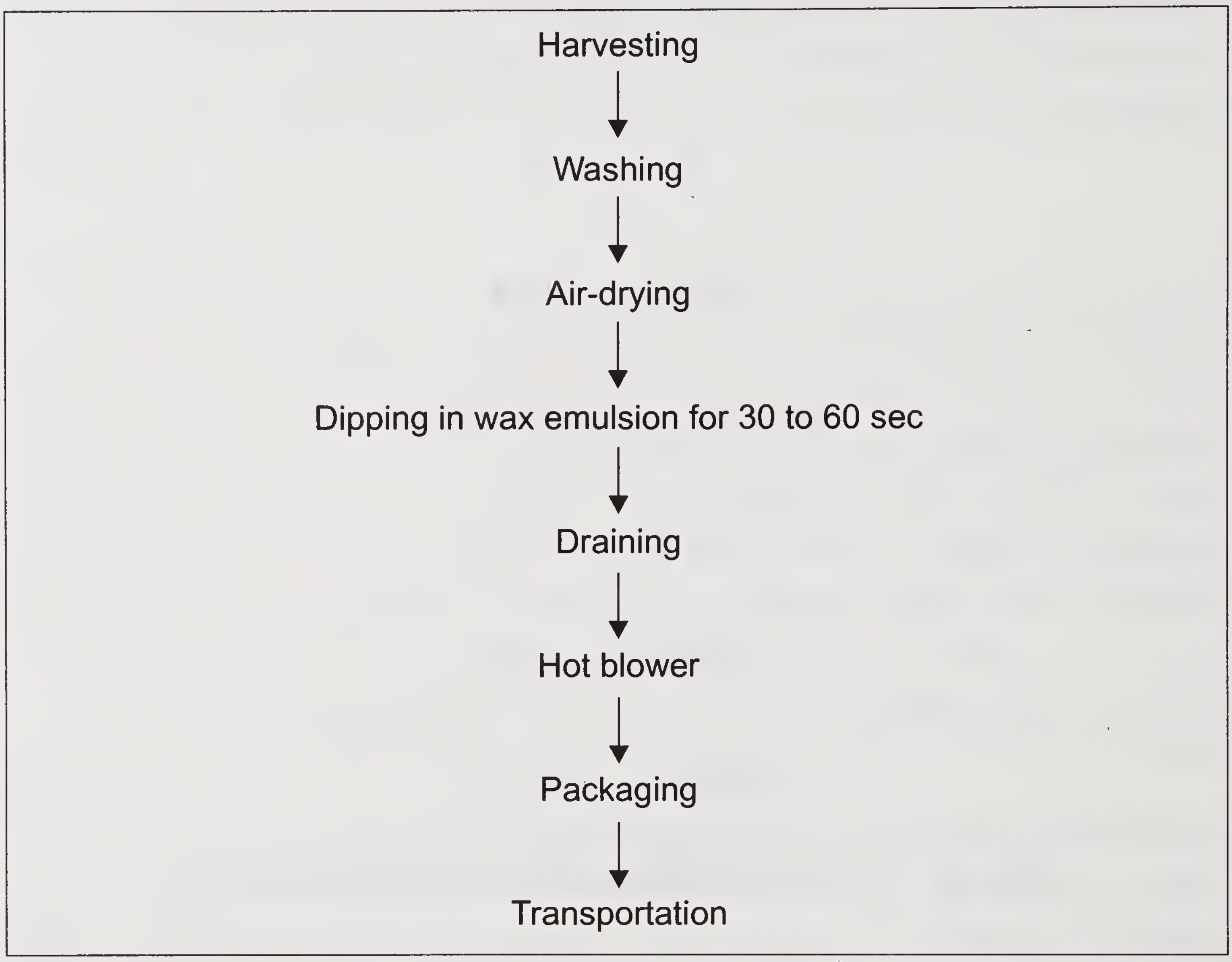


**Fig. 3.2** Steps involved in waxing

### 3.4.4 Inducing or Enhancing Ripening Agents

Harvesting prior to ripening and artificial ripening of fruits and vegetables to be used are commonly followed in our country to avoid post-harvest losses during transit. The ripening rate can be enhanced or induced by smoking treatment or by ethylene application or by growth regulators. To induce uniform ripening of bananas, smoking and ethylene have been used. Growth regulators have been found to accelerate ripening; in apple and apricot by 2, 4, 5-trichlorophenoxy acetic acid (2, 4, 5-T); in banana by 2, 4-T dichlorophenoxy acetic acid (2, 4-D); in apple varieties by naphthalene acetic acid (NAA). As a post-harvest treatment, 1,000-ppm ethephon promotes ripening in tomato, banana and mango.

### 3.4.5 Retarding or Delaying Ripening Agents

These are used to check ripening during transportation. Besides physical factors such as low temperature, higher concentrations of $CO_2$, low $O_2$ concentration and waxing, retarding ripening of fruits can also be achieved by growth inhibitors — maleic hydroxide and methyl esters of naphthalene acetic acid.

### 3.4.6 Pre-cooling Method

It is a rapid cooling process administered in commodities for the removal of field heat. It is to be done immediately after harvest. Pre-cooling reduces respiration rate of the freshly harvested commodities by reducing metabolic activities, and thereby extending shelf-life. In general, pre-cooling reduces: (i) field heat, (ii) respiration rate, (iii) ripening rate, (iv) loss of moisture and (v) ethylene production.

Pre-cooling method is selected based on the nature of the product, value and quantity of the product, cost of labour, equipment and materials, product heat-transfer characteristics, surface to volume ratio of the product and the final processing to be followed.

Success of the pre-cooling depends on: (i) proper time between harvest and pre-cooling; (ii) initial and final product temperature including atmospheric temperature; (iii) accessibility of cooling medium and quantity of produce taken for the process.

## 3.5 Heat Treatment Methods

Heat treatment to certain commodities is mainly to destroy insects and their eggs and for maintaining quality of the produce during storage period. Heat treatment methods are: vapour heat treatment, hot-water dip and spray and hot-air treatment.

Heat treatment is mainly used for slowing down ripening of climacteric fruits and vegetables by reducing respiration rate; sweetening commodities either by increasing sugars or by decreasing acidity, which ultimately gives taste; and preventing storage disorders like superficial scald on apples and chilling injury on subtropical fruits and vegetables, thus increasing shelf-life of products.

### 3.5.1 Vapour Heat Treatment

This is used for insect control. Externally vapours are generated, and heat of vapourization is used to treat products.

Fruits are heated with warm-air saturated with water vapour at temperature between 40°C and 50°C to kill insect eggs and larvae as a quarantine treatment before fresh shipment.

### 3.5.2 Hot Water Dip and Spray

This method is generally used for control of fungal pathogens, spores and latent infections either on the surface or in the first few cell layers under the peel of the fruits or vegetables. It is quite safe for controlling fungal growth in fruits and vegetables. Many fruits and vegetables tolerate hot-water at 50 to 60°C up to 10 minutes but shorter exposure at the temperatures can control many post-harvest plant pathogens. Compounds 'Generally Recognized as Safe' (GRAS) can be applied in hot-water to improve efficiency of anti-fungal action.

### 3.5.3 Hot-Air Treatment

Forced hot-air treatment is used to control both fungal and insect attack and to study commodities' response to high temperature. In this method, LDO or electricity is used for generating hot-air for the treatment. Time of incidence with hot-air is a critical factor for the success of the treatment. Hot-air can be applied by placing fruits or vegetables in the heated chamber with a ventilating fan or by applying forced hot-air, during which speed of the air circulation is precisely controlled. This method heats slowly than hot-water or vapour heat, although forced hot-air will produce heat faster than a regular heating chamber. Controlling temperature of hot-air and incident time of exposure are two critical factors for maximizing efficiency of the process.

Chapter 4

# Packaging Technology

## 4.1 Introduction

Packaging is one of the important unit operations recommended for raw, processed or value-added products for increasing their shelf-life and maintaining their essential quality. It has become an essential part of the value-chain analysis for food safety, organoleptic characteristics, agro-economics and easy transportation. Packaging is of importance for the final choice of the consumer, as it directly involves convenience, appeal, information, branding and also helps maintaining quality of the product for use. Ultimate use of packaging is for providing best quality products to users and fetching higher returns to growers (Sagar and Maini, 1997).

Packaging is for : (i) assembling produce in convenient units for handling, storage, transportation and marketing; (ii) protecting produce during handling, transportation, storage and marketing and maintaining its quality for end-use; (iii) providing information to users regarding quality and quantity of products.

## 4.2 Packaging Requirement

(a) Package must have sufficient mechanical strength to protect contents during handling, transportation, storage and stacking one over other, so that they do not lose their original state. The basic idea of packaging is for maintaining product quality; (b) It must meet handling and marketing requirements in terms of size, shape and weight in accordance with the international standards. The current trend is to avoid too many sizes and shapes of packages. Pelletization and mechanical handling makes standardization essential for economic operation. To maintain quality, material density should be enhanced during transition as dense materials save cost of storage and transportation; (c) Packaging material must not contain any toxic chemicals that can transfer or produce toxin in human-beings or deteriorate product quality during transportation. Further, material of construction of packaging material should retain quality of product during storage; (d) Packaging should be such that it allows rapid cooling of the contents to maintain quality of the product. It should be stable to moisture, high humidity and high air-flow rate, thereby, enhancing shelf-life; (e) Packages should be stackable and interlockable and should permit permissible limit for stacking one over other. (f) The package should be re-usable or recyclable for easy disposability and it should not pollute environment after use. It should permit three 'R' i.e. reduce, recycle and reuse; (g) The packages should provide adequate ventilation to store product in good conditions; (h) The package should be of suitable standard depending on the market value of the commodity and for better returns.

## 4.3 Advantages of Packaging

Packaging provides a beneficial modified micro-environment that not only maintains quality of the product during transit but also gives more value to products of growers, and that also finally helps in the following.

- Minimizing post-harvest losses by protecting against mechanical damage, microbes, pests, dust, dirt, moisture loss, pilferage etc.
- Efficient handling during transit and marketing for better returns. It also saves cost of transportation and storage.
- Giving better appeal to promote sale and adoption.
- Providing hygienic conditions within the package.
- Enhancing marketing distance and time for better returns.
- Protecting nutritive quality during transit and marketing.
- Preventing contamination by other commodities during handling, transportation and marketing.
- Providing information of the contents to users through labelling — quality and quantity of product, content, expiry date etc.
- Ready-to-use facility for easy transportation and marketing, hence more returns.

## 4.4 Packaging Material Classification

They are classified on the basis of the materials being used by the traders in the past; the present configuration involved for the efficient packaging, and the packaging for the specialized job. Classification is as on the basis of the traditional materials, recent materials and specialized materials (Thakur and Lal, 1989).

### 4.4.1 Traditional Packaging Materials

*Natural Materials*. These include baskets and other traditional containers made from bamboo, palm-leaves, straw and other agricultural and forest materials, available locally . The characteristic features of such containers are as follows.

- Labour cost and raw material cost involved in making them is low, and they provide good ventilation, thus longer life.
- They are locally available.
- Technique involved in making package is simple and is efficient in use.
- They are eco-friendly and do not contribute to pollution.

*Natural and Synthetic Fibres.* These include packaging materials made from jute or cotton or woven plastic or paper; sacks are inexpensive and readily available; moreover they are reusable and have good load-bearing capacity.

*Wood.* Soft-wood planks can be assembled into wooden-boxes of required dimensions, generally known as wooden-crates. If they require cushioning, coir-rope can be woven outside crates, they are known then wire-bound veneers. It is recommended to use soft-wood available in the local market, which should not disturb ecology.

### 4.4.2 Advanced Packaging Materials

*Corrugated Fibre-board (CFB) Boxes/Cartons/Cases.* They are also known as cardboard or fibre-board or pasteboard boxes. The CFB is made from a layer of corrugated fibre-board sandwiched between two additional layers of fibre-boards. Technology involved in manufacturing corrugated fibre-board is economically viable, environment friendly and is socially acceptable for long distant transportation and storage. The characteristic features of the material are: (i) it is the most acceptable packaging material for handling agriculture, horticulture and floriculture products; (ii) is lightweight (20 to 25% lighter as compared to the wooden-box of the similar size) and is cleaner, thus an eco-friendly option; (iii) has excellent cushioning property and smooth non-abrasive surface, which protects products efficiently during transportation and storage; (iv) is cheap, reusable and recyclable; (v) has excellent printability and thus permits better labelling; (vi) is easy to stack for storage and even in transportation, thus saves cost; (vii) is available in wide range of sizes, designs and strengths as per the capacity desired with no extra cost involved, since it can be prepared locally.

*Plastic Crates.* These are mostly moulded from high-density polyethylene sheets (HDPE). This packaging material has following advantages.

- It is strong, rigid and permits concept of reuse and recycle, hence more in demand.
- It is easy to clean, keeps materials always in presentable form, and is environment friendly.
- In it ventilation is good and provides more life and better quality to products.

- It can be stacked when filled and nested when empty. Thus, saves space and money.

*Moulded Trays*. These may be moulded from paper pulp or plastic, and are suitable for packaging individual fruits and vegetables as per the required size and shape.

*Paper Pulp Moulded Trays*. They are made from recycled paper or pulp with starch binder, and, therefore, are less expensive. They absorb surface moisture from the product so are good for small fruits and berries which are easily damaged by water. This increases shelf-life during transportation. Cost of transportation through their use is comparatively less.

*Thermoformed Plastic Trays.:* These are made from thermoplastics, which can be softened by heating and hardened by cooling. They can be regarded as derivatives of ethylene. They are also known as vinyl plastics, which contain chlorine or fluorine or phenyl groups. These trays permit rigid packaging, thus are better for fully ripened fruits; produce is immobilized within the pack, thereby damage is less during transit; they are suitable for microwave cooking without loss of vitamins; and they are recyclable in nature.

*Plastic Film Bags*. Polyethylene and polypropylene bags are mainly used as packaging materials. They have following characteristics (i) low cost of handling, including stitching and replacement; (ii) are used for consumer size packs in fruits and vegetables marketing; (iii) retain water vapour, and hence maintain quality of product; (iv) permit ink written labelling and branding; (v) can create/maintain modified atmosphere inside the package that helps extend storage life of the commodities.

*Plastic Boxes*. These are ideal for consumer packs and have good sale appeal. They are rigid containers most suitable for packaging soft and delicate commodities. They can be fabricated into different shapes and sizes to suit requirements of growers, traders and middle-men.

*Net or Mesh Bags*. These are for packing fruits like apple, citrus, guava, sapota and vegetables like onion, potato etc. They have the following features: (i) they are sturdy in nature and are locally available; (ii) are of low cost in original purchase and replacement; (iii) have uninhibited airflow and thus extend shelf-life of the products; (iv) their manufacturing technology and use is simple and cheaper; (v) their display is attractive, which accelerates purchase.

*Sleeve Packs*. Heat shrinkable film of 1.5- to 2- mm thickness is used for manufacturing sleeve packs. Some of the features of these are: immobilization of the packed fruits; their manufacturing technology is simple; superior visibility gives them good sale appeal; their cost is low in original purchase and replacement; their protective qualities are better, hence increased shelf-life.

### 4.4.3 Specialized Materials

*Cling Films.* Polyethylene films of 15 microns thickness are used for manufacturing cling films. Some of the features that make them ideal packaging material are: low water vapour transmission rate, high gas permeability, intimate package with individual produce of varying sizes, produce remains fresh, dust- and insect- free; self-sealing-type films are commercially available at the reasonable cost.

*Shrink Films or Stretch Films.* In manufacturing them, plastic-like polyethylene, polystyrene, polyvinyl chloride, polyester and rubber hydrochloride are used; these plastics have heat-shrinkable nature. By stretching film under controlled temperature and tension, film wrapped over produce stretches and then contracts by cooling.

## 4.5 Active Packaging

It is an innovative approach of food preservation, which is simple, convenient and efficient in use. Active packaging is a group of technologies in which package is active and is actively involved with food products or interacts with the internal atmosphere to extend shelf-life while maintaining quality and safety. This packaging, sometimes referred to as 'interactive' or 'smart' packaging, is intended to sense internal or external environmental changes and then responds by changing its own properties or attributes (Brody, 2006).

### 4.5.1 Potential Technologies for Active Packaging

There are a number of potential technologies used in active packaging such as oxygen scavenging, anti-microbial packaging, and ethylene and moisture control, which ultimately check respiration rate during transportation and storage and delay ripening process, hence produce has a longer shelf-life (Holley, 2005).

*Oxygen Scavenging.* Most important objective of active packaging is removal of oxygen using absorption, interception and scavenging. The most widely researched and patented area is the use of oxygen absorbing systems. This ultimately checks respiration rate, hence increases shelf-life of the product. In this method, containers are so designed that they absorb oxygen of the enclosure, and thus retard respiration process.

*Anti-microbial Packaging.* Active packaging system comprising incorporation of anti-microbial agents into polymer-surface coatings and surface attachments can be of immense value. Most publicised anti-microbial agents are silver salts on zeolite incorporated in plastic films or sheets or on the material surfaces and into absorbent pads for fresh meal and produce. This method helps in checking microbial counts and hence promote longer shelf-life. At the international market, products free from microbial contamination have high value.

*Ethylene Control.* Ethylene accelerates ripening in fruits, followed by senescence. Removal of ethylene from the plant environment can significantly retard post-harvest catabolic activity in the fresh produce, modify atmosphere for preservation process and retard ripening, thus promoting longer shelf-life. Active packaging permits containers that control ethylene.

*Moisture Control.* It is one of the most important methods for packaging products for later use. It is a prime step in transportation of product so that respiration and ripening stage can be checked. Since metabolism of fats and carbohydrates produce water, condensation or sweating is a problem in many kinds of packaged foods, particularly fresh fruits and vegetables and minimally processed and prepared foods. Use of humectants between two highly permeable layers of plastic film has been found to buffer humidity inside the food package. Moisture control yields protection to product during handling, transit and storage (Rameshwar, 1988).

*Gas Permeability Control.* **$O_2$ control method**. There are two common methods employed: $O_2$ control and $CO_2$ control. Recently, package material designers have developed high oxygen permeable packaging material, which helps extending shelf-life. $O_2$ permeation rates of 18.06 in % $m^2$/day and $CO_2$ permeation rates of 7.74 in % $m^2$/day are achievable and effective at various controllable ratios for high respiration rate of fresh produces such as broccoli, mushroom, asparagus and strawberry.

**$CO_2$ control**. It is a complementary approach to control factors responsible for deterioration of product. A mixture of iron powder and $Ca(OH)_2$ in sachet, which scavenges both $O_2$ and $CO_2$, has been used to package fresh ground-coffee in flexible bags.

Chapter 5

# Storage of Horticultural Crops

## 5.1 Introduction

Fruits and vegetables are rich in many nutrients that are important for our daily life. But a substantial quantity of them are lost due to lack of storage facilities. Hence, proper storage of fruits and vegetables is important after harvest (Mehta and Bajaj, 1983). Need-based storage minimizes post-harvest losses during bulk production; extends period of availability of a wide range of fruits round-the-year; stabilizes market by meeting demand and controlling fluctuation rate; besides controls respiration, transpiration, ripening, and any undesirable biochemical changes and disease infection.

## 5.2 Storage Methods

Various storage methods are: cold storage, controlled atmosphere storage, modified atmosphere storage, hypobaric storage system or low pressure storage and low-cost storage.

### 5.2.1 Cold Storage

Choice of methods depends on the type of products available (quality- and quantity- wise), duration of storage required, cost of storage involved and climatic conditions of the place where storage is made. Fruits and vegetables after harvesting continue to respire at the expense of the stored food material, which depending upon the rate of metabolism, declines or accelerates ageing, as is evidenced by shrivelling accompanied by changes in texture, flavour and quality. Fruits and vegetables respire and lose heat and moisture through natural pores in the skin. Removal of heat from freshly harvested commodities without quality loss is the most desired method for extending storage life of perishables, which is accomplished by washing them in cold water at the production site —that is for removal of the field heat. After removal of the heat, adequate size of cold storage is required. Storage life of freshly harvested commodities is governed by the following.

- Prevailing climate (temperature, relative humidity and air-flow rate) and cultural practices of the region.

- Variety and stage of maturity at harvesting.
- Quantity of product available during harvesting season.
- Incidence of infection at the time of harvesting and type of crops and their susceptibility to climate.
- Methods of picking, harvesting, transportation, handling and the extent of damage prior to storage.
- Time lag between the harvest of the commodity and its subsequent storage.
- Rate of cooling of products, which greatly varies as per climatic conditions and types of crops.
- Storage temperature and relative humidity required and prevailing in the harvesting season.
- Rate of accumulation of $CO_2$ concentration inside the refrigerated storage chamber, which ultimately affects shelf-life of the products.
- Air distribution system in the refrigerated cold room, which helps in maintaining quality of products.
- Post-harvest treatments, size of package, quantity per package, ventilation/air circulation inside the refrigerated storage are important for storage life.
- Sanitary conditions inside the refrigerated storage rooms may affect expected outcome.
- Total cost involved in storage and processing.

Cold storage is one of the widely adopted methods for bulk handling of perishable products between production and marketing or processing. Maintaining adequately low temperature is critical, otherwise it will cause chilling injury to the produce. Further, relative humidity of the store-room should be kept as high as 80 – 90% for most of the perishable products; below or above which has detrimental effects on the keeping quality of the produce.

### 5.2.2 Controlled Atmosphere Storage

This is defined as an atmosphere in which oxygen is brought down at the low level and carbon dioxide is at the high level; created by the natural respiration of the packed commodities or by artificial means. These gases are controlled by the sequence of measurements and corrections throughout the storage period, depending upon the type of the fruits and vegetables in storage (Kader, 1980).

As this method involves control of $O_2$ and $CO_2$ around the immediate surface of the commodity and within the fresh fruits and vegetables, there is reduction in the respiration rate of the commodity (Bhowmik and Pan, 1992). The levels of these gases are maintained by constant monitoring and adjustment within the gas-tight stores or containers. Owing to respiration, gas levels constantly change and they are adjusted to the predetermined level by introducing fresh gas or nitrogen (Kader, 2004).

### 5.2.3 Modified Atmosphere Storage

It is defined as the introduction of an atmosphere other than air into a food package without further modification or control and flushing into the product enclosure. The mixture is maintained throughout the storage life and no further measurement or control is required. In modified atmosphere packaging or modified atmosphere storage(MAS), a fruit or a vegetable is enclosed in a sealed plastic film, which is permeable to respiratory gases. Within the package, gases will change, thus, producing lower concentration of $O_2$ and higher concentration of $CO_2$ than that in the fresh air, and thus retard ripening. The MAS is the development of the modified atmosphere around the product through permeable polymeric films. It is an inexpensive method compared to controlled atmosphere storage. In MA storage, there is an alteration in the composition of gases in and around the fresh produce by respiration and transpiration, when such commodities are sealed in plastic films. These films restrict accumulation and transmission of respiratory gases, and result in the accumulation of $CO_2$ and depletion of $O_2$ around the produce that increases storage life. This method is used for products that have high commercial value and require constant attention during transit and storage for higher returns.

Atmosphere inside the sealed plastic film bag depends on the characteristics of the package material used, inside environment and respiration rate of the produce. Changes in the gas content may take some time to reach equilibrium, and speed of atmosphere changes can be accelerated by flushing with $N_2$ to reduce $O_2$ rapidly or with an appropriate mixture of $CO_2$, $O_2$ and $N_2$ or pack can be connected to a vacuum pump to remove air so that respiratory gases change fast within the pack (Zagroy and Kader, 1988).

*Advantages.* Retardation of maturation, ripening and senescence during storage by arresting respiration.

- Alleviation or control of chilling injury, especially due to low temperature.
- Reduces incidence and severity of disease-causing organisms—fungi, bacteria, insects and pests.
- Reduces incidence of physiological disorders and other defects.
- Reduces sensitivity to ethylene.
- Modified atmosphere and controlled atmosphere with an oxygen

concentration less than or equal to 1.0% and carbon-dioxide concentration more than or equal to 5% have insecticidal and fungi static effects.

### 5.2.4 Hypobaric Storage System or Low Pressure Storage

In this, storage chamber is placed under low pressure through vacuum application. Reduction in pressure decreases partial pressure of $O_2$ and its availability to produce. The reduction in the partial pressure of $O_2$ is proportional to the reduction in pressure. As the produce in the hypobaric storage is constantly respiring, atmosphere within the store should be constantly monitored. A vacuum pump is used for evacuating air, and stored atmosphere is constantly replenished from outside air. Air inlet and air evacuation are balanced to achieve required low pressure.

*Advantages.* $O_2$ level in the store can be accurately and easily achieved by simply measuring pressure inside the store with a vacuum gauge, which reduces cost of operation.

- Constant removal of ethylene gas from the store is also achieved, which checks ripening of stored fruits and vegetables.

### 5.2.5 Low-cost Storage

Refrigerated storage which is the best method for storing fruits and vegetables in fresh form is energy-intensive and also involves huge capital. A low-cost option to maintain lower temperature in an enclosed chamber has been a matter of prime importance. Evaporative cool storage or zero energy cool chamber is one such alternative system that is being explored. This is not only a cheaper option but is an effective one also for most of the fruits and vegetables.

Zero energy cool chambers are made of cheap quality porous bricks and river-bed sand and are well-designed structurally. In the evaporative cooling, a part or a whole of heat of the moist air is converted into latent heat, thereby producing lower temperature.

In zero energy cool chamber, fruits can be stored up to 10 days with acceptable minimum rotting and quality loss, as against 5 days at the room temperature, thereby doubling shelf-life of fruits and vegetables (Anonymous, 1985).

It is alternative to refrigerated cold storage to meet short-term storage needs at the farm level, especially during summer, when temperature is generally very high and relative humidity (RH) is relatively low, and heavy weight loss due to transpiration from freshly harvested produce is also high. These structures at the field level maintain high RH (80-90%) with temperature close to wet bulb and, therefore, drastically reduce weight losses as compared to storage at the ambient conditions.

*Advantages.* It is a low-cost, eco-friendly storage, as it does not require any conventional fuel for operation.

- It is installed at the farm level; the field heat from products can be removed immediately after harvest.
- Product shelf-life increases to double in such a system, hence enough time is at hand to decide marketing destination of the produce.
- Method of installation is simple and is made from locally available materials.
- The method is promising for bulk material and is an immediate mean for minimizing post-harvest losses.

Chapter 6

# Transportation System

## 6.1 Introduction

Maintaining quality of the produce during transit is a prime requirement in this present era of processing and value-addition. Therefore, adequate provision for transporting material from field to processing unit or market for sale is vital. An economical transportation system that is simple to use and with low cost of operation is required.

## 6.2 Distribution Patterns

Transportation method is one of the determining factors for choosing packaging. Each distribution mode — road transport, rail transport, and air transport and ship transport— has its own characteristics with respect to the available technology and constraints on the packaging of goods.

### 6.2.1 Road Transport

Method of loading and storage, whether loose or unitized, is important in maintaining produce quality during road transport. Principal hazards in road transport are vibrations —repetitive shock-and -bouncing of the packages. Vibrations are due to loading and suspension system characteristics of the vehicle and also due to road conditions. Older vehicle, accidents and traffic jams can be causes for losses of produce during transit. Cost of road transport is gradually increasing on account of rising prices of petroleum products. And there is likelihood of mechanical and climatic damages to products during road transit.

### 6.2.2 Air Transport

It is an expensive method and provides poor temperature control compared to refrigerated land and sea transport methods, but it provides comparatively shorter transit time. It is mainly used for transporting highly perishable and valuable commodities to distant domestic and export markets. And is often used for early season cherries, strawberries and some of the tropical fruits. Compared to the other modes of transport, air transport is less hazardous. Any damage to the produce in the transport is due to associated ground operations and rough handling. Besides, the damage is owing to high frequency vibrations from air-craft engines and low temperature and low pressure associated with flying at relatively higher altitudes in unheated and unpressurised cabins. Transportation of bulk material is one of the major constraints in air transport.

### 6.2.3 Sea Transport

Major transport of the perishables in the international trade is by sea. The produce is normally stacked up to 6-10 m in height, and is subjected to low frequency vibrations from engine and propellers. Pitching and rolling of the vessels result in appreciable stress, particularly at the lower level of the Cargo. In ship transport, temperature and air refreshment control is required due to length of the time involved. The produce is pre-cooled to a desired temperature before loading into the ship. Sea transportation is generally preferred for long distance transportation and for products having longer shelf-life such as garlic, onion, ginger, potato. The methods of sea transport include: ambient sea transportation, refrigerated break bulk, refrigerated containers, modified atmosphere and hypobaric containers (Smit, 1987).

### 6.2.4 Rail Transport

Efficient rail transportation can be achieved by linking rail terminals to major produce markets and also to fruits-and-vegetables packing stations. This allows direct transfer of produce from packing or buying point to transportation system. Both unrefrigerated and refrigerated systems can be used for rail transportation of perishable products like leafy greens and potatoes. Various factors considered important for different transportation systems are given in Table 6.1.

**Table 6.1** Factors to be considered for selecting appropriate transport facility

| Factors | Recommendations |
|---|---|
| Long distance transport | Use rigid containers to protect better commodities quality-wise. They do not break easily and protect produce from injuries |
| Heat build-up and gas concentration | Arrange containers to allow air circulation freely on the pallets or on the containers. This prevents overheating of commodities and allows free exchange of gas between commodity and environment |
| Use of traditional | Use newspaper/dried leaves or paddy straw to line |

(*Continued*)

**Table 6.1** (*Concluded*)

| Factors | Recommendations |
|---|---|
| containers such as bamboo-baskets etc. | sides and bottom to protect commodities from injuries owing to sharp edges |
| Under-packed and over-packed commodities | Ensure that commodities are not under-packed or over-packed. Under-packing results in damage due to vibrations and over-packing results compression |
| Control of respiration and transpiration | Transport commodities preferably at dawn or at night when temperature is low. This inhibits fast respiration and water loss from products |
| Up-and-down movement of containers inside vehicles | Use vehicles with good shock-absorber |
| Space for ventilation in vehicles | Allow space between cover/ top of truck and produce for ventilation |
| To reflect heat of sun during day transport | Paint canvas/roof of truck with white colour |
| Use of deep containers | Avoid using deep containers since produce at the bottom will be compressed |
| Placement of fragile materials inside the vehicle | Load fragile materials near the centre of the vehicle where vibrations are lesser compared to front and rear ends of the vehicle |
| Cost of transportation | Select transportation means depending on the value of the products and distance of travel |
| Simple in operation | Use transportation means according to local conditions and value of products |
| Techno-economic feasibility of transportation | The transportation means must be simple in use and locally available<br>— It should not destroy quality of products during transit<br>— It must transport at a reasonable cost and at a faster rate |

Chapter 7

# Preservation of Fruits and Vegetables

## 7.1 Introduction

Fresh horticultural produce is diverse in morpholgical structure, in composition, and in general physiology. All fresh commodities are high in water content and can be subjected to desiccation and mechanical injury. They are also susceptible to attack by bacteria and fungi. Magnitude of post-harvest losses estimated for fresh fruits and vegetables range from 5 to 25% in the developed countries and 20-50% in developing countries.

In India, about 50% of the total fruits and vegetables produced annually are lost due to poor post-harvest practices. Reduction in post-harvest losses is complementary means for increasing production and also reducing cost on preventing losses after harvest. Therefore, foods are being preserved using various methods during transport and storage, thus increasing shelf-life and promoting health. Food preservation is defined as the science which deals with the process of preventing decay or spoilage of food to be stored in a fit condition for future use. Foods are preserved for the following reasons.

- Making seasonal food available throughout the year or making food available for later use other than its usual season.
- Adding variety to diet and maintaining quality.
- Increasing shelf-life of food, thus increasing supply and also more returns to growers.
- Stabilizing prices of food by meeting gap between demand and supply.
- Saving time by reducing preparation time and energy.
- Improving nutrition of population by maintaining and boosting quality of product.

With increased industrialization, mechanization and education, standards of living of people have risen, and they demand better food quality. And the high quality foods in greatest demand are the ones that are highly perishables. Fortunately, most perishable foods can be made stable and acceptable by judicious application of food-preservation technologies. Food preservation improves food supply. With perhaps only 15% of world's population regularly consuming preserved foods as important components in the diets, potential for the growth of the food-preservation industry is enormous.

Basic principle of food processing is to combine all forms of physical processes into a small number of basic operations, which are called unit operations. These processes may appear diverse but careful analysis will show that these complicated and different processes can be broken down into unit operations, example e.g., baking of bread, freezing of meat, tempering of oils etc.

In the process engineering, prime consideration is on the extent of heating or cooling that is required, and then on the conditions under which it is to be accomplished. This physical process qualifies to be called as a unit operation and includes material handling, cleaning, separating, disintegrating, pumping, mixing, heat exchanging (heating and cooling), evaporation, drying, forming, packaging, controlling and energy conservation.

## 7.2 Nature of Food

Most of the fruits and vegetables are perishables. In a good season, there may be a local glut, particularly of fruits, but owing to insufficient transport facilities, lack of good roads and poor availability of packing materials, surplus is not delivered quickly to natural markets in urban areas. Moreover, the surplus often cannot be stored for off-season sale because of inadequate local cold-storage facilities. Thus, cultivators do not get good remuneration for the produce either because of glut or due to spoilage

### 7.2.1 Perishable Foods

They deteriorate quickly after harvesting; and include tomatoes, mangoes, papayas, peaches, plums and other juicy fruits, and some juicy vegetables such as cucumber, snake-gourd, bittergourd. These foodstuffs have high moisture content and are susceptible to spoilage.

### 7.2.2 Semi-perishable Foods

They have comparatively lesser moisture, and include beetroots, carrots, peas, green-beans, pumpkins and apples. Roots, vegetables and eggs contain certain natural inhibitors to spoilage. Pasteurized milk, smoked fish and pickled vegetables need mild preservation resulting them to have tolerance to environmental conditions during distribution and handling. Some of the foods are made shelf-stable by canning or by reduction in moisture content.

### 7.2.3 Non-perishable Foods

They have very low moisture content and include mature foodgrains, cereals, pulses and nuts and are not much susceptible to spoilage by microorganisms and enzymes. Their shelf-life is more as compared to perishable and semi-perishable foods, and they do not require any expensive storage.

## 7.3 Food Sources

Food is primarily composed of carbohydrates, fats, water and/or proteins that can be eaten or drunk for nutrition or pleasure. Items considered for food may be obtained from plants, animals or other categories such as fungi and fermented products like alcohol. Almost all foods are of plant and animal origin.

Other foods include various edible fungi, including mushrooms. Fungi and ambient bacteria are used in the preparation of fermented and pickled foods such as leavened bread, wine, beer, cheese, pickles and yoghurt. Many eat seaweeds such as spirulina as food, which is a blue-green alga (cyanobacteria).

### 7.3.1 Foods of Plant Origin

Many plants are eaten as food (Table7.1). There are around 2,000 plant species which are cultivated for food. Vegetables are eaten as food, and they include root vegetables (such as radish and carrots), leafy vegetables (such as spinach and lettuce), stem vegetables (such as bamboo-shoots and asparagus) and inflorescence vegetables (such as globe-artichoke and broccoli); many herbs and spices have high flavour. Onions represent an important class of bulbs grown as food. Members of cabbage family including cauliflower, kale, collards are widely eaten. Turnips, rutabaga, radish and beets are biennial plants. They are storehouse of rich supplies of carbohydrates in their roots. In general, fruits usually mean tree-fruits or berries (apple, pear, peach, citrus, strawberries, blue-berries, gooseberries, currants, blackberries and raspberries, plums, cherries apricots).

## 7.4 Food Preservation Scope

Fruits and vegetables are important supplements in human diet. There is a world-wide demand for high quality foods, which are fresh, tasty and nutritious. This has created a considerable interest for the development of new or improved post-harvest storage and processing techniques for fruits and vegetables. Competition for markets which has resulted in more liberalized trade requires much greater emphasis on efficient-and-effective post-handling, processing and distribution.

**Table 7.1** Typical composition of foods of plant origin

| Food | Composition—Edible portion (%) | | | | |
|---|---|---|---|---|---|
| | Carbo-hydrate | Protein | Fat | Ash | Water |
| ***Underground vegetables*** | | | | | |
| Potatoes | 18.9 | 2.0 | 0.1 | 1.0 | 78.0 |
| Sweet-potatoes | 27.3 | 1.3 | 0.4 | 1.0 | 70.0 |
| ***Vegetables*** | | | | | |
| Carrot | 9.1 | 1.1 | 0.2 | 1.0 | 88.6 |
| Radish | 4.2 | 1.1 | 0.1 | 0.9 | 93.7 |
| Asparagus | 4.1 | 2.1 | 0.2 | 0.7 | 92.9 |
| Beans, snap, green | 7.6 | 2.4 | 0.2 | 0.7 | 89.1 |
| peas, fresh | 17.0 | 6.7 | 0.4 | 0.9 | 75.0 |
| lettuce | 2.8 | 1.3 | 0.2 | 0.9 | 94.8 |
| ***Fruits*** | | | | | |
| Banana | 24.0 | 1.3 | 0.4 | 0.8 | 73.5 |
| Orange | 11.0 | 0.9 | 0.2 | 0.5 | 87.1 |
| Apple | 15.0 | 0.3 | 0.4 | 0.3 | 84.0 |
| Strawberries | 8.3 | 0.8 | 0.5 | 0.5 | 89.9 |
| Melon | 6.0 | 0.6 | 0.2 | 0.4 | 92.8 |

**Source:** FAO, 2005.

Traditional food-processing technologies such as freezing and canning are no longer leading consumer demand. Although, these methods had contributed to improved availability and safety in the past, conventional heating and cooling involved in these reduce many quality attributes of the foods. Consumers are at present much aware and demand for fresher and safer products around the globe.

In spite of the large amount of production, utilization of produce is low; 20-30% of the produce is wasted because of spoilage due to insufficient transport facilities, improper road conditions and poor availability of packaging materials. And so the surplus produce cannot be taken quickly enough to natural markets in urban areas; and it cannot also be stored for sale in the off-season because of inadequate local cold storage facilities.

Spoilage during glut at the producing centres can be prevented by converting them into new categories of processed products. And in view of the globalization of Indian economy, there is ample scope for export of agricultural commodities, in general, and processed foods, in particular. With increasing urbanization, rise in lower and middle class purchasing power and changes in food habits, there is an increasing demand for factory-made jams, jellies, fruit-beverages, dehydrated foods and pickles in the domestic market as well. And considerable demand is for mangoes (fresh and canned), fruit-juices and salted-cashews; that are good source for foreign exchange.

### 7.4.1 Post-harvest Losses of Fruits and Vegetables

There have been considerable post-harvest losses of fruits and vegetables (Table 7.2).

Careless and improper handling of fruits and vegetables reduces their value and storing quality, ultimately causing enormous losses and depriving rightful benefits to growers and consumers. At present, more than 50% of the fruits and vegetables valued at ₹ 67,500 million are reported to go waste annually, and by converting them into new categories of proposed products, there will be a saving of ₹ 6,750 million.

Two promising approaches can be adopted for reducing losses. One is creation/expansion of cold-storage facilities in the fruits and vegetables producing regions and also in the major urban consumption centres to ensure supply of fresh fruits and vegetables throughout the year. And another is to process fruits and vegetables into a variety of products for a long-time preservation.

At present, fruits and vegetables preservation industry in India is able to tap only less than 2% of the total production into canned fruits, juices and beverages, squashes, pulps, jams and jellies, pickles and chutneys as against 40-60% in the developed countries. Preservation and processing of produce is primarily for extending consumption period, for value-addition and also for diversification to range of products suiting to consumers' preferences. The basic preserving processes are

**Table 7.2** Post-harvest losses of fruits and vegetables in India

| Fruit/vegetable | Estimated losses (%) |
|---|---|
| Grape | 27 |
| Banana | 20-50 |
| Apple | 14 |
| Orange | 20-45 |
| Lemon | 20-55 |
| Papaya | 40-60 |
| Potato | 5-40 |
| Tomato | 5-50 |
| Onion | 16-35 |
| Cauliflower | 49 |
| Cabbage | 37 |

canning, freezing, dehydration, salting, pickling and freeze-drying. Advanced technologies of processing have a great potential to expand farm produce market beyond region and country by converting perishable produce into stable forms. Processing can change horticulture produce into new and more usable forms, which can offer convenience and linkage to consumers at large(Table 7.3).

**Table 7.3** Fruits' and vegetables' value-added products

| Fruits/Vegetables | Products |
|---|---|
| ***Fruits*** | |
| *Aonla* | Preserve, Jam, Candy, Syrup, Pickle, *Murabba, Chutney*, Dried shreds, *Triphla, Chyawanprash,* Sauce, Nectar, Toffee, *Churan* |
| Guava | Jelly, Cheese, Toffee, Nectar, Canned-guava, Squash, vinegar |
| Mango | Juice, RTS, Nectar, Squash, Jam, Preserve, Toffee, *Amchur, Chutney*, Fruitbar, Beverages |
| Pineapple | Canned pineapple, Juice, Squash, Syrup, Jam, Candy |
| Banana | Canned banana, Dried banana, Toffee, Banana-chips, Beverage |
| Pomegranate | Juice, Squash, Syrup, *Anardana* (dried product) |
| Papaya | Jam, Candy, Nectar, Pickle, Sauce, Canned papaya, Papain |
| Grape | Wine, Juice, Raisin, *Manukka* |
| *Karonda* | Jelly, Candy, Pickle, Preserve |
| Fig | Dried fig |
| *Ber* | Candy, Preserve, Canned *ber,* Jam |
| *Bael* | Preserve, Nectar, Squash, and Canned-*bael* |
| Citrus fruits | Juice, Pickle, Marmalade, Squash, Cordial, Candy |
| *Jamun* | Jelly, Syrup, Vinegar |
| Apple | Jam, Preserve, Juice, *Chutney*, Cider |
| Mulberry | Juice, Squash |
| Date | Dried date |
| Strawberry | Jam, Juice |
| Cherry | Jam, Candy, Canned cherry, Dried cherry |
| Pear | Jam, Chutney, Pickle, Preserve, Canned pear |
| ***Vegetables*** | |
| Carrot | Jam, Preserve, Pickles, Candy, Canned carrot |
| Cabbage | Sauerkraut, Dried cabbage |
| Cauliflower | Pickle, Dried and canned cauliflower |
| Brinjal | Pickle |

(*Continued*)

**Table 7.3** *(Concluded)*

| Fruits/Vegetables | Products |
|---|---|
| Peas | Pickle, Dried peas, Frozen peas, Canned peas |
| Green chilli | Pickle, Chilli paste |
| Beetroot | Pickle, Canned beetroot |
| Radish | Pickle, Canned and dried |
| Pointed gourd | Canned and dried *parwal,* Ash gourd *(Petha)* candy |
| Bittergourd (Karela) | Pickle, Dried bittergourd |
| Garlic | Pickle, Powder, Garlic paste |
| Onion | Pickle, Dried powder, Flakes, Paste |
| Beans | Canned and dried beans |
| Ginger | Pickle, Preserve, Candy, Dried ginger, Ready-to-serve, Syrup, Ginger paste |
| Potato | Chips, *Papad,* Starch, Canned potato |
| Spinach | Canned spinach |
| Watermelon | Juice, Squash |
| Mushroom | Juice, Squash, Dried mushrooms, Pickle |
| Cucumber | Pickle |

### 7.4.2 Setting Processing Industries

Various factors that have to be taken into consideration for setting up fruits and vegetables processing industries are as follows.

*Availability of Raw Materials.* In India, a wide variety of fruits and vegetables are available in abundance in the season. A contract between growers and processing units (contract farming) would ensure continued availability of good quality raw materials at predetermined rates to the industry. And fruits like mango, guava, sapota, banana, cashewnut, pineapple and *aonla* are not grown in many countries, and their products are likely to find a ready market in those very countries.

*Transport Facilities.* Cost of transportation is added while calculating cost of processed products along with the processing cost. At present, there is considerable improvement in road and rail transport, and the day is not far off when even remotest rural fruits and vegetables producing areas will be connected to processing factories in distant parts of the country. However, cost of transport is an additional burden on the consumers.

*Availability of Containers.* Availability of right quality, size and shape of containers is also one of the prime requirements for setting-up of the processing industry. At present, there are not many manufacturers of cans—Metal Box Company of India is the premier manufacturer with factories in different parts of the country. Generally, bottles and cans are the two major types of containers required by the food-processing industries.

*Manpower Availability.* India is in an advantageous position as compared to developed countries for having a large reservoir of manpower, but skilled manpower is in short supply in the food-processing, and thus the productivity of the vlaue-added products in general is low. Proper training in factory or institution, good working conditions and reasonable wages would go a long way to increase productivity.

*Capital for Initial and Operating Installations.* In recent years, with Government support, a number of big industries have diversified into the area of fruits and vegetables processing. There is, however, scope for small-scale units, which require less capital. Fundamentally, to cater to the needs of the local people, it is advisable to have small or cottage industries for locally available fruits and vegetables.

*Availability of Marketing Facilities.* Although there is a demand for preserving products and it is likely to grow further in future, but these products are not readily available in small towns due to reluctance of shopkeepers in stocking such items. Establishment of growers' cooperatives would help in marketing such products, and there is the policy of the Government to encourage establishment of such cooperatives. There is also a need to federate local growers into business group so that they can avoid middleman bargain.

Fruits and vegetables processing industry in India in the organized sector is comparatively a recent phenomenon. This industry is highly decentralized with a majority of units in the private sector (95%). The Agricultural and Processed Food Export Development Authority (APEDA) is seized with the problem of increasing exports of fruits and vegetables, both in fresh as well as processed form (APEDA, 2008).

## 7.5 Benefits and Losses from Food Preservation

Methods of foods preservation are drying, refrigeration, freezing, smoking, salt and sugar addition, heat processing, canning, chemical addition and ionizing radiation. Each method has its own advantages and disadvantages.

### 7.5.1 Drying (Freeze Drying, Spray Drying, Sun-drying)

*Advantages*

- Produces concentrated form of food.
- Inhibits microbial growth and autolytic enzymes.
- Retains most of the nutrients.
- Saves cost of transportation and storage.
- Make products available for later use.
- Preserves quality for longer duration.

*Disadvantages*

- Causes loss of some nutrients, particularly thiamine and vitamin C if processed at high temperature.
- Sulphur dioxide is sometimes added to dried fruits to retain vitamin C but consumers may be sensitive to sulphur dioxide.
- Cost of drying through electrical and other conventional fuel-based dryers is quite high, thereby increasing cost of dried products.

### 7.5.2 Refrigeration

*Advantages*

- Slows down microbial multiplication.
- Slows down autolysis by enzymes.
- Increases shelf-life of products.
- Retains nutrition of products.

*Disadvantages*

- Slow down loss of some nutrients with time.
- Cost of refrigeration is quite high, hence not economical.
- Conventional refrigeration process is not eco-friendly.

### 7.5.3 Freezing

*Advantages*

- Prevents microbial growth by low temperature and unavailability of water.
- Generally good retention of nutrients.
- Increases shelf-life of products for a longer duration.

*Disadvantages*

- Blanching of vegetables prior to freezing causes loss of some B-group vitamins and vitamin C.
- Unintended thawing can reduce product quality.
- Cost of freezing is comparatively high.
- Most of the freezers are conventional-energy-based, therefore, are not eco-friendly.

### 7.5.4 Smoking

*Advantages*

- Preserves partly by drying and partly by incorporation of substances into smoke.

*Disadvantages*

- Eating a lot of smoked foods has been linked with causing some types of cancers.
- Cost of smoking and prevention of its contamination is quite costly.

### 7.5.5 Addition of Salt and Sugar

*Advantages*

- Makes water unavailable for microbial growth.
- Process does not destroy nutrients.
- All substances used are locally available.
- Process is eco-friendly.

*Disadvantages*

- Increases salt and sugar contents of food, thus affecting taste and flavour.
- There is a need to standardize methods specific to local needs.

### 7.5.6 High Heat Processing (Pasteurization)

*Advantages*

- Inactivates autolytic enzymes.
- Destroys microorganisms.
- Operation is simple in use, and is efficient.

*Disadvantages*

- Loses heat-sensitive nutrients.
- Cost of processing is high.
- Skilled manpower is required.

### 7.5.7 Canning (involves high heat processing)

*Advantages*

- Destroys microorganisms and autolytic enzymes.
- Retains nutrients' availability for a longer duration.

*Disadvantages*

- Water soluble nutrients are lost.
- Cost of canning is quite high.

### 7.5.8 Chemical Preservatives

*Advantages*

- Prevents microbial growth.
- No loss of nutrients is observed.
- It is quick and quite efficient method of preservation.

*Disadvantages*

- People are sensitive to some chemical preservatives.
- Special care is required for taking quality and quantity of chemicals, which should not have any gradual effect on human-beings.

### 7.5.9 Ionizing Radiations

*Advantages*

- Sterilizes foods (such as spices) that can have change of flavour on heating.
- Inhibits sprouting in potatoes.
- Extends shelf-life of strawberries and mushrooms.

*Disadvantages*

- Longer shelf-life of fresh foods can lead to greater nutrient losses than if eaten soon after harvesting.
- Infrastructural facilities required are more for the operations.
- It is not suitable for small processors.

## 7.6 Nutrient Stability of Food

During processing and various preservation methods, there are chances of nutrient losses. And this depends on the type of food products and availability of types of nutrients in them (Table 7.4).

**Table 7.4** Nutrient stability characteristics of food

| Nutrients | Stability characteristics |
|---|---|
| Vitamin A | Quite stable during processing and cooking |
| Vitamin C | Unstable, losses occur with exposure to air, light, heat and copper<br>Also dissolves in cooking water |
| Vitamin D | Very stable, to heat but sensitive to exposure to air and light |
| Vitamin E | Relatively stable, excepting at deep-frying temperatures |
| Vitamin K | Stable in cooking but sensitive to light |
| Thiamin | Quite unstable to heat and alkaline conditions. Lost during refining of cereals. Dissolves in cooking water |
| Riboflavin | Stable to most processing but leaches into cooking water |
| Vitamin $B_6$ | Moderate retention during most of the processing |
| Vitamin $B_{12}$ | Moderate retention, but losses occur when heated in acid and alkaline conditions |
| Folic acid | Large losses can occur during cooking<br>Presence of copper aids destruction |
| Pantothenic acid | Relatively stable during most home processing |
| Biotin | Good retention during most home processing |

### 7.6.1 Saving Food Nutrients

There are number of techniques available, which help in saving nutrients while processing. Following are a few important points to be considered for saving nutrients.

- Do not store fresh foods for longer periods–purchase just enough that lasts for a week or so.
- Store foods in a cool dark place.
- Slice or chop pieces as large as possible.
- Add raw food once water starts boiling.
- Use water as little as possible for cooking.
- Cook food in shortest possible time (especially vegetables; longer cooking causes larger nutrient losses).
- Do not use copper pot or utensils for cooking.
- Do not use baking-soda to preserve vegetables colour; this increases vitamin losses.
- Use cooking water and liquid from canned foods for gravies, sauces and soups.
- Microwave cooking is a good way to save nutrients, as it is quick and also avoids use of water.
- Do not cook food at high temperature; as there are higher chances of losses.

## 7.7 Food Spoilage

This can be caused by a combination of light, oxygen, heat, humidity and/or all kinds of microorganisms, combined with available moisture in food, and also by the food condition. Food spoilage means that original food nutritional value, texture, flavour has been damaged, and that the food has become harmful for human consumption.

Food spoilage can be defined as any decay or undesirable decomposition of the constituents by excessive growth of microorganisms or by other physical and chemical causes. Food becomes unfit for human consumption if maximum prescribed microorganisms' limit is crossed.

Principal causes of spoilage are growth of microorganisms during storage, action of naturally occurring enzymes in food and their multiplication during storage, chemical reaction and physical degradation and desiccation, and type of storage environment and its consequences. The major causes of food deterioration are: (i) growth and activities of microorganisms—bacteria, yeasts and moulds during storage; (ii) activities of food enzymes and other chemical reactions within food during processing and storage; (iii) non-enzymatic reactions such as oxidation and mechanical damage; (iv) infestation by insects, parasites and rodents; (v) gain or loss of moisture during storage, i.e. uneven availability of moisture; (vi) reactions with oxygen and light; (vii) physical stress or abuse or tampering by external factors; (viii) inappropriate temperature of storage; (ix) adverse effects of climate; (x) All foods have tissues and they are of organic origin. Some foods, such as meat and fish, having living tissues should be killed before they should reach consumers. Other foods, such as fruits and vegetables may be stored and distributed in living state. Because of the organic nature, food is susceptible to deterioration or spoilage by saprophytic and parasitic microorganisms.

Factors of spoilage of food during processing and storage can be divided into biological, chemical and physical factors. There is a cumulative effect all of these factors together.

### 7.7.1 Process of Food Spoilage

*Autolysis.* The word autolysis means self-destruction and is used to describe cellular breakdown caused by enzymes contained within the food. This breakdown starts immediately after harvest or slaughter. In many instances a limited amount of enzyme's activity may be beneficial; for example, in ripening of fruits and tenderization of meat. It is recommended that for increasing shelf-life, autolysis process should be reduced to minimum.

*Microbial Spoilage.* Once cellular structures become disorganized, food becomes vulnerable to attack by microorganisms. The main agents are bacteria, moulds and yeasts. These organisms breakdown complex organic matter into simpler compounds and cause alterations in flavour, texture, colour and smell of food. Artificial good environment is created by preservation processes to control microbial growth.

At one time only, many forms of deteriorations may take place depending on the types of food and environment.

**Activities of microorganisms.** They are so small that they can only be seen through microscope. Microorganisms responsible for spoilage of foods are bacteria, yeasts and moulds. Bacteria are found anywhere in or out of food. Their growth depends upon a number of external factors. They are present in active form or resting form (spore stage). And they are much more difficult to be killed than moulds and yeasts. In vegetative stage, bacteria are destroyed at boiling temperature but their spores are difficult to be destroyed and require long-time application of heat. Some of the moist-heat resistant bacteria are present in the soil, hence preparation and processing of root vegetables require special care. During their growth, bacteria produce certain substances, which slow down or stop their growth and may inhibit multiplication of other organisms. Yeasts are microscopic unicellular organisms which are non-motile round or oval. Yeasts reproduce by 'budding'. They require less moisture and acidic *p*H to grow. They grow well in light sugar solution and acidic medium, and are undesirable when found growing on fruits, juices, squashes, *sharbat* and honey etc. They spoil appearance, taste, texture and wholesomeness of fruits. Moulds are made up of mycelia and spores. They grow in a network of hair-like fibres called mycelia. Majority of the moulds are sensitive to heat and are destroyed when heated at 60 °C for 30 min. Boiling destroys moulds and their spores. Some of the common moulds are *Aspergillus, Penicillium*, *Rhizopus* and *Helminthosporium*.

Yeasts and moulds can thrive in high-acid foods and fruits—tomatoes, jams, jellies and pickles. Processing high-acid foods at temperature 100°C (212°F) in a boiling water canner for appropriate length destroys yeasts and moulds; examples of spoilage are: storage rot in grapes and strawberry caused by *Botrytis cinerea*; blue mould rot in tomato caused by *Penicillium* sp. (also by *Fusarium* sp.); black mummy rot of grapes caused by *Guignardia bid wellii*; watery soft rot in apple caused by *Sclerotinia sclertiorum*; blue mould on oranges caused by *Penicillium digitatum*; eating spoiled food caused by bacteria can cause food poisoning.

**Action of enzymes.** Enzymes produced by living organisms catalyze chemical reactions, and can be easily inactivated by heat. They are found in all fresh foods, plants and animals. Their action is important for ripening of fruits and vegetables up to a certain stage; the action may be desirable but continuous action renders food inedible by bringing undesirable changes in food tissues. These changes are darkening of cut surface, fermentation of soft spots and development of off flavours. Enzymes convert starch into sugar, protein into amino acids and pectin into pectic acid, and therefore change constituents of food. Some fruits and vegetables turn brown when damaged or when their cut surfaces are exposed to air due to enzymes — phenolase, peroxidase and polyphenol oxidase

*Action of Insects*. Worms, bugs and fruit-flies may change food and render it unfit for human consumption. Injuries caused by these insects serve as entry point by which microorganisms reach inner tissues. Dehydrated fruits and vegetables are commonly infested by insects during storage.

*Physical/Mechanical Change*. All changes which are caused by freezing, burning, drying, poor selection of packaging material for transportation and storage of foods also cause spoilage of foods. Sometimes fruits are bruised or scratched during harvesting and handling. If proper precautions are not taken, injured spots become entrance points of microorganisms. Removal of diseased, damaged and scratched fruits during grading and post-harvest treatment of fruits with fungicides like thiabendazole are useful in reducing rots caused by mechanical damage (Lam and Wang, 1988).

*Spoilage due to Chemical Reaction*. These reactions are not catalyzed by enzymes in tissues or microorganisms, e.g. rancidity of fat. Atmospheric oxygen and even sunlight cause certain foods to undergo various undesirable changes in chemical composition. Oxidation resulting in production of off-flavour is called non-enzymatic browning or maillard reaction.

(i) Fat + lypolytic microorganisms → Fatty acids + glycerol
(ii) Proteins + proteolytic microorganisms → Amino acids + amines + ammonia + hydrogen sulphide
(iii) Carbohydrates + fermenting microorganisms → Acids + alcohol + gases

Moisture is required for chemical reactions and microbial growth. Moisture can cause pitting, lumping, caking, crystallization and stickiness in foods. And deterioration includes off-colour development. Banana, tomato, lemon and squash should be stored at about 10°C for retaining their quality.

*Storage Conditions.* Temperature, oxygen, light, duration of storage, container for storage, other conditions prevailing in storage influence microbial growth and food spoilage.

## 7.8 Nature's Seal on Quality

Every food has a characteristics appearance, odour, taste and feel, which are associated with normancy. Any deviation with respect to changes in colour of foods may be an indication of change in their nutritive value. Raw vegetables which have lost their bright colour and are wilted, are of lower value than those with good colour and firm tissues. The odour from ripe melons and bananas is an indication of their eating condition.

Quality of foods is checked by human senses. It is a method of determining seal of quality imprinted by nature on the food. The combination of these senses with the information accumulated is adequate to obtain optimum responses from foods. But, senses can fail when food poisoning or nutritive values are considered. No one can see poison in foods. It is an internal reaction, which takes place just like an action behind the curtain.

Chapter 8

# Preservation with Sugar and Salt

## 8.1 Introduction

Salt can be used in the preservation of food alone or in combination with drying. It is important not only as a dietary supplement but also in the seasoning of the food to improve organoleptic properties of the food products. However, adding of the right quantity of salt as per the requirement is crucial for the success of the preservation method. Proper standardization of methods, therefore, is necessary before their use for different fruits and vegetables.

Salt at 15–25% is sufficient to preserve most of the products. It inhibits enzymatic browning and discolouration and also acts as an antioxidant. Salt solution(brine) is used for canning and pickling of vegetables that contain very little sugars, and hence sufficient lactic acid cannot be formed by fermentation to act as a preservative (Soomoro, 2002).

## 8.2 Salt as Preservative

- Salt causes high osmotic pressure, resulting in plasmolysis of microbial cells.
- It dehydrates food as well as microorganisms by drawing-out and tying-up moisture by ion hydration.
- It ionizes to yield chloride ions that are harmful to microorganisms.
- It reduces solubility of oxygen in water, sensitizes cells against carbon-dioxide and interferes with action of proteolytic enzymes.

Presence of salt at higher concentrations makes water unavailable for bacterial growth. When concentration of salt is higher than its concentration in the bacterial cells, then water cannot be absorbed by the cellular membrane. Rather flow will be in the opposite direction, and cells will be depleted of their water content; dehydrating microbial cells. Salt also inhibits enzymatic browning, discolouration and also acts as an antioxidant. Salt effectiveness varies with its concentration and with the temperature and methods of mixing it with food items.

For centuries, salt has been known to improve palatability and acceptability of food. Addition of salt is known to improve flavour and acceptability of many foods, particularly meat, fish, poultry products, vegetables and even fruits. Sodium chloride reduces sourness of acids and increases sweetness of sugar. Organic acids (such as malic, tartaric and lactic acids) increase saltiness of sodium chloride and sweetness of sucrose but decrease sweetness of fructose. All sugars tested reduced saltiness of sodium chloride. Addition of 1% salt to solution containing 5 – 10% sucrose increased sweetness. Salt improves natural flavours and may weaken bitterness.

Salt is added appropriately for preparation and control of lactic acid fermentation in sauerkraut, pickles and green-fermented olives, and other vegetable pickles in brine. Salt is used for storage of cucumbers and other vegetables, olives and other fruits for subsequent processing into canned, glass-packaged or flexible packaging, and in brine storage of citrus peel (orange, lemon, and grapefruit) and of cut melons for subsequent production of candied and glazed products. Addition of salt is for temporary storage and handling of peeled and sliced or cut-apples, potatoes etc. and to inhibit enzymatic browning and discolouration during preparation for canning, freezing or dehydration. To prevent undesirable effects of hard water on the texture of peas and beans during blanching, salt-water blanching has been done to prevent absorption of calcium and magnesium from hard water by peas and beans and to reduce losses by leaching of soluble constituents. The composition of brines commonly used in canning vegetables is given in Table 8.1. Salt content of such brines usually averages 1.5-2.0%. Salt brines are used as the secondary heat transfer media in ice manufacturing and in cooling air in meat coolers and other cold-storage practices.

## 8.3 Cane Sugar for Preservation

Cane sugar should not contain more than 0.7% of ash, not more than 1.5% moisture and not less than 96.5% of sucrose. It may contain sulphur-dioxide, not exceeding 70 parts per million (cane sugar, *misri*, refined sugar, honey, jaggery).

The high osmotic pressure of sugar creates conditions that are unfavourable for growth and reproduction of most of the bacteria, yeasts and moulds. Usually 70% sucrose in solution will stop growth of all microorganisms in foods. Foods in which sugar aids preservation include syrup and confectionary products, filling in chocolate, canned fruits and juices, honey, jams, jellies, marmalades, conserves and fruits like dates. Sugar acts only as a preservative by osmosis and not as a true poison for microorganisms.

**Table 8.1** Composition of brines used for canning vegetables

| Product | Brine, salt kg/100 litres of water |
|---|---|
| Green beans | 1.50 – 2.30 |
| Beans, kidney (*Rajmah*) | 1.00 – 1.50 |
| Beans, sprouts | 1.50 – 1.75 |
| Beets | 1.5 – 2.00 |
| Cabbage | 2.25 – 3.00 |
| Maize, whole kernel | 1.25 – 1.50 |
| Okra | 0.75 – 1.00 |
| Peas green | 1.75 – 2.00 |
| Spinach | 1.50 – 2.25 |

## 8.4 Canning of Fruits

Canning consists of placing food in a sealable container, then closing, heating and cooling it. In the commercial practice, syrups of desired brix are prepared either according to a formula by which a known weight of sugar is added to a given volume of water or by adding sufficient water to a known weight of sugar to get a desired volume of syrup. In canning fruits, sugar in the form of syrup is used to bring out full flavour of fruits; sugar is not to make contents excessively sweet. Strength of the syrup depends on the kind and variety of the fruit. Generally more acidic fruits require denser syrups. For example, addition of 23 litres of water to 23 kg of sugar will produce 36 litres of syrup of 50° brix. Similarly, to prepare 23 litres of syrup of 50° brix, using 13.98 kg of sugar, sufficient water is added to obtain the required quantity.

## 8.5 Syrup Strength Measurement

Different kinds of hydrometers used are Brix or Balling, Baume specific gravity and Twaddel. A refractometer can also be more conveniently employed for measurement of syrup strength.

Brix or Balling hydrometer gives directly percentage of sugar by weight in syrup. It is calibrated at 20°C and correction is required for other temperatures. On the Baume hydrometer, divisions range from 0 to 70 degrees. Relationship between Brix and Baume scales is given in Table 8.2. Specific gravity in case of Baume reading may be deduced by adopting following formula.

$$\text{Specific gravity} = \frac{145}{145 - \text{Baume reading}}$$

Twaddell hydrometer is usually calibrated at 15°C; divisions range from 0 to 200 degrees; one Twaddell degree corresponds to 1.005

**Table 8.2** Relationship between degree brix reading and composition of syrup

| Degree brix at 20 °C | Weight of sugar to be added to each litre of water (g) | Volume of syrup from one litre of water (litre) | Weight of sugar contained in one litre of syrup (g) |
|---|---|---|---|
| 1 | 2 | 3 | 4 |
| 10 | 111 | 1.067 | 104 |
| 11 | 123 | 1.076 | 114 |
| 12 | 136 | 1.085 | 125 |
| 13 | 149 | 1.093 | 136 |
| 14 | 163 | 1.101 | 147 |
| 15 | 176 | 1.111 | 158 |
| 16 | 190 | 1.119 | 170 |
| 17 | 204 | 1.127 | 181 |
| 18 | 219 | 1.137 | 193 |
| 19 | 234 | 1.146 | 204 |
| 20 | 250 | 1.157 | 216 |
| 21 | 266 | 1.167 | 228 |
| 22 | 282 | 1.176 | 240 |
| 23 | 300 | 1.187 | 252 |
| 24 | 317 | 1.198 | 264 |
| 25 | 334 | 1.208 | 276 |
| 26 | 352 | 1.220 | 289 |
| 27 | 370 | 1.231 | 301 |
| 28 | 389 | 1.243 | 313 |
| 29 | 409 | 1.256 | 326 |
| 30 | 430 | 1.269 | 338 |
| 31 | 450 | 1.281 | 351 |
| 32 | 472 | 1.294 | 364 |
| 33 | 494 | 1.309 | 377 |
| 34 | 517 | 1.323 | 390 |
| 35 | 540 | 1.338 | 403 |
| 36 | 564 | 1.353 | 417 |
| 37 | 589 | 1.369 | 430 |
| 38 | 614 | 1.384 | 444 |
| 39 | 641 | 1.401 | 458 |
| 40 | 669 | 1.419 | 471 |
| 41 | 697 | 1.437 | 485 |
| 42 | 726 | 1.454 | 499 |
| 43 | 756 | 1.474 | 513 |
| 44 | 788 | 1.494 | 527 |
| 45 | 820 | 1.514 | 542 |
| 46 | 855 | 1.536 | 557 |
| 47 | 890 | 1.558 | 571 |
| 48 | 926 | 1.580 | 586 |

specific gravity. A food substrate concentrated to 65% or more contains substantial solids that can be preserved with mild heat treatment; provided it is protected from air. The prepared products can be stored without hermetic sealing, although such a protection is useful.

Jams contain 0.5-0.6% acid; invert sugar should not be more than 40%. At home, it can be prepared by using recipes as given in the Table 8.3.

**Table 8.3** Ingredients for preservation of fruits and vegetables

| Fruits/vegetables | Ingredient for one kg pulp | | |
|---|---|---|---|
| | Sugar (kg) | Citric acid (g) | Water (ml) |
| *Aonla* | 0.75 | - | 150 |
| Apple | 0.75 | 2.0 | 100 |
| Carrot | 0.75 | 2.5 | 200 |
| Grapes | 0.70 | 1.0 | 50 |
| Guava | 0.75 | 2.5 | 150 |
| *Karonda* | 0.80 | - | 100 |
| Mango | 0.75 | 1.5 | 50 |
| Plum | 0.80 | - | 150 |
| Peach | 0.80 | 3.0 | 100 |
| Pear | 0.75 | 1.5 | 100 |
| Papaya | 0.70 | 3.0 | 100 |
| Strawberry | 0.75 | 2.0 | 100 |
| Sapota | 0.75 | 3.0 | 100 |

Chapter 9

# Food Preservation through Thermal Processing Methods

## 9.1 Introduction

Thermal processing or heat input is commonly used for food preservation. Most of the microorganisms are killed or inactivated by heat treatment due to protein denaturation and inactivation of enzymes. Heating up to a certain definite temperature is critical for the success of the process. Different thermal processing methods used for preservation of fruits and vegetables are canning, blanching, pasteurization, sterilization and evaporation (Jain, 2003).

## 9.2 Heat Treatment

Two main methods of preservation involving heat are sterilization and pasteurization (canning); commonly employed in most of the fruits and vegetables industries.

### 9.2.1 Sterilization

This involves use of heat for total destruction of microorganisms and their spores. The sterilized food then must be placed in air-tight containers to prevent further entry of spoilage organisms. A steel-can coated with a thin layer of tin is the most common type of container. For some products inside of the container can be coated with lacquer to protect against corrosion. And glass-bottles and jars are used for some products, particularly jams and preserves. In the recent years, flexible good quality plastic containers are being used for a variety of liquid products, particularly milk and cream. However, recycling of plastic is a great challenge to prevent pollution.

Because of the resistance of certain bacterial spores to heat, sterilization frequently means treatment at 121°C (250°F) with wet heat for 15 minutes. Every particle of the food must receive this treatment. And during the time, many changes occur in food, which affect quality.

In commercial practice, all food cans are not sterilized. Nevertheless, they usually do not spoil food because conditions in the can are not favourable for the organisms — the *p*H may be too low or oxygen may be lacking. The term "Processing" is preferable to "Sterilization" when applied to canned foods. Acidity of fruits, tomatoes and juices lowers death or sterilizing temperature of organisms, occurring on these products, which explains why acid fruits are sterilized easily, even if spore-bearing organisms are present.

*Sterilization Below100°C.* Fruit juices are usually processed commercially at temperature ranging from 65 to 85 °C. Higher temperature spoils flavour. This happens when heating is done of sealed container or by the flash pasteurization; filling hot and sealing.

*Heating at 100 °C.* Fruits are easily preserved at 100 °C and heating at this temperature is usually for cooking fruits rather than for sterilization. Vegetables, excepting with high acidity, when sterilized by heating, must be heated at 100 °C for many hours to be sure that all spores have been killed.

*Intermittent Processing at 100 °C.* Action of heat is more effective if sterilization time is divided into three periods—three sterilizations of 1 hour each at 100 °C are much more effective than a single sterilization at 100 °C for vegetables of low acidity. This method at 100 °C does not destroy spores of *Clostridium botulinum* in non-acid foods.

### 9.2.2 Canning Process

The process of sealing food-stuffs hermetically in containers and sterilizing them by heat for long storage is known as canning. The modern canning process usually involves following operations.

*Cleaning and Preparation.* All inedible parts are removed from fruits and vegetables and are graded and washed. This is a pre-processing section, where mainly cleaning is performed.

*Blanching.* Most vegetables and fruits are blanched either by immersing in boiling water or by exposing them to steam. This is often a continuous process in which they are passed through a tunnel and exposed to steam; exposure period may vary from 2 to 10 minutes. Blanching inactivates enzymes that affect food stability. In addition, blanching drives out air bubbles trapped within fruits and vegetables, thus allowing a better "fill". If too much air remains in cans desired temperature may not reach during sterilization, and microorganisms may survive inside the cans.

*Filling and Exhausting.* Washed open cans are filled automatically with weighed amount of fruits and vegetables. For vegetables, fruits and some other types of foods, cans are topped up to 1 cm with liquid. The

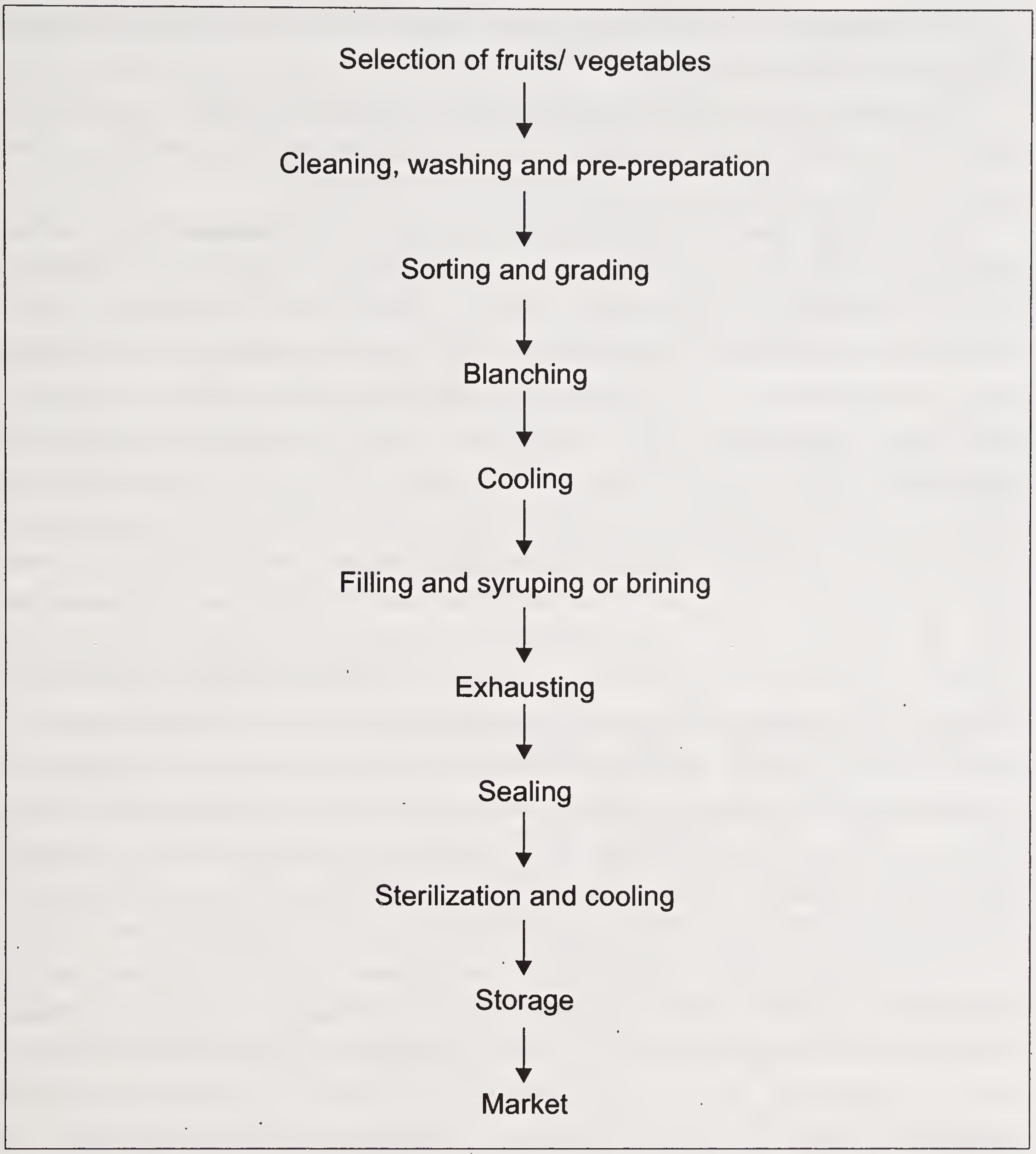


**Fig. 9.1** General canning process of fruits and vegetables

liquid is normally brine for vegetables and sugar-syrup for fruits. After filling, cans are passed to an exhaust box to be exposed to hot-water or steam so that, when the lid is sealed, a partial vacuum is created in the can.

*Sealing*. Lids are placed on the cans, and they are passed on to an automatic sealing machine, which bends edges of the lid and flanges on to the can-body into a roll. The roll is then flattened forming a hermetic seal.

*Exhausting*. Removal of air from the cans is known as exhausting. Containers are exhausted either by heating or mechanically. It prevents corrosion of tin-plate, minimizes oxidation and helps in better retention of nutrients.

*Sterilization:* The amount of heat required for adequate sterilization depends on the following.

**Can size and nature of contents**: Heat takes longer to penetrate into a large can. Heat penetration is faster in convection packs such as soups than in conduction packs such as corned-beef.

***p*H of the food**: Sterilization is designed to eliminate *Clostridium botulinum* and its spores, since it is the most dangerous and heat-resistant microorganism likely to be present in the canned foods. Therefore, foods are classified into groups depending on the heat treatment necessary to eliminate this microorganism. Based on the *p*H, fruits and vegetables can be classified into:(i) *High acid fruits and vegetables*: Foods which have a *p*H below 3.7; very few bacteria can survive at the condition. Consequently only a mild heat treatment is necessary to eliminate yeasts and moulds, which may be present, since they are less heat resistant than bacteria. For most can sizes, heating at 100 °C for 8 to 16 minutes will be sufficient. Bacterial spores may survive but will be unable to germinate, and therefore cannot cause spoilage; (ii) *Medium acid fruits and vegetables*: They have *p*H between 4.5 and 5.0. Many spoilage bacteria can grow in this range and therefore heat treatment needs to be severe than the earlier type. *p*H is still too low to allow growth of *Clostridium botulinum*; (iii) *Low acid fruits and vegetables*: These have *p*H above 4.5,and foods included are meat, fish and most of the vegetables. To ensure complete destruction of bacteria, especially *Clostridium botulinum,* such foods are to be subjected to severe heat treatment. The temperature required depends on the time of exposure to heat. Use of high temperature for a shorter time is preferable, since such a treatment will have lesser effect on the nutritive value of the product— vitamins destruction will be minimized. Also undesirable flavour changes can be avoided if High Temperature Short Time (HTST) process is used.

*Cooling.* Can is cooled gradually, first by reducing steam pressure and then by cold-water. Since temporary leakage may occur at this point, cooling water is made clean and sterile. Water is sterilized by chlorination in which usual chlorine level is between 3 and 5 ppm. Cooling is continued till temperature reaches 38°C. This helps in avoiding rusting, and also reduces microorganisms invasion in the can present in the water on the surface; being drawn into can through temporary modern canning process, which is automated and run on a continuous system rather than using batch processes.

### 9.2.3 Aseptic Canning

In aseptic filling, bulk products and containers are sterilized separately. In a quick technique of canning, high temperature reduces sterilization time and improves quality of the product markedly. Containers are then filled aseptically before sealing. In the case of cans, they are filled through a small vent-hole, which is closed by soldering.

Aseptic canning is used mainly for liquid foods, which are heat-sensitive, and therefore likely to be over-cooked in standard canning. Change in flavour and colour and reduction in nutritive value are minimized if products are sterilized using a multi-plate heat exchanger; as the one is used for milk pasteurization.

Main reasons for spoilage of canned foods are: (i) insufficient sterilization, which means spores of anaerobic bacteria may survive and germinate; (ii) leakage if improperly sealed; (iii) Corrosion of can that may be due to attack by contents; particularly acid foods or damage due to storage in unsatisfactory conditions.

## 9.3 Heat Pasteurization

Heating of fruit and vegetable products in the containers or by other methods to a temperature below boiling point of water for a definite period is termed as pasteurization. Pasteurization is of two types — High Temperature and Short Time (HTST) and other is Low Temperature and Long Time (LTLT). In the HTST, 72 °C temperature for 15 seconds and in LTLT, 62.8 °C temperature for 30 minutes are maintained. Pasteurization destroys pathogenic organisms associated with fruits and vegetables, thus preventing their spoilage and extends products' shelf-life by decreasing microbial population and inactivating some enzymes.

Pasteurization is employed for milk, beer, wine, fruit-juices etc. However, the method of pasteurization differs from product to product. A food manufacturer regards pasteurization as the means of extending shelf-life of a food by using heat to reduce number of spoilage organisms.

*Effect on Nutrients.* Pasteurization affects vitamins contents to a greater extent than other nutritional constituents.

- Vitamin C and vitamin $B_2$ are most sensitive whereas vitamin A and D are moderately affected. Ascorbic acid being most sensitive undergoes oxidation, resulting in the formation of dehydro-ascorbic acid; about 8% loss of vitamin C takes place during pasteurization.
- Vitamins E and K are least affected.
- Thiamine undergoes 3-20% destruction, and riboflavin reduces by 5%.
- Niacin content increases by 10%, probably owing to liberation of protein-bound nicotinic acid.

Fruit-juice is held at a certain temperature for at least 30 min and then cooled rapidly to 10 °C (50 °F) in Holder process. And in HTST process, fruit-juice is held at a temperature higher than holder process for at least 15 seconds and immediately cooled to 10 °C (50 °F).HTST process is preferred since it affects less on the nutritive value and fruit-juice flavour.

## 9.4 Blanching (Scalding/Parboiling/Precooking)

It is recommended for dehydration of fruits and vegetables. Fruits and vegetables are immersed in boiling water or treated with steam to inactivate oxidative enzymes — catalase and ascorbic acid oxidases. Blanching is a cooking technique. In this, food material is boiled in the water for a short time, often followed by plunging into cold-water to stop cooking process. Blanching is commonly used to remove peels from tomatoes and almonds. And it is a must for almost all vegetables that are to be frozen. Blanching cleanses surface dirt and organisms, brightens colour and stops vitamins losses. Blanching time is crucial and varies with the vegetable and its size. Under blanching stimulates enzymes activity and is worse than no blanching. Over-blanching causes losses in flavour, colour, vitamins and minerals. Therefore, standard method of blanching should be followed.

As soon as blanching is over, vegetables should be cooled quickly and thoroughly to stop cooking process. To cool, plunge basket of vegetables into a large quantity of cold-water, 60 °F or below. Change water frequently or use cold running water or ice-water. If ice is used, one pound of ice is needed for each pound of vegetables.

### 9.4.1 Blanching Types

*Water Blanching*. For home-scale blanching, most satisfying is to heat all vegetables in the boiling water. Use one gallon water per pound of vegetables. Place vegetables in a blanching basket and lower it into the boiling water. Place a lid on the blancher. As the water reaches to boiling temperature, start counting blanching time (Table 9.1).

*Steam Blanching*. For broccoli, pumpkins, sweet-potatoes and winter-squashes, both steaming and boiling are satisfactory.Steam blanching takes about 1.5 times longer than water blanching.

To steam, use a pot with a tight lid and a basket that holds food at least three inches above the bottom of the pot. Pour an inch or two amount of water in the pot and bring water to boil.

Place vegetables in the basket in a single layer so that steam reaches to all parts of the vegetables quickly. Cover pot and keep heat high (Table 9.1).

*Microwave Blanching.* It may not be so effective, since research shows that some enzymes may not be inactivated. This may result in off-flavour and loss of texture and colour. This blanching is suitable for low quality vegetables, and it works in small quantities. This does not save time or energy.

### 9.4.2 Blanching Timings

Recommended time for blanching for various vegetables depends on the nature of the food and its nutrient content.

**Table 9.1** Blanching time for vegetables

| Vegetables | Blanching time (minutes) |
|---|---|
| Asparagus | |
| Small stalk | 2 |
| Medium stalk | 3 |
| Large stalk | 4 |
| Beans-snap, Green or wax | 3 |
| Beet | Cook |
| Broccoli | |
| Flowerets 1½ inches across | 3 |
| Seamed | 5 |
| Cabbage or Chinese cabbage (Shredded) | 1½ |
| Carrots | |
| Small | 5 |
| Diced, sliced or lengthwise strips | 2 |
| Cauliflower | |
| Flowerets, 1 inch across | 3 |
| Celery | 3 |
| Corn | |
| (Corn on the cob) | |
| Small ears | 0.7 |
| Medium ears | 0.9 |
| Large ears | 0.11 |
| Whole ears | 0.4 |
| (ears blanched before cutting corn from cob) | |
| Brinjal | 4 |
| Mushroom | |
| Whole (Steamed) | 5 |
| Buttons or quarters (Steamed) | 3.5 |

(*Continued*)

**Table 9.1** (*Concluded*)

| Vegetables | Blanching time (minutes) |
|---|---|
| Slices (Steamed) | 3 |
| Okra | |
| Small pods | 3 |
| Large pods | 4 |
| Onions | |
| (blanch until centre is heated) | 3-7 |
| Rings | 10-15 seconds |
| Peas-edible pod | 1.5-3 |
| Peas-green | 1.5 |
| Peppers-sweet | |
| Halves | 3 |
| Strips or rings | 2 |
| Pumpkin | Cook |
| Soybean-green | 5 |
| Sweet-potatoes | Cook |
| Turnip | |
| (Cubes) | 2 |

### 9.4.3 Blanching Effects

Effects of blanching are as follows.

- Inactivates oxidative enzymes, thus increases shelf-life of products.
- Decreases bacterial load, thus prevents spoilage of products.
- It gives desired appearance of the finished product by fixing colour, especially in case of green-leafy vegetables and other coloured vegetables, thus more returns can be procured from the products.
- Retains vitamins in the blanched vegetables.

Chapter 10

# Low Temperature, Evaporation and Fermentation for Preservation

## 10.1 Low Temperature for Preservation

Cold preservation of food may be categorized into: refrigeration and freezing. Household and commercial refrigerants usually run at 4.0-7.0°C. Commercial refrigeration (cold or chill storage) may use slightly lower temperature, depending upon the nature of the product refrigerated. Freezing is done at –18°C or below. Chill storage will preserve perishable foods for days or weeks. Frozen storage (deep-freezing) will preserve products for months or even years (Maini and Anand, 1992).

Refrigeration has certain advantages over freezing; it takes lesser energy to cool a product just above its freezing point than its freezing requires. Refrigeration storage requires lesser insulation, and it does not cause texture and flavour losses in the products; caused by freezing.

### 10.1.1 Freezing

Living cells contain often two-thirds or more water to their weight. There are organic and inorganic substances, including salts, sugars and acids in the aqueous solutions, and also complex organic molecules such as proteins. To some extent gases are also dissolved.

Physical, chemical and biological changes occurring during freezing and subsequent thawing are complex and not fully understood. Freezing point of the product is lower than that of pure water. Because of the high content of water in most foods, most of them freeze at temperature between 0°C and –3°C. The temperature of the food undergoing freezing remains relatively constant till most of food is frozen; after that temperature approaches to that of the freezing medium(Table 10.1).

Freezing refers to foods maintained in a frozen condition. For good freezing, temperature at –18°C or below is required.

### 10.1.2 Freezing Effects on Foods

For each commodity, there is a temperature below which injury

**Table 10.1** Freezing point of fruits and vegetables

| Fruits/vegetables | Temperature (ºC) |
|---|---|
| Water lettuce, cabbage | 0 |
| Cauliflower, peas | –0.6 |
| Asparagus, Raspberries | –1.1 |
| Carrots, beet | –1.7 |
| Potatoes | –2.2 |
| Garlic | –3.3 |
| Bananas | –3.9 |

occurs. Lowest safe temperature varies according to the nature of the commodity. Following are some of the affects observed in different products.

- In refrigerated storage, flavours between many types of food mixes together if they are stored side-by-side. Butter and milk absorbs odour from fish and fruits; which is not desired.
- Nutrient losses are observed, e.g. a loss of 50% vitamin C from asparagus in 7 days at 0°C was observed.
- Fruits and vegetables lose firmness and crispness; hence lose market value. Desiccation may occur in frozen foods owing to poor packaging.
- Protein and fat changes may also occur when moisture is lost from the surface of the frozen foods.
- Some physical changes may also occur such as crystallization (ice-cream, concentrated milk). Similar types of changes may occur in sweetened citrus juices as well.
- Deterioration of colours occur through oxidation and formation of brown or black coloured compounds in fruits due to polyphenol oxidase action.

### 10.1.3 Freezing Methods

Refrigeration needs for freezing foods are the sum of the requirements for lowering temperature of the foods to their freezing points and lowering temperature of the frozen foods to that of the storage-chamber temperature. Some of the commonly employed freezing methods are quick-fast freezing, slow freezing and air freezing.

*Quick-Fast Freezing.* It is the process by which the temperature of the food is lowered to about – 20°C within 30 minutes. This may be achieved by direct immersion or indirect contact of foods with the refrigerant and by the use of air-blasts of frigid air, blown across the food being frozen. Quick freezing is promising process for overall product quality.

*Slow Freezing.* In this process, desired temperature is achieved within 3 to 72 hours. This is essentially the type of freezing utilized in home-freezer.

*Freezing Air.* There are two types of air systems: still air and forced air. Still air freezing is accomplished by placing packaged or loose foods in the suitable freezing rooms. Still air freezing is the cheapest and slowest method; in this product remains in freezing chamber until frozen. The freezing time for a given package of food can be reduced drastically by installing fans in the chamber. Very cold air moved at high speed results in rapid freezing. Dehydration is a serious factor that needs to be considered when freezing unpackaged foods (i.e. individual peas, berries or fish) by either still or blast air method. Packaging of foods prior to freezing has obvious advantages in controlling this dehydration, but has the disadvantage of insulating foods.

## 10.2 Evaporation for Food Preservation

Evaporation involves heat transfer to a boiling liquid so that solvent vapours are removed from aqueous solutions of sugar, salt, sodium-hydroxide, glycol, glue, milk and fruit-juices. In these solutions, concentrated solution is the desired product, and the evaporated water is normally discarded. In some cases, water with small amount of dissolved minerals is evaporated to get solid-free water to use as a boiler feed or as a process-water for special chemical processes. In some cases, evaporation is practised to concentrate solution so that upon cooling, crystallization is initiated and desired product is separated out. Evaporation is practised in the food industry for pre-concentration of liquids, prior to drum-drying, spray-drying or crystallization, to reduce volume of liquid to minimize storage, packaging and transportation costs and to reduce water activity, and thereby aiding in food preservation (Dash and Chandra, 2001).

### 10.2.1 Factors Influencing Evaporation Process

Following are the factors that influence evaporation process.

*Concentration of Liquid.* Liquid fed to an evaporator is relatively dilute with low viscosity compared to water. Hence its heat transfer coefficients are quite high. And as evaporation progresses, solution becomes concentrated and viscous, thereby decreasing heat transfer coefficient.

*Temperature Sensitivity of Materials.* Food products, milk, vegetable and fruit extracts are sensitive to higher temperature and undergo degradation.

*Pressure and Temperature.* The higher the operating pressure of the evaporator, the higher will be boiling temperature, which increases as the concentration of the solution increases.

### 10.2.2 Evaporation Equipment

A variety of evaporators are used in the food industry; general types of evaporators consist of common systems such as: (i) Heat exchanger; (ii) Separator (vapour is separated); (iii) Condenser (to condense vapour).

And industrial evaporators include: (i) Open kettle pan; (ii) Horizontal tube evaporator; (iii) Vertical tube evaporator; (iv) Long tube vertical type evaporator; (v) Falling film type evaporator; (vi) Forced film type evaporator; (vii) Agitated film evaporator

### 10.2.3 Evaporator Operation

Evaporators may be operated as a single stage (single effect evaporators) or as a multiple stage (multiple effect evaporators). Single effect evaporator is simple in operation and cost, however, it runs at a relatively low efficiency. In multiple effect evaporators, latent heat of the vapours is recovered, and hence they are energy-efficient. In the forward feed multiple effect evaporator, fresh feed is added to the first effect and flows to the next in the same direction as vapour flows. This method of operation is used when feed is not uniform or when the final concentrated product may be damaged by high temperature.

## 10.3 Fermentation for Preservation

Fermentation is a process of decomposition of carbohydrates by microorganisms or enzymes. In this, food is preserved by organic acid formation by microorganisms. Alcoholic, acetic acid and lactic acid are three important kinds of fermentation processes involved in the food industry. Care should be taken to seal fermented products to protect them from air for avoiding unwanted or secondary fermentation.

Keeping quality of alcoholic beverages, vinegars and fermented pickles depends upon the presence of alcohol, acetic acid and lactic acid, respectively. Wines, beers, vinegar, fermented drinks and fermented pickles are prepared by above-mentioned processes.

Fermentation means breakdown of carbohydrates by microbes (or enzymes) under anaerobic conditions. In common usage, fermentation refers to both aerobic and anaerobic breakdown of carbohydrates. Thus, conversion of lactose to lactic acid by *Streptococcus lactis,* which takes place anaerobically and of ethyl alcohol to acetic acid, that is aerobically by *Acetobacter,* are both referred to as fermentation. Preservative effect of fermentation is by chemicals excreted by microorganism during the reaction. Principle chemicals involved in reaction are acids (lactic acid) and alcohol. These inhibit growth of common pathogenic organisms in fruits and vegetables (Joshi and Thakur, 2000).

In fermentation, a complex mixture of carbohydrates, proteins and fats undergoes modification under the action of microorganisms and enzymes. The proteinaceous materials undergo proteolysis or "putrefactive" breakdown and lipids undergo "lipolytic" breakdown. Nature and extent of these changes depend upon the food, microorganisms' types and conditions affecting their growth.

*Advantages.* Advantages of fermentation for preservation are given as follows.

- Fermentation produces flavour and textural changes in the product.
- Fermented foods are more nutritious than unfermented ones, and hence add value.
- Microorganisms in addition to breakdown of complex compounds, synthesize several vitamins and other growth factors, thereby increasing value of products.
- Indigestible carbohydrates — cellulose and hemicellulose— are converted into digestible carbohydrates such as sugars and sugar derivatives.

*Disadvantages.* There are a few disadvantages encountered in fermented process.

- During fermentation, proteolytic organisms breakdown proteins, which result in putrid and rotten odour and flavour.
- Lipolytic organisms hydrolyze lipids into free fatty acids, resulting in the rancidity.

To obtain a product of the desired quality in storage, controlled fermentation becomes necessary. There are a number of factors which influence growth and metabolic activities of the microorganisms in the food fermentation—acidity, alcohol, use of starters, temperature, oxygen and salt.

Alcohol (14%) acts as a preservative in wines as yeasts cannot grow at that concentration, and acetic acid (2%) prevents spoilage of many products. And lactic acid (1.8%) and salt (2.5%) act as the preservative in fermented pickles. Some industrial fermentation processes commonly employed in the food industries are given in Table 10.2.

### 10.3.1 Order of Fermentation

It appears that microorganisms first attack on carbohydrates, then on proteins; finally, on fats. There is an order of attack even with carbohydrates; first sugars, then alcohols, then acids. Since, first requirement for microbial activity is energy; it appears that $CH_2$, CH, CHOH, COOH and carbon linkage such as CN radicals are useless to microorganisms.

**Table 10.2** Some industrial fermentation processes in food industries

| Microorganism | Product |
|---|---|
| Lactic acid bacteria | Cucumber – Dil pickles, sour pickles<br>Cabbage - Sauerkraut<br>Turnip – sauerruben<br>Lettuce- lettuce kraut<br>-Mixed Chinese vegetables<br>Cabbage – Kimchi<br>Vegetables and milk – Tarhana<br>Vegetables and rice – Sajurasin |
| Lactic acid bacteria with other microorganisms | - with yeast- Nukamiso pickles<br>- with moulds- Soy sauce |
| Acetic acid bacteria | - Wine cider or any alcoholic and sugary or starchy products may be converted to vinegar |
| Yeasts | Fruit - Wine, vermouth |

### 10.3.2 Types of Fermentation

Microorganisms are used to ferment sugar by complete oxidation, partial oxidation, alcoholic fermentation, butyric fermentation and other minor fermentative actions.

- Bacteria and moulds are able to breakdown sugar (glucose) to carbon-dioxide and water. Few yeast types can accomplish this action.
- The most common fermentation is one in which partial oxidation of sugar occurs. In this, sugar is converted to an acid. And acid finally may be oxidized if allowed to yield carbon-dioxide and water. For example, some moulds are used in the production of citric acid from sugar solution.
- Yeasts are the most efficient converters of aldehydes to alcohols. Many species of bacteria, yeasts and moulds are able to yield alcohol. The yeast *Saccharomyces ellipsoideus* is of great industrial importance in alcoholic fermentations.
- Lactic acid fermentation is very important in food preservation. Sugar in the foodstuff may be converted to lactic acid and other end-products. Lactic acid fermentation is efficient and causes rapid growth of fermenting organisms. Natural inoculations are such that in a suitable environment, lactic acid bacteria will dominate, as in the souring of milk.
- Butyric fermentation is less useful in preservation. The organisms are anaerobic and impart undesirable flavours and odours to foods.

Anaerobic organisms capable of infecting man and causing diseases are commonly butyric fermenters. Carbon-dioxide, hydrogen, acetic acid and alcohols are some of the other fermentation products.

- In addition to above, there is a fermentation that involves much gas production. It is useful in food preservation, although gas production is disadvantageous. Energy-wise it is less efficient to produce gases (carbon-dioxide and hydrogen) that have little or no preserving power in concentrations as compared to lactic acid. The important food spoilage organisms are capable of growing in such an environment. In gaseous fermentation, sugar molecules are altered to form acids, alcohol and carbon-dioxide. It is usually necessary to include some other controlling influences such as adding sodium chloride to a substrate with this form of fermentation.
- There are many fermentative actions possible in foods, which are detrimental to acceptability of treated foods. Generally, organisms are capable of attacking higher carbohydrates such as cellulose, hemicelluloses, pectin and starch, and will injure texture, flavour and quality of treated foods.

Chapter 11

# Preservation of Foods by Radiations

## 11.1 Introduction

The need for the preservation of food has never been felt as strongly as is in the context of the present scenario of rising population. Increasing gap between demand and supply of food, varied agroclimates, inadequate post-harvest practices, seasonal nature of produce and long distances between production and consumption centres, underscores the need to devise improved conservation and preservation strategies.

The traditional and conventional methods of preservation practised in India are drying, fermentation, refrigeration, freezing and canning. Of late, controlled atmosphere (CA) and modified atmosphere (MA) storages and conventional cold storages are also becoming popular.

Along with the traditional methods of processing and preservation, technology of food irradiation, referred now as "Radiation Processing of Food", is gaining worldwide attention with greater acceptance by the general public. In food irradiation process, food is exposed to high energy rays to improve product safety and shelf-life. Potatoes, onions, spices, fresh fruits and vegetables may be irradiated to prevent growth of food-poisoning bacteria, to eliminate parasites or to delay ripening and spoilage. More than 50 countries worldwide including India have approved irradiation use for over 100 food items, and about 38 of the countries are applying technology on a limited commercial scale.

Radiation is broadly defined as the energy moving through space in invisible waves. Light, infrared heat and microwaves are various forms of radiant energies. Broiling and toasting use low-level of radiant energy to cook food.

For food preservation, ionizing radiations, also known as irradiation, are used. These shorter wavelength rays are capable of damaging microorganisms.

Irradiation disrupts biological processes that lead to decay. The radiation energy is absorbed by molecules that make-up organisms and foods. This brings change in the DNA, causing death of microorganisms and insects and also prevents sprouting of potatoes and onions (Beraha, 1961).

## 11.2 Radiation Processing of Food

It involves controlled application of short-wavelength radiations of electromagnetic spectrum, which includes radio-waves, microwaves, infrared, visible and ultraviolet rays. The short-wavelength radiations are also known as ionizing radiations and include gamma rays, accelerated electrons and X-rays (Dharkar and Sreenivasan, 1972).

*Radiations Effects on Microorganisms and Food.* When ionizing radiations strike bacteria and other microbes, their high energy break chemical bonds (radiolysis) of molecules that affect vegetative cell growth and integrity. The most vital effect is on the deoxyribonucleic acid (DNA) that can no longer multiply and cause illness or spoilage. Molecules in cell nuclei are required for growth and replication.

Ionizing radiations also break chemical bonds within food itself. Chemical changes in food are due to radiations varying in nature; some are desirable, others are not. Some food changes that occur due to radiations are as follows.

- Changes structure of certain foods that are too fragile to withstand irradiation, for example, lettuce and other leafy vegetables that turn 'mushy'.
- Delayed ripening and maturation in certain fruits and vegetables; thus increases shelf-life.
- Reduction or destruction of some vitamins.
- Alteration in flavour compounds is also possible.
- Formation of compounds that were not originally present requires slow control of radiations.
- Generation of free radicals, some of which recombine with other ions. These ions and radicals are direct radiolysis products that react with food constituents to form stable products or indirect radiolysis products.

*Radiation Processing.* **Benefits.** This processing is a cold process, and therefore unlike heat can be used on agricultural commodities without changing their fresh-like character.

- This does not alter significantly nutritional value, flavour, texture and appearance of food.
- Owing to highly penetrating nature of the radiation energy, it is very effective.
- Pre-packaged foods can be treated for improving shelf-life.
- The processing facilities are environment-friendly and are safe for the workers and the public around.
- Use of cobalt-60 does not leave any harmful or toxic residues on foods as in the case of chemical fungicides.

**Limitations.** The processing is a need-based technology and cannot be applied to all kinds of foods.

- It cannot make a bad or spoiled food look acceptable.
- Amenability of a particular food for radiation processing need to be tested in a laboratory.
- Only those foods for which specific benefits are achieved by applying appropriate doses and those duly permitted under the PFA Rules can be processed by this (PFA, 2003).
- It cannot destroy already present pesticides and toxins in the foods.

## 11.3 Food Irradiation Methods

Two different methods, gamma rays and electron beam, may be used to irradiate foods. Gamma radiation is used to preserve bulk quantities of food such as boxed, frozen chicken-breasts or ground beef. For this, food is processed at the food plant, packaged with oxygen-permeable film and transported to an irradiation facility. At the irradiation facility, a conveyor transfers palletized products to an irradiation chamber. Here food is exposed to controlled amount of gamma rays from a radioactive source such as cobalt-60. Gamma rays evenly penetrate food, rapidly killing food poisoning bacteria, harmful parasites or insects without altering food nature. Irradiated foods are not radioactive since rays do not remain in the food.

*Irradiation Chamber.* An industrial irradiator used for food products consists of a room with 2-metres thick concrete walls with the radiation source (cobalt – 60). A conveyor system automatically moves product into the room for irradiation and then removes it. When personnel enter the room, the source is lowered to the bottom of a pool, where water absorbs radiation energy and protects workers. Gamma radiation source is cobalt – 60 rods in stainless steel-tubes. The tubes are stored under water and raised into a concrete irradiation chamber to treat food. These rays emitted are more powerful than rays emitted by a microwave oven. Rays from microwave oven cause rapid heating of food, but gamma rays with much shorter wavelength and higher frequencies only penetrate rapidly in the food and produce little or no heat. For this reason, food irradiation has often been referred as cold pasteurization. And so no radioactive waste is produced at the time of food irradiation (Alkawdi, 1990). Cobalt-60 rods slowly decay to non-radioactive nickel. A food irradiation facility does not contain nuclear reactor. Food is exposed only to degrading cobalt-60. As with other food preservation methods—canning and drying, food irradiation eliminates only microorganisms within the food. Therefore, irradiated product must be handled appropriately to prevent recontamination.

Certain foods such as hamburger, patties may also be irradiated with electron beams emitted from linear accelerators. In this, food is exposed to a stream of electrons that kill bacteria, parasites and insects. This method of irradiation can only be used on foods less than 2 inches thick; due to limiting penetrating capacity of electron beams. Unlike gamma irradiator, linear accelerator units can be turned on and off with a switch.

*Radiation Dose Measurement.* The dose applied to a food product is measured in terms of kilo Grays (kGys). One kilo Gray is equivalent to 1,000 Grays (Gy), 0.1 Megarad (M rad), 100,000 Rads. The basic unit is the Gray, which is the amount of radiation energy that 1 kilogram (2.3 pounds) of food receives. The amount of radiations applied to a food product is carefully controlled and monitored by plant-quality control personnel. The dose applied to the food depends upon its composition, perishability degree, and potential to harbour harmful microorganisms. The amount of radiations that food product absorbs is measured by a 'Dosimeter'. Highly sophisticated scientific methods can be used to test foods for radiation exposure. This would be very important for controlling imports of unlabelled irradiated products.

**Irradiation Conversion Units**

| | | |
|---|---|---|
| 100,000 rads | = | 1 Megarad (M rad) |
| 1 Gray (Gy) | = | 100 rads |
| 1 kilo Gray (kG) | = | 100,000 rads |
| 1 kKGy | = | 0.1 M rad |
| 10 kGy | = | 1 M rad |

Doses of radiations are generally divided into three main categories (Table 11.1).

## 11.4 Irradiation Processes

While term radiation pertains to all forms of treatments to food products; with ionizing radiation, specific types of radiation treatments are used in the food industry.

*Radurization.* It is a process of pasteurization by radiation use. And it is primarily used to treat foods with high moisture and *p*H. Microbes targeted are mainly spoilage organisms. In dried and acidic foods, yeasts and moulds can be denatured. Treatment dose for redurization is approximately 1 kGy.

*Radicidation.* The process is used to eliminate pathogens. This process kills only vegetative cells; means it will not kill spores. Even certain radiation-resistant vegetative cells can survive, and also some strains of bacterium *Salmonella.* Refrigeration is required for the product after treatment. The dose for radicidation ranges from 2.5 to 5.0 kGy.

**Table 11.1** Doses of radiations

| Purpose of Dose | |
|---|---|
| ***Low Dose*** | |
| Sprout inhibition in bulbs and tubers | 0.03–15 kGy |
| Delay in fruit ripening | 0.25–0.75 kGy |
| Insect disinfestation including quarantine treatment and elimination of food-borne parasites | 0.25–1.00 kGy |
| ***Medium Dose*** | |
| Reduction of spoilage microbes to improve shelf-life of meat, poultry and seafoods under refrigeration | 1.50–3.00 kGy |
| Elimination of pathogenic microbes in fresh and frozen meat, poultry and seafoods | 1.50–3.00 kGy |
| Reducing number of microorganisms in spices to improve hygienic quality | 10.00 kGy |
| ***High Dose*** | |
| Sterilization of packaged meat, poultry and their products which are shelf-stable without refrigeration | 25.00–70.00 kGy |
| Sterilization of hospital diets | 25.00–70.00 kGy |

*Radappertization.* It involves treating products to radiations of approximately 30 kGy. This level of radiations kill all vegetative cells and also destroy spores of organisms such as *Clostridium botulinum*. Such levels are generally deemed sufficient for clinical sterility, but are not usually employed on food items. Based on the recommendations of the International Consultative Group on Food Irradiation, many nations limit doses to 10 kGy for many of the food items.

## 11.5 Infrastructural Requirements for Radiation Processing

The radiation processing facility generally consists of the following four major parts: (i) a source of gamma radiation (cobalt-60) for treating food products; (ii) a radiation processing cell (Irradiation cell), where incident radiation is allowed to strike food; (iii) product conveyors and control mechanisms for product contact to radiation and controlling full process of radiation; and (iv) safety devices and interlocks for overall control of process.

## 11.6 Statutory Requirements and Regulatory Approvals

The commercial radiation processing of food in India is regulated by two sets of rules—Atomic Energy (Control of Irradiation of Food) Rules, 1996; and Prevention of Food Adulteration Act (Fifth Amendment) Rules, 1994.

And radiation processing of food requires following licenses: (i) License from the Department of Atomic Energy (Control of Irradiation of Food) rules for operation of radiation processing facility; (ii) License under PFA Rules from the Food and Drug Administration for radiation processing of a food item.

## 11.7 Nutritional Quality of Irradiated Foods

Food proteins, carbohydrates and fats have been found relatively stable to irradiation up to 10 kGy. Minerals have also been reported to be stable to irradiation. However, vitamins A, C, E and $B_1$ (thiamine) tend to be susceptible to irradiation at doses of 1 kGy or above. These vitamins are also sensitive to heat processing. Reduction of these vitamins in foods is minimal, and would not create a risk of deficiency in the diet. A joint committee of the FAO, WHO and IAEA claims that losses of vitamins in foods treated with irradiation doses of 1 kGy or less are minimal and compatible with the losses of vitamins in heat-treated foods and food stored for an extended period of time. Low doses of irradiation do not cause significant decrease in the nutritional quality.

The foods that have current approval by the U.S. Food and Drug Administration (FDA) to be treated with ionizing radiations are in Table 11.2.

## 11.8 Status of Food Irradiation in India

There are approximately 50 countries worldwide permitting irradiation of food in 200 facilities. The food technology division of the Bhabha Atomic Research Centre, Mumbai, has done extensive research on irradiation of various agriculture and food products by using gamma rays from cobalt-60 source. Two facilities have also been set up based

**Table 11.2** Food permitted to be irradiated under FDA's regulations

| Food | Purpose | Dose |
|---|---|---|
| Fresh foods | Growth and maturation inhibition | 1 kGy Max. |
| Fresh pork | Control *Trichinella spiralis* | 0.3 KG – 1 kGy Max |
| Dry enzyme preparation | Microbial disinfection | 10 kGy Max |
| Foods | Arthropod disinfection | 1 kGy Max. |
| Dry spices/seasonings | Microbial disinfection | 30 kGy Max. |
| Poultry | Pathogen control | 3 kGy Max. |
| Frozen meats (NASA) | Sterilization | 4.4 kG y Min. |
| Refrigerated meat | Pathogen control | 4.5 kGy Max. |
| Frozen meat | Pathogen control | 7 kGy Max. |

on this technology. One is at Lasalgaon, Nasik, for onions and the other is at Vasi, Navi Mumbai, for spices and herbs. More than half a dozen cobalt-60 facilities are of 1 kGy or above. The government of India has approved radiation processing of more than 14 items or groups of items.

Technically and from regulatory requirement point of view, two types of radiation processing facilities are feasible—facilities based on radioisotopes and on electron accelerators. In India Centre for Advanced Technology (CAT) is developing 10MeV, 10kW linear electron accelerators for this. The CAT is a nodal agency for the development of accelerators and accelerator-based technology for radiation processing of foods. It is setting up a multi-product facility based on 10 MeV, 10 kW linac, in Indore for demonstration of electron beam technology. Radiation processing facility based on 10MeV, 1 kW linac is being set up at the Central Food Technological Institute, Mysore.

In 1994, Govt of India approved irradiation of onions, potatoes and spices for internal marketing and consumption. Atomic energy has developed two facilities for food irradiation. One commercial irradiation facility is for medical products in Mumbai, which can be used for the treatment of spices also and another is a small pilot-scale food package irradiator at the Food Technology Division, Bhabha Atomic Research Centre, Mumbai, that can treat up to 500 kg of onions and potatoes per hour.

Irradiated food cannot be recognized by sight, smell, taste or touch; all packages of irradiated foods marketed in India are labelled with the words “Processed by Irradiation Method”.

Chapter 12

# Preservation by using Chemicals

## 12.1 Introduction

A preservative is defined as any substance which is capable of inhibiting, retarding or arresting the growth of microorganisms. Chemical preservatives interfere with the cell membrane of the microorganisms, their enzymes or their genetic mechanisms. These are added after the foods are processed.

An ideal preservative should have the following characteristics.

- It must have a wide range of antimicrobial activities, so that all types of microbial growth can be checked.
- It should be nontoxic to human-beings; otherwise it may produce gradually ill effects.
- It should be simple, economical in use and also simple in operation.
- It should not have any effect on the flavour, taste or aroma of the original food.
- It should not be inactivated by food or any substance in the food.
- It should not encourage development of resistant microorganisms.
- It should kill rather than inhibit microorganisms.
- It should not hide inferior quality of food.

**Effectiveness of preservative**. It has been observed that effectiveness of the preservative depends not only on its quality but also on the food products, which are treated by it. Various factors affecting preservative effectiveness are as follows: (i) concentration of the chemical preservative; (ii) kind, number, age and previous history of the organism; (iii) temperature; (iv) time of application; (v) chemical and physical characteristics of food.

## 12.2 Chemical Preservation

Chemicals used in the preservation of foods range from very simple substances such as salt and sugar, to complex compounds such as benzoates etc. The Table 12.1 lists some of the most commonly used preservatives and the foods in which they are used, keeping in view that all of these have been deemed GRAS (Generally Recognized As Safe) in the amounts specified.

**Table 12.1** Chemicals used for food preservation

| Chemical | Amount GRAS | Organism(s) affected | Use in foods |
|---|---|---|---|
| Sulphites | 200-300 ppm | Insects and micro-organisms | Dried fruits, wine, lemon-juice |
| Dehydro-acetic acid | 65 ppm | Insects | Strawberries |
| Sodium nitrite | 120 ppm | Clostridia | Cured meat |
| Ethyl formate | 15-220 ppm | Yeast and moulds | Dried fruits and nuts |
| Propionic acid | 0.32% | Moulds | Breads, cakes, cheeses |
| Sorbic acid | 0.2% | Moulds | Hard cheeses, cakes salad-dressings |
| Benzoic acid | 0.1% | Yeast and moulds | Margarine, soft drinks, ketchup, salad-dressings |

The details of the accepted food preservatives are given in Table 12.2.

*Chemical Preservatives' Working.* In this, preservation of food products is usually based on the combined or synergistic activity of several additives, intrinsic product parameters (composition, acidity, water activity) and extrinsic factors (processing temperature, storage atmosphere and temperature). It is important to standardize amount of chemical preservative as per the quantity and nature of food products. The time of exposure should also be standardized; otherwise it may produce gradually ill effects on the health of human-beings.

*Factors Affecting Chemical Preservatives.* The factors are chemical composition and concentration of microorganism species and initial number of microorganisms in the product. All these determine efficiency of chemical preservatives. Sulphur-dioxide can generally be used as a universal preservative for most kinds of foods as it has antiseptic action on the bacteria as well as on the yeasts and moulds. Benzoic acid has a preservative action, which is stronger against bacteria than on yeasts and moulds; sorbic acid acts on moulds and certain yeast species, and in higher dosages it also acts on bacteria, excepting lactic and acetic ones. Formic acid is more active against yeasts and moulds than bacteria.

If the food is contaminated primarily because of carelessness and hygienic treatment, then efficiency of these preservatives is comparatively less. Dosage level can be reduced with the initial lower number of

**Table 12.2** Accepted food preservatives

| Agent | Acceptable daily intake (mg/kg body weight) | Commonly used levels (%) | Products |
|---|---|---|---|
| Lactic acid | No limit | No limit | - |
| Citric acid | No limit | No limit | Fruit-juices, Jams, other sugar preservatives |
| Acetic acid | No limit | No limit | Vegetable pickles, other vegetable products |
| Sodium diacetate | 15 | 0.3 - 0.5 | - |
| Sodium benzoate | 5 | 0.03-0.2 | Vegetable pickles, preserves, Jams, Jellies, Semi-processed products |
| Sodium propionate | 10 | 0.1-0.3 | Fruits, Vegetables |
| Potassium sorbate | 25 | 0.05-0.2 | Fruits, Vegetables, Pickled products, Jams, Jellies |
| Methyl paraben | 10 | 0.05-0.1 | Fruit-juices, Juice concentrates, pickles and pickled tomatoes |
| Sodium nitrite | 0.2 | 0.01-0.02 | - |
| Sulphur dioxide | 0.7 | 0.005-0.2 | Fruit-juices, Dehydrated fruits and vegetables, Semi-processed products |

microorganisms in the product. The efficiency of the majority of the chemical preservatives is higher at lower *p*H values, i.e. when the medium is acidic. Dispersion of the chemical in the food has impact on its absorption and diffusion through cell membrane; and this determines preservation. Thus, smaller the slice of the fruits and vegetables, higher is the action of the preservative. Preservative dispersion is slowed down by viscous foods (e.g. concentrated fruit juices). Dose level is also established as a function of product temperature and characteristics of the microflora and the time period for various preservatives. To have a chemical sterilization by benzoic acid, a few weeks are needed, but shorter time is required for sulphurous acid.

*Advantages of Chemical Preservatives.* They are useful as they can create freshness, maintain colour or prevent discolouring of fruits and vegetables, keep fruits from turning spoiled, and treated products are relatively healthier compared to salt and sugar preservation.

*Disadvantages of Chemical Preservatives.* When recommended for long-term preservation, they can pose health hazards. Overdoses can potentially cause cancer and can disrupt functioning of the body cells.

Thus, foods with such chemicals cannot be consumed by those who are allergic to preservatives.

### 12.2.1 Gaseous Chemical Preservatives

*Carbon-dioxide.* It is a colourless, odourless, non-combustible gas, acidic in odour and flavour. In commercial practice, it is sold as liquid under pressure (58 kg/ $cm^3$) or solidified as dry ice. Carbon-dioxide is used as a direct additive in storage of fruits and vegetables. It inhibits growth of psychotrophic microorganisms and prevents spoilage of fruits and vegetables. It retards ripening of fruits and vegetables and growth of yeast and mould. There have been many explanations suggested by different authors that it affects permeability of the membranes surrounding cells. Some have suggested that carbon-dioxide interferes with protein binding amino acids in the cell. However, finally it has been suggested that it interferes with enzymes and their activity. Different studies have shown that all three of the above explanations are possible, so it could be a combination of all the three. The following contains some of the established facts concerning carbon-dioxide and microbes.

- Its inhibition effect increases as temperature decreases. This is because carbon-dioxide is easily soluble in water at lower temperatures.
- The optimum concentration ranges from 20 to 30%. No supplementary effects could be documented by using concentrations above 20 – 30%.
- The inhibition effect increases as *p*H decreases.
- Microbes that are classified as gram negative are more susceptible to inhibition effect than those classified as gram positive.
- Carbon-dioxide under pressure has a greater antimicrobial effect than the normal carbon-dioxide.

*Sulphur-dioxide and Sulphites* Sulphur-dioxide has been used as a fumigant for many centuries, and especially as a wine preservative. It is colourless, suffocating, pungent smelling, non-flammable gas, and is highly soluble in cold water (85 g in 100 ml at 25°C).

Sulphur-dioxide and its various sulphites soluble in water and at low *p*H levels yield sulphurous acid, bisulphite and sulphite ions. Various sulphite salts contain 50-68% active sulphur-dioxide. At *p*H less than 4.0, antimicrobial activity reaches maximum. Sulphur-dioxide is used as a gas or in the form of its sulphites; bisulphite and metabisulphite salts are powders. Gaseous form is produced either by burning sulphur or by its release from compressed liquid form. Metabisulphites are more stable than sulphites. Sulphur-dioxide and sulphites are used in preservation of a variety of food products; in addition to wines, are dehydrated dried fruits and vegetables, fruit-juices, acid pickles, syrups, semi-processed fruit products etc. Sulphur-dioxide is added to foods for its antioxidant and reducing properties and to prevent enzymatic and non-enzymatic browning reactions.

*Chlorine.* Various forms of chlorine [chlorine ($Cl_2$), sodium hypochlorite ($NaCOCl_2$), calcium hypochlorite ($CaCOCl_2$) and chlorine dioxide gas ($ClO_2$)] constitute most widely used chemical sanitizers in the food industry. These compounds are used as water adjuncts in processes such as product washing, transport and cooling of heat-sterilized cans and in sanitizing solutions for equipment surfaces.

### 12.2.2 Commonly used Lipophilic Acid Food Preservatives

- Sodium benzoate is a common preservative for acid or acidified foods such as fruit-juices, syrups, jams and jellies, sauerkraut, pickles, preserves, fruit-cocktails etc. Yeasts are inhibited by benzoate to a greater extent than are moulds and bacteria.
- Sorbic acid is generally considered nontoxic and is metabolized among other common food preservatives. WHO has set the highest acceptable daily intake (25 mg/kg of body weight) for sorbic acid. Sorbates are used for mould and yeast inhibition in a variety of foods, including fruits and vegetables, fruit-juices, pickles, sauerkraut, syrups, jellies, jams, preserves and for high-moisture dehydrated fruits.
- Sorbic acid and its salts are practically tasteless and odourless in foods, when used at the reasonable levels (<0.3%) and their antimicrobial activity is generally adequate. Potassium sorbate, a white, fluffy powder, is highly soluble in water (over 50%) and when added to acid foods is hydrolyzed to its acid form.
- Acetic acid is a general preservative, inhibiting many species of bacteria, yeasts, and to a lesser extent of moulds. It is also a product of lactic acid fermentation, and its preservative action even at identical *p*H level is higher than that of lactic acid. The main application of vinegar (acetic acid) is in products such as pickles, sauces and ketchup.
- Malic and tartaric acids are used in some countries mainly to acidify and preserve fruit-sugar preserves, jams, jellies etc.
- Citric acid is a tricarboxylic acid having pleasant and sour taste, found naturally in variety of fruits. It is widely used in carbonated beverages and as an acidifying agent of foods owing to its unique flavour. It has an unlimited acceptable daily intake and is highly soluble in water. Its effectiveness as an antimicrobial agent is lesser than other acids.
- Ascorbic acid or vitamin 'C' is isomer isoascorbic or erythorbic acid

and its salts are highly soluble in water and safe to use in foods.

- Propionic acid is short chain fatty acid ($CH_3$ $CH_2$ COOH) and affects cell membrane permeability. Sodium or calcium propionate is used extensively in prevention of mould growth, particularly rope development in baked goods and cheese foods. Both are effective against moulds with little or no inhibition for most yeasts and bacteria. Their effectiveness decreases with decrease in *p*H. An optional upper limit of *p*H is 5 - 6, depending upon the food items. They appear to be ideal preservatives for bread and baked goods as they have little inhibitory effect on yeasts and can be added to dough of yeast-raised baked goods without interfering with leavening.

### 12.2.3 Preservation by Antibiotics

Antibiotics are chemical substances produced by microorganisms, which have the capacity of inhibiting growth or destroying other kinds of microorganisms. Their use and application in medicine is well-known. Some antibiotics are also used to preserve fruits, vegetables and their products.

Subtelin from *Bacillus subtilis* is used to facilitate preservation of asparagus, corn and peas. It is effective against gram-positive bacteria and spore-forming organisms. Canned peas and tomatoes containing 10 and 20 ppm of subtelin are found free from growth of microorganisms (Ray and Daeschel, 1992).

Nisin produced by *Streptococcus lactis* is non-toxic, and is widely used in food industry and in canned foods. It is commonly used in canning of mushrooms, tomatoes and milk products. Nisin suppresses growth of spoilage organisms, mainly gas-producing, spore-forming bacteria and toxin-producing *Clostridium botulinum*.

Chapter 13

# Modern Methods of Preservation

## 13.1 Pulsed Electric Field Processing

Preference of the consumers for processed foods with more 'natural' flavour and colour and also with a sufficient shelf-life led to the development of preservation technologies that do not have adverse effects on the quality of the food. Food-processing techniques developed are with the solutions to prevent microorganisms' growth without compromising on the initial quality of the product. In the last four years, preservation based on the pulse electric field (PEF) technology, used for milk preservation, has reached the highest point in commerce, scientific and technological developments. Now PEF processing is also getting importance in the fruit-juice and dairy industries.

The PEF processing is for processing cells by means of brief pulses of the strong electric field. It holds potential as the type of the low temperature alternative pasteurization process for sterilizing food products. In this processing, substance is placed between two electrodes and pulsed electric field is applied. The field enlarges pores of cell membranes, which kills cells and releases their content. The PEF is a developing technology, still under research. Nearly all cells have pores which control flow of nutrients into and out of the cell. Once pores are sufficiently enlarged, contents of the cell are released into the surrounding medium,and foreign matter may enter into the cell membrane (Rice, 1994).

*Principles of PEF Processing.* This technology is based on the phenomenon that biological membranes are punctured when extent impulse is applied. This is often referred to as the non-thermal; as the structural damage to membranes is realized at low energy level compared to heating process. For food applications, this has led to formulations; of which first one is a mild preservation, where PEF treatment is targeted only for inactivation to extend shelf-life. Secondly, a versatile process (High Electrical Field Pulses: HEFP) has been developed for plant foods. Pretreatment enhances excretion of compounds from tuberous plants, and improves drying properties of the vegetables to be dried.

The PEF produces products with slightly different properties than conventional pasteurization treatments. Most of the enzymes are not affected by the PEF. The fact that the maximum temperature reached in this process is lower than the thermal pasteurization; it maintains some of the flavours associated with the raw material. The lack of heat treatment makes PEF somewhat comparable to irradiation treatment. Spores with their protective coats and dehydrated cells are often able to survive. The survival of spores and enzymes means that products should be refrigerated after passing through PEF to slow down action of enzymes and to keep pathogens away from growing.

As a mild preservation treatment, PEF is used to inactivate microorganisms at the low temperature. And typical process is a hybrid of heat treatment and electrical pulses, supplied at temperature-time combination of 50°C for 3 seconds. Heat load experienced by the products under these conditions is much less than pasteurization at temperatures in the range of 70-90°C for 30-60 seconds. Processing conditions in this process can be achieved optimally, as the initial organoleptic and seasonal quality of fruit-juices are not compromised. Recently, large-scale equipment processes have been demonstrated that allow industrial applications of 2,000 litres/hour, based on the PEF technology.

PEF treatment has considerably added value to specific products range. The PEF treatment is a possible solution for eliminating pathogens found in raw milk for preparation of cheese, and for a second extension of shelf-life of stable acid products, e.g. fruit-juice, obtained from the concentrate. Shelf-life of fresh-orange juice extends from a few days to a few weeks by this. The PEF is only a solution to increase shelf-life of the product when an aseptic process is adapted.

*Advantages and Limitations of PEF Processing*. It is effective for inactivation of vegetative bacteria only, and is not effective towards bacterial spores. Applications will, therefore, be found in the range of acid products and products that are distributed in the refrigerated condition. Second limitation is that treatment does not inactivate enzymes. And so even after treatment, products are liable for enzymatic spoilage.

The major cost of the PEF process is determined by the initial investment in the equipment. This means that major additional cost per unit is determined by depreciation. Stock Food and Dairy systems have calculated the total cost for the PEF treatment of orange-juice at 0.01 Euro per litre (Table 13.1).

## 13.2 High Pressure Processing

Another method designed to maintain foods in their raw, natural

**Table 13.1** Foods processed using PEF

| Products | Process and quality attributes |
|---|---|
| Apple juice, fresh and reconstituted | Pasteurization – No change in solid concentration, *p*H and vitamin C. Loss of calcium, magnesium, sodium and potassium. No sensory difference between processed and untreated juices |
| Commercial cheese, sauce, reformulated | Preservation—Better flavour and appearance than comparable products |
| Green-pea soup | Cooking—No sensory difference after four weeks storage at 4°C |
| Liquid whole egg | Pasteurization—Prevention of coagulation, superior quality |
| Orange-juice | Preservation—at the Pilot scale; less than 6% flavour loss, negligible vitamin C and colour change |
| Orange-juice fresh | Pasteurization— Minimal loss of flavour, colour and vitamin C |

state and to only destroy contaminating organisms is high pressure processing (HPP). When the organisms are placed under the conditions of very high pressure, their proteins get denatured, resulting in loss of enzymatic and biological activities. And the organisms lose their viability and perishability. This is easily accomplished for vegetative bacteria than for spores, which require much higher pressures (Tauscher, 1999).

Studies showed that this processing is beneficial in extending shelf-life of processed fruits. Modern high pressure treatments allow food materials to be under pressure as high as 9,000 atmosphere, applied uniformly throughout the food, independent of its mass. This method is currently applied to fruit-jams and juices, particularly, in Japan. Raw materials are placed in chambers under very high pressure for 10-60 min. prior to opening release valve. Both the equipment and the process are costly, and as the result major commercial limitation to this method is economical rather than technical. As a commercial process, this treatment can significantly increase cost of food (Table 13.2).

In this, food is preserved by being pressed inside a vessel exerting pressure of 70,000 pounds per square inch (4,921 kg/cm$^2$) or more. Processed food retains freshness, flavour, texture and nutrients, while disabling harmful microorganisms and slowing spoilage using hydrostatic pressure through water, which is pumped into a sturdy closeable steel-vessel. Foods of any shape or size are equally squeezed around their surface area without crushing food particles. It is effective

**Table 13.2** Products processed using high pressure technology and changes in quality attributes other than microbial changes

| Product | Quality attributes |
|---|---|
| Avocado puree | Prevents discolouration. Inhibition of undesirable browning reaction in low *p*H |
| Banana puree | Prevents discolouration. Reduction in polyphenol oxidase activity when combined with blanching |
| Cheese | Precise control of rennet coagulation of milk |
| Jam | Commercial production. Improved retention of colour and flavour of fresh-fruit |
| Meats | Thawing. Reduction in drip loss and less colour change |
| Meat tenderized | Commercial production (Japan). Improved retention of sensory characteristics |
| Orange-juices, fresh squeezed | Preservation. Retention of colour and cloud stability during storage |
| Pink grape fruit-juice fresh squeezed | Preservation. Retention of colour and cloud stability during storage |
| Potato | Freezing. Reduction in freezing time in potato cylinders |
| Soy proteins | Manufacturing less firm but more elastic and extensible gels. Improved preservation of colour and aroma |
| Tofu | Freezing. Production of small-sized ice crystals |
| Tomato-juice | Juice production. Modification of physical and sensory characteristics deemed desirable |
| Yoghurt | Storage. Reduced syneresis or weeping |

for most moist foods such as fruits, vegetables, sauces and ready-to-eat meats. The high pressure cycle takes no longer than six min compared to traditional high temperature processing that takes an hour or more, without causing chemical changes that degrade food quality (Farr, 1990).

The critical process factors in the HPP include pressure, time at pressure, time to achieve treatment pressure, recompression time, treatment temperature, initial temperature of products, vessel temperature distribution at pressure, product *p*H, product composition, product water activity, packaging material integrity and concurrent processing aids. Some types of *Clostridium botulinum* are capable of surviving even in the most extreme pressure and temperature of the HPP, and there is no absolute indicator for the microbial sterility by the HPP.

*Benefits and Applications of High Pressure Food Preservation.* Unlike heat treatment, HPP does not disrupt chemical bonds, so nutrient and flavour components of the food are left intact, resulting in a product that has generally a far fresher taste, crisper texture, higher nutritional value and fresh colour compared to thermally processed counterparts. The HPP treated fruit-juices no longer have that cooked flavour (Swientek, 1992).

- This Process inactivates microbes by damaging their outer cell membrane. With an understanding of an appropriate processing condition, HPP can also inactivate some enzymes—pectin methyl esterase that impacts on cloud stability of orange and other fruit-juices.
- HPP pasteurization inactivates microbes, leaving a product free of additives and the one that retains its taste and nutritional value for an extended period of time. Successful HPP products on global food markets include sliced small goods (Spain, USA); fruit-jams, fruit-jellies and rice (Japan); fruit-juices (France, Italy, UK, USA); ready-to-eat meats (USA); and apple sauce (Canada). Most of these are high-value specialized products attracting premium prices and lower value products, receiving a terminal in-pack treatment to assure their safety.
- No nutrient degradation is possible with the HPP.
- The process enhances food safety and shelf-life extension of minimally processed foods.
- Creation of novel products with unique texture by pressure induced gelation and denaturing of proteins.
- Easy scale-up to commercial production.
- Clean technology with no pollution.

However, there are a few disadvantages or limitations in use of the HPP, which are summarized as follows.

- To fabricate pressure vessels and seal that can withstand high pressure during cycles of pressurization and depressurization.
- Equipment is expensive.
- HPP alone cannot inactivate bacterial spores.
- HPP cannot process dry foods or foods having less water.

*Equipment for Batch HPP Treatment.* The essential equipment required for HPP treatment are: (i) a pressure vessel of cylindrical design; (ii) two end closures; (iii) a mean for restraining end closures (for example, yoke, threads, pin); (iv) a low pressure pump; (vi) an intensifier which uses liquid from low pressure pump to generate high pressure process fluid for system compression; and (vii) necessary system controls and instrumentation.

## 13.3 Ultrasound Processing

This technology uses energy generated by sound waves of 20,000 or more vibrations per second. And has a wide range of current and future applications in the food industry, including inactivation of microorganisms and enzymes. However, most developments for food applications in the present context are non-microbial; the bactericidal effect due to ultrasound is attributed to intracellular cavitations— micro-mechanical shocks disrupting cellular structural and functional components up to the point of cell lysis. Due to some limitations, its current probability for commercial development is low; combination of ultrasound with other preservation processes (e.g. heat and mild pressure) appears to have a greater potential for industrial applications.

Low-intensity, high-frequency sound waves result in the improvement of food products or process monitoring owing to accelerated diffusion. Their industrial applications include texture, viscosity and concentration measurements of solids or fluid concentration of eggs, meats, fruits and vegetables, dairy and other products thickness, flow level and temperature measurements for monitoring and control of processes.

*Critical Process Factors.* They are assumed to be as follows: The amplitude of ultrasonic waves, the exposure/contact time with microorganisms, type of microorganisms' present in the food and their concentration, volume of food to be processed, composition of food and temperature of treatment. When ultrasound is used in combination with other processes, then their critical process factors should also be taken into account.

The ultrasound lacks power and versatility to inactivate microorganisms for food preservation; however, this may be used in combination with other preservation processes to enhance primarily microbial inactivation in foods.

As stated above, mechanism for inactivation of vegetative bacteria appears to be intracellular cavitations. Maximum effectiveness results in cellular lysis. For spores, mechanism is still not clear. Cavitation may play a role, but it is an auxiliary one, since ultrasound alone has no effect on spores.

At the current state of commercial development for the purpose of food preservation, ultrasound has a potential to enhance effectiveness of other processing methods. No mathematical model has still been formulated for inactivation of microorganisms by ultrasonic methods.

## 13.4 Ohmic Heating Process

To improve uniform transfer of heat to food products, attempts were made to carry out thermal treatment in the scraped-surface heat-exchanger, followed by aseptic packaging in aluminum cans. This worked well for uniform fluid products such as smooth puddings, but failed when larger particulate matter was incorporated, as it heated slowly than the surrounding fluid. The entire process has to be slowed down to ensure that particulates are properly treated once solution is undergoing ohmic heating.

*Principal.* An electric current is passed through food and solid materials for heating up as fast as or even faster than the surrounding fluid. Electrical current heats all particles quickly and efficiently such that final temperatures required for killing or inhibiting bacteria are achieved with far less heat than is required for total cooking. This results in products of improved quality. The process is at present commercial but the total volume of products treated in this manner is small. Ohmic heating (sometimes also referred to as Joule heating, electrical resistance heating, direct electrical resistance heating, electro-heating and electro-conductive heating) is defined as a process of passing electric currents through foods or other materials to heat them.

Inductive heating is a process where electric currents are induced within food owing to oscillating electromagnetic fields generated by electric coils.

### 13.5 Pulsed-Light Treatment

This involves use of high intensity light for killing microorganisms on the surface of the food or of the packaging material. This procedure developed under the trade name 'Pure Bright', uses a light spectrum containing wavelengths from ultraviolet to near-infrared. The light spectrum generated with this equipment is similar to that of sunlight reaching earth's surface but Pure-Bright intensity is 20,000 times higher. The intense flashes of light produced by the Pure Bright system are used to destroy microorganisms (Dunn, 1995).

Application of pulsed light has been found to reduce up to nine logs of vegetative microorganisms and more than seven logs of bacterial spores on the smooth, non-porous surface such as that of the packaging material.

This treatment was approved by the FDA in 1996. It allows use of pulsed light for food treatment at influences up to 12 $J/Cm^2$. This is currently being applied in the pharmaceutical packaging material where translution aseptically manufactured bottles and containers are sterilized through light treatment chamber.

Industrial implementation of light pulse technology for preservation is rather slow; despite its potential for generation of safe, nutritious and high quality products.

*Principle and Equipment of Light Pulse Generation.* White light pulse is generated by electrically ionizing zenon-gas-filled flash lamp for a few hundred millionth of a second with a high power, high-voltage pulse.

The pulse is produced by storing it electrically in a high-energy density capacitor and releasing it in short, high-intensity, high-peak power pulses. Electrical energy is used to energize lamp, which is converted with high efficiency to broadband white light emission (Ansari, 2004). The system consists of two main parts: (i) power unit and (ii) lamp unit

The power unit generates high-voltage, high-current pulses used for energizing lamps. This unit operates by converting line voltage AC power into high voltage DC power to charge a capacitor. Once the capacitor is charged to a pre-set point, a high voltage switch discharges light energy from capacitor to lamp.

*Applications and Advantages of Light Pulses.* Main applications of light pulses are as follows.

- It reduces microbial population on the surface of the packaging materials, transparent pharmaceutical products, food or other surfaces. In processed meat products such as sausages, light pulses increase their shelf-life under refrigeration.
- Fresh tomatoes exposed to pulse light and held at low temperature are of acceptable quality for more than 30 days.

*Disadvantages.* Disadvantages in the use of this method are as follows.

- Polyethylene, polypropylene, nylon and many other non-benzene based plastics generally transmit pulsed light well (Gustavo, 1997).
- The choice of packaging material for packaged foods to be treated by light pulses is limited, because packaging material must transmit at least 10-50% of the light energy over a predetermined wavelength range of less than 320 nm.

## 13.6 Oscillating Magnetic Fields

There are mixed results in inhibition of microorganisms when placed in the oscillating magnetic field (OMF). Some studies indicated that magnetic fields had an inhibitory effect on the microbial population, while others showed no effect or in some cases, a stimulating effect was observed. In one study, foods with high electrical resistance were subjected to one or more pulses of oscillating magnetic fields, and it was observed that a single pulse of magnetic field decreased microbial population by at least two orders of magnitude. The process involves little thermal energy input, thus avoiding thermal denaturiziation of food components during treatment.

To inactivate microorganisms, OMF has a potential to pasteurize food with improvement in quality and shelf-life compared to conventional pasteurization processes. Experiments have showed that strong static fields (SMF) or oscillating magnetic fields (OMF) of 5-50 Tesla have potential to inactivate vegetative microorganisms. Preservation of food with OMF involves sealing food in a plastic bag and subjecting it to 1-100 pulses in an OMF at 0-50°C for total exposure time of 25-100 msec. No special preparation of food is required before treatment of the food by the OMF.

However, the method is still in a experimental stage, and more research is needed to understand the changes in microbial population when treated with the OMF.

Chapter 14

# Preservation by Dehydration and Concentration

## 14.1 Introduction

Drying is a simple, safe and easy-to-learn method for food preservation. It removes biologically active water from the food so that bacteria, yeasts and moulds cannot grow. It also slows down the enzyme action. Processing for drying should be done in such a way that food value, natural flavour and characteristic cooking quality of the fresh material is retained. Many fruits are preserved by drying than by any other methods of preservation. The residual moisture in the vegetables should not be more than 6-8%, and in fruits, it should be about 10-20%. Dried fruits can be used as such or after soaking; while dried vegetables are usually soaked in water overnight and then cooked.

In the food industry, term "dehydration" means artificial drying (Van Loesceke, 1998). Dehydration implies control over climatic conditions within a chamber or micro-environment controlled conditions. Dried foods from a dehydration unit have better quality than sun-dried counterparts. Dehydration methods are more expensive than open sun-drying. But dried fruits yield from a dehydrator is higher. Owing to continued respiration of tissues and fermentation, sugar concentration of fruits reduces during sun-drying. While cooking also, qualitative dehydrated foods are usually far superior to sun-dried ones. On the basis of the cost economy, however, sun-drying is advantageous, but if the time and quality are considered, dehydration merits. Further, sun-drying cannot be practical in many areas due to unfavourable weather conditions (Jayaraman and Dasgupta, 1992).

Drying or dehydration has following advantages compared to other preservation methods.

- It requires less storage space due to reduction in bulk of the product.
- Cost of processing is very low, as less labour and no sugar is required.
- Weight of the product is reduced to 1/4 to 1/9 of its original or fresh weight, and thus its transport cost is also reduced.

There are three basic types of drying processes: (i) sun-drying or solar-drying; (ii) atmospheric drying, including batch (kiln, tower and cabinet driers) and continuous (tunnel, belt, belt-trough, fluidized bed, explosion puff, foam mat, spray, drum and microwave) drying; (iii) sub-atmospheric dehydration (vacuum shelf/belt and freeze-drier)

The scope has been expanded to include use of low temperature; low energy process like osmotic dehydration. Food-stuffs may be dried in air, super-heated steam in vacuum, in inert gas or by direct heat application. Air is generally used as a drying medium because it is plentiful, convenient, and above all, over-heating of food can be controlled in it (Mishra and Agarwal, 2005). Air conveys heat to food; causes water to vapourize, and is the vehicle to transport liberated vapours from dehydrating food. More air is required to conduct heat to food to evaporate water present than is needed to transport vapour from the chamber. In general, temperature (heat input), air-flow rate and humidity are three important parameters for drying food, which are to be regulated as per the needs of the products and climatic conditions.

*Types of Dryers*. Particular type of dryer is chosen on the basis of the nature of the commodity to be dried, desired form of the finished product, and economics and operating conditions (Table 14.1).

**Table 14.1** Types of dryers

| Dryer | Product to be dried |
|---|---|
| Drum dryer | Milk, vegetable juices, bananas |
| Vacuum shelf-dryer | Limited production of certain foods |
| Continuous vacuum dryer | Fruits and vegetables |
| Continuous belt (atmospheric) dryer | Vegetables |
| Fluidized-bed dryer | Vegetables |
| Foam-mat dryer | Juices |
| Freeze dryer | Meats |
| Spray dryer | Whole eggs, egg yolk, blood, albumin and milk |
| Rotary dryer | Some meat products; not used for food |
| Cabinet dryer | Fruits and vegetables |
| Kiln dryer | Apples, some vegetables |
| Tunnel dryer | Fruits and vegetables |

## 14.2 Dehydration

It is an operation in which both heat transfer and mass transfer takes place. Heat is transferred to water in the product, and water vapourizes. Then water vapours are removed.

Dryers for dehydration can be grouped into two classes: (i) one in which heat is carried into the dryer by hot-gas. The gas gives up heat to water in the food and carries away water vapours produced. The hot gas may be the product of combustion or heated air; (ii)in the second type, heat is transferred to the product through a metal plate, which also carries the product. The product is usually held under a vacuum and water vapours are removed by a vacuum pump. In some cases, the product is exposed to air and vapours are removed by circulating air.

It is possible to supply heat by infrared, dielectric and microwave heating methods. An acceptable dehydrated food should be competitive price-wise with other types of preserved foods; should have a stable odour and appearance, comparable with fresh product or with products processed by other means; reconstitute readily; retain nutritive value; and should have good storage stability.

**Nutritive value of dried and dehydrated foods**. In drying, food loses its moisture content that results in increased concentration of nutrients in the remaining mass. Protein, fat and carbohydrates are present in larger amounts per unit weight in the dried peas (Table 14.2).

**Table 14.2** Essential elements in fresh and dried peas

| Particulars | Peas (% composition) | |
|---|---|---|
| | Fresh | Dried |
| Protein | 7 | 25 |
| Fats | 1 | 3 |
| Carbohydrates | 17 | 65 |
| Moisture | 74 | 5 |
| Ash | 1 | 2 |

A range of chemical changes takes place during drying, and these contribute to final quality of both the dried items and their reconstituted counterparts in terms of food colour, flavour, texture, viscosity, reconstitution rate, nutritional value and storage stability. These changes are product specific, but a few types occur in virtually all foods undergoing dehydration.

- Browning reactions may be from any of the usual causes including enzymatic oxidation of polyphenols or other susceptible compounds of the oxidizing enzymes not inactivated.
- Most of the vitamins like vitamin C, B complex are light and heat sensitive and are lost during blanching with heat or chemicals prior to drying. Fat soluble vitamins (A, D, E and K) are mostly contained within the dry matter of food and are not therefore concentration during drying.

- Caramalization of sugars and souring of other materials if heat is excessive, is another common type of browning.
- Thiamine is heat-sensitive and is destroyed by sulphuring.
- The biological value of dried protein is dependent on the method of drying. Low temperature treatment of protein may increase digestibility of protein over native material.
- Rancidity is an important problem in dried foods. Oxidation of fats in foods is greater at higher temperature of dehydration. Protection of fats with antioxidants is an effective control.
- Fruits are generally rich source of carbohydrates and poor source of proteins and fat. Their discolouration may be due to enzymatic browning or caramelization type of reactions. Addition of sulphur dioxide to tissues controls browning. Slow sun-drying leads to extensive deterioration unless tissues are protected with sulphites or other suitable agents. Burning sulphur is the least expensive method of obtaining such protection, and is done prior to drying.

*Dehydration of Fruits and Vegetables.* Dehydration is a means of producing dried fruits of new forms and of better quality than is possible by sun-drying. Some of the fruits which are commercially dehydrated are: apples, apricots, peaches, nectarines, pears, grapes, figs and cherries; banana puree is drum-dried. Freeze-dried fruits are of exceptionally good quality (Achanta and Okos, 1996).

In dehydration of vegetables, enzyme system needs to be inactivated. This is accomplished by heating in boiling water or by steaming. Vegetables' moisture content should be less than 4% for satisfactory storage and quality retention. Vegetables are usually dried in tunnel, cabinet or belt driers. For some powdered vegetable products, drum-dryer and spray-dryer are used. Before blanching, cabbage should be shredded, carrots and potatoes may be sliced, green beans may be sliced and dry beans may be cooked. Potatoes, carrots and beets are lye-peeled. Blanching time varies for different vegetables (Table 14.3). In general, 1-3 min are adequate for leafy vegetables, 2-8 min for peas, beans and corns and 3-6 min for potatoes, carrots and similar vegetables. Safe drying temperature for most vegetables is between 60° and 62°C, but 73°C is permissible for cooked and dried beans, 68°C for carrots, 71°C for corn and 57°C for onions and squash. The final moisture content desired for most vegetables is 4%, while 2 to 3% is recommended for most powders. Calcium-chloride treatment of potatoes for dehydration offers a means for controlling heat damage during drying and to control non-enzymatic browning during storage at warm temperature (Fig. 14.1)

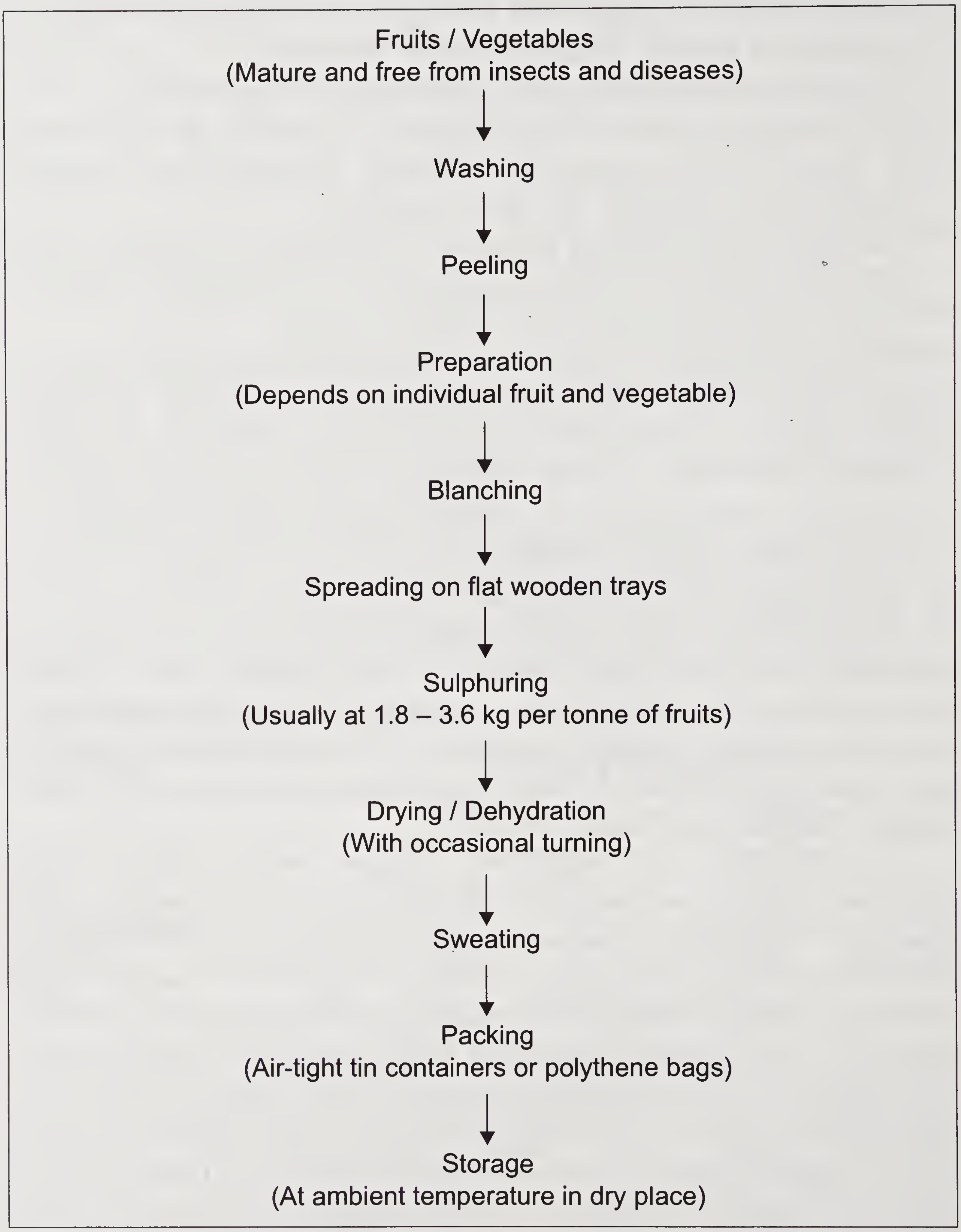


**Fig. 14.1** Drying/dehydration of fruits and vegetables

*Mechanical Dehydration.* The different unit operations employed for various fruits and vegetables are given in Table 14.3.

*Packaging of Dehydrated Products.* Vegetables are ordinarily packaged in tin containers. If packaged dehydrated foods are to be stored for a considerable period of time, it is advisable to use low-temperature storage. For long-term storage, functional containers hermetically sealed and resistant to penetration by insects are required.

**Table 14.3** Different unit operations employed in drying

| | | | |
|---|---|---|---|
| Banana | → Wash, peel, half length-wise or slice cross-wise 12-mm thick | → Sulphuring time (30 min) | → Drying temp. 55-60°C or sun- dry |
| Grape | → Dip in boiling 0.5% caustic soda solution, then rinse | → Sulphuring time (1 hr) | → 55-60°C or sun-dry |
| Mango | → Wash, peel, cut into 12-mm thick slices | → Sulphuring time (2 hr) | → 45-50°C or sun-dry |
| Papaya | → Wash, peel, remove seeds and cut into 6-mm thick slices | → Sulphuring time (2 hr) | → 60-65°C or sun-dry |
| Apple | → Wash, peel, core trim and cut into 5-mm thick slices | → Immerse in 2% salt solution for 30 min to prevent browning, then sulphuring (2g $SO_2$/kg of fruits for 30–40min) | → 60-65°C or sun-dry |
| *Aonla* | → Wash, grate, add salt at 40 g/kg grated material | → - | → Sun-dry |
| Cauliflower | → Wash, remove stalks, break flowers apart into pieces of suitable size | → Blanch 4-5 min, immerse for 1 hr in 1% KMS solution and drain | → 55-60°C or sun-dry |
| Cabbage | → Wash, remove outer leaves and cut core into fine shreds | → Blanch 5-6 min, immerse for 10 min in 0.5% KMS solution and drain | → 55-60°C or sun-dry |
| Green peas | → Wash, remove shells, and collect grains | → Blanch or steam 3-4 min, immerse in 0.5% KMS solution and drain | → 60-65°C or sun-dry |
| Onion | → Remove outer dry scales, cut into 5-mm thick slices | → Dip for 10 min in 5% salt solution and drain | → 60-65°C or sun-dry |
| Garlic | → Peel cloves, use as such or cut into 5-mm thick slices | → Dip for 10 min in 5% salt solution and drain | → 60-65°C or sun-dry |
| *Palak, methi* and other leafy vegetables | → Sort, wash and trim off rough stems and shred stalks | → Blanch for 2 min in boiling water or steam | → 60-65°C or sun-dry |
| Tomato | → Wash | → Blanch for 30-60 seconds, peel and slice 10-mm thick | → 60-65°C or sun-dry |
| Carrot | → Wash, scrape stalk and tips, cut into 10- mm thick slices | → Blanch for 2-4 min in boiling 2% common salt solution | → 60-65°C or sun-dry |
| Beans | → Wash, remove strings, split pods length-wise | → Blanch for 4-5 min | → 60-65°C or sun-dry |

### 14.2.1 Freeze-Drying (Lyophilization)

Freeze-drying, a dehydration process, is typically used to preserve perishable material or to make material convenient for transportation. Freeze-drying works by freezing material and then reducing surrounding pressure and adding enough heat to allow frozen water in the material to sublime directly from solid phase to gaseus phase.

Basic process of this drying is sublimation/removal of water content from frozen food. Dehydration occurs under a vacuum, with plant/ animal product solidly frozen during the process. Shrinkage is eliminated or minimized, and a near perfect preservation results in. Freeze-dried foods last longer than other preserved foods and are very light, so are perfect for space travel also. This drying requires a freeze drier and a vacuum pump for removing moisture. Over 400 different types of freeze-dried foods have been commercially produced since 1960s. Unsuitable for freeze-drying are lettuce and watermelon because they have high water content to be freeze-dried properly. Freeze-dried coffee is the best known freeze-dried product.

*Drying Process.* There are three stages in freeze-drying—freezing, primary drying, secondary drying.

**Freezing.** This consists of placing the material in a freezer-drying flask and rotating this flask in a bath, called a shell-freezer, which is cooled by mechanical refrigeration, dry ice and methanol or liquid nitrogen. On a larger scale, freezing is done in a freeze-drying machine. In this, it is important to cool material below its eutectic point (the lowest temperature at which solid and liquid phases of the material can coexist). This ensures that sublimation rather than melting will occur in the following step. Larger crystals are easier to freeze dry. To produce larger crystals, product should be frozen slowly or can be cycled up and down in the temperature. This cycling process is called **annealing**. However, food or objects with formerly living cells, large ice crystals will break cell wall. As discovered by Clarence Birdseye, when food is frozen at – 40°C to – 45°C or below, then it tastes better. Usually, freezing temperatures are between –50°C and –80°C. Freezing phase is the most critical one, because the product can be spoiled if its done badly.

**Primary drying.** During this phase, pressure is lowered (to the range of a few milli bars) and enough heat is supplied to the material for water to sublimate. The amount of heat necessary can be calculated using 'sublimating molecules' or latent heat of sublimation. In this initial drying phase about 95% of the water in the material is sublimated. This phase may be slow (can be several days in the industry), because if too much heat is added, material structure can be altered.

Pressure is controlled through partial vacuum. The vacuum speeds sublimation, making it useful as a deliberate drying process. Further more, a cold condenser chamber and/or condenser plate provides surface for water vapour to resolidify on. This condenser plays no role in keeping material frozen, rather it prevents water vapour from reaching vacuum pump, which could degrade pump's performance. Condensor temperatures are below –50°C (–60°F). It is important to note that in this range of pressure, heat is mainly brought by conduction or radiation; convection effect can be considered as insignificant.

**Secondary drying.** This is for sublimating water molecules that are absorbed during freezing process, since mobile water molecules are sublimated in the primary drying phase. This part of the process is governed by the materials adsorption isotherms. And temperature is raised higher than that of primary drying phase and can even be above 0°C, to break any physico-chemical interactions that have formed between water molecules and frozen material. Usually pressure is also lowered to encourage sublimation. However, there are several products which are benefited by increased pressure. After the completion of the process, the vacuum is usually broken with an inert gas such as nitrogen, before sealing the material. At the end of the operation, final residual humidity in the product is around 1 to 4%; which is extremely low.

Fundamentally above mentioned three processes required for freeze-drying are governed by following steps.

- Freezing – The product is frozen. This provides a necessary condition for low temperature drying.
- Vacuum – After freezing, product is placed under vacuum. This enables frozen solvent in the product to vapourize without passing through liquid phase; a process known as sublimation.
- Heat – It is applied to frozen product to accelerate sublimation.
- Condensation – Low temperature condenser plate removes vapourized solvent from vacuum chamber by converting it back to a solid. This completes separation process.

*Freeze-Drying Equipment*. There are following three categories of freeze-dryers.

**Rotary freeze-dryer**. It is used for liquid products— pharmaceutical solutions and tissue extracts.

**Manifold freeze-dryer.** It is used for drying a large number of small containers and for the products that will be used in a short period of time. This dryer dries product to less than 5% moisture content. And without heat primary drying (removal of unbound water) can be achieved. A heater needs to be added for secondary drying, which will remove bound water and will lower moisture content.

**Tray freeze-dryer.** It is used to produce most dried products for a long-term storage. This dryer allows product to be frozen in place, and performs primary (unbound water removal) and secondary (bound water removal) freeze-drying, thus producing end product dried to the maximum. The dryer can dry product in bulk or in vials. When drying in vials, freeze-dryer is supplied with a stopper mechanism that allows sealing of the vial before it is exposed to atmosphere.

Appropriate packaging for freeze-dried products is in laminated aluminum-foil pouches flushed with nitrogen. These pouches are then packed in corrugated cartons.

*Applications of Freeze-Drying.* Freeze-dried products include: **Freeze-dried fruits**: Mango, Banana, Sapota, Guava, Strawberry; **Freeze- dried vegetables**: Red onions, White onions, Pink onions, Cucumber, Cabbage, Potato, Egg-plant, Okra, Cauliflower, Bell pepper Green, Sweet corn, Garlic; **Freeze-dried herbs**: Coriander, Garlic, Chillies, *Aloe vera*, Bittergourd, *neem*, Mint.

*Advantages of Freeze-Drying.* Following are the advantages of freeze-dried products : original flavour, shape, colour and texture and original nutritive value is retained; light weight so cost of storage and transportation can be reduced; quick and complete reconstitution for use; long shelf-life at ambient temperature; easy handling and cheaper transportation; and no additive or preservative, hence better quality.

This process has been popularized in the form of freeze-dried ice-cream. And instant coffee is also freeze-dried.

### 14.2.2 Osmotic Drying

It is an alternative technology to reduce water content as well as to improve quality of the final product. This process is being used in industries to dehydrate fruits, vegetables etc. Osmotic drying is done by immersion of cut-fruits/vegetables in the concentrated solutions of sugar or salts (Rashmi, 2005).

In this dehydration, prepared fresh material is soaked in a heavy (thick liquid sugar or strong salt) solution, and then it is sun- or solar-dried. During osmotic treatment, material loses some moisture also. Syrup or salt solution has a preservative effect on the colour, flavour and texture (Fernandes, 2006). This effect remains throughout the drying process, and dried produce resulted-in is of high quality. This process makes little use of sulphur-dioxide.

Osmotic dehydration is a useful technique for concentration of fruits and vegetables, realized by placing the solid food, whole or in pieces, in the sugar or salt aqueous solution of high osmotic pressure. It gives rise to at least two major simultaneous counter-current flow: a significant amount of water flows out of the food into the solution and solute transfers from the solution into the food (Pokharkar and Prasad, 1998).

Main process variables for osmotic drying are: pre-treatment, temperature, nature and concentration of dehydration solutions, agitation during soaking, additives, and drying in hot-air oven, vacuum-oven or solar-drying

Some general rules for osmotic drying can be noted as follows.

- Water losses and solid gains are mainly controlled by raw material characteristics and are influenced by possible pre-treatments.
- It is not worthwhile to use osmotic dehydration for more than 50% weight reduction, as through osmosis water loss mainly occurs during the first two hours, and the maximum solid gains are within 30 minutes.
- Mass exchange rate increases with temperature till 45°C, above which enzymatic browning and flavour deterioration begins.
- The best processing temperature depends on food, mass exchange and concentration solutions (usually high is preferred).
- Phenomena which modify tissue permeability are over-ripeness, pre-treatment with chemicals ($SO_2$), blanching or freezing, and favour solids gain as impregnation phenomenon enhances.
- Types of sugars utilized as osmotic substances strongly affect kinetics of water removal, gain of solids and water content equilibrium. Low molar mass saccharides (glucose, fructose, sorbitor) favour sugar uptake.
- Addition of NaCl to osmotic solutions accelerates driving force of drying.

*Applications of Osmotic Drying.* Osmotic dehydration as a pre-treatment is mainly related to improvement in nutritional, organoleptic and functional properties of the product (Table 14.4).

- As osmotic dehydration is effective at ambient temperature, heat damage on colour and flavour is minimized, and high concentration of sugar surrounding fruit and vegetable pieces prevents discolouration.
- And through selective enrichment in soluble solids, high-quality fruits and vegetables are obtained with functional properties "compatible" with different food systems. These effects are obtained with reduced energy inputs compared to traditional drying process. The main energy-consuming step is reconstitution of the diluted osmotic solution, and could be obtained by concentration or by addition of sugar (Ertekin and Cakaloz, 1996).

**Table 14.4** Technical data on some osmotically dehydrated products

| Fruit /vegetable | Type of cut | Treatment |
|---|---|---|
| Banana | 5-mm slices | 2 hr, 80% sugar<br>2,000 ppm $SO_2$ at 70°C |
| Carrot | 10mm x 10mm x 2mm discs or 5-mm slices | 4 hr, 60% sugar + 10% salt<br>4,000 ppm $SO_2$ |
| Mango, green | 8-mm slices | 2 hr, 25% salt<br>8,000 ppm $SO_2$ |
| Mango ripe | 8-mm slices | 2 hr, 60% sugar<br>8,000 ppm $SO_2$ |
| Onions | 2-mm slices | 2 hr, 60% sugar + 10% salt<br>4,000 ppm $SO_2$ |
| Papaya | 8mm x 8 mm slices | 4 hr, 80% sugar<br>2,000 ppm $SO_2$ at 70°C |
| Strawberries | Whole | 4 hr, 80% sugar<br>4,000 ppm $SO_2$ |
| Sweet-peppers, red | 6-mm dices | 2 hr, 60% sugar + 10% salt<br>4,000 ppm $SO_2$ |

**Source:** Rosa and Giroux, 2001.

### 14.2.3 Microwave Drying

Conventional drying of foods is a slow process. Microwave heating increases temperature of the interior water parts of the solids. It has three main advantages, which are as follows.

- Ease of control due to rapid response of such high heating.
- A penetrating quality that leads to uniform drying owing to increase in temperature of treatment.
- Selective absorption by liquid water, which leads to uniform moisture profile within the particle.

Microwave drying under vacuum is being investigated on apple, mango, pineapple and grapes. Use of microwave for heating products cause vapourization of water without causing changes in their composition. Microwave energy penetrates deeply into food products, and can reduce processing time by 90%.

Common alternating electric current reverses its direction 60 times a second. In microwaves same happen, but at frequencies corresponding to 915 or 2,450 MHz. Food and certain other materials contain molecules that act as dipoles (they exhibit positive and negative charges at opposite ends of the molecules). Such molecules are also called polar. Water molecules are polar with negative charge centred near oxygen atom and positive charge near hydrogen atoms. Most household microwave ovens operate on a frequency of 2,450 MHz in a continuous wave (cw) mode. Source of radiations in a microwave oven is magnetron tube. Microwave energy from the magnetron is transferred to oven cavity through a waveguide section. The microwave radiations produce heat inside the food. The heat is produced when water molecules in the food vibrate (at a rate of 2,450,000,000 times per second) when food absorbs microwave radiations. And the movement of the molecules produces friction that causes heat. This heat cooks or warm up food. This is how food is preserved by microwave heating. Microwave vacuum dehydration was first used for concentration of citrus-juice in France.

## 14.3 Methods of Concentration

Evaporation concentrates food by removing most of the water. Foods that are commonly concentrated include evaporated and sweetened condensed milks, fruits and vegetables juices, sugar-syrups, jams and jellies, tomato-paste and other types of purees, butter-milk, whey and yeast.

Water is the predominant ingredient in most of food materials and exceeds 85% in fruit and vegetable juices. This water content can frequently be reduced to lower container, storage and shipping costs or to achieve other desirable results in food processing. Foods are concentrated before drying because of the technical and economical advantage of this processing.

### 14.3.1 Solar Evaporation

It is the oldest method of food concentration. It is slow and is mainly used to concentrate salt solutions in human-made lagoons. It is a simple to use eco-friendly option for concentration.

### 14.3.2 Open Kettles

Open-heated kettles are used for jellies, jams and some soups. High temperature and long concentration times damage many foods. Kettles are still used to produce maple-syrup, as the high heat produces its desirable colour and typical flavour.

### 14.3.3 Flash Evaporators

They subdivide food and bring it into direct contact with steam. The concentrated food is drawn off from the bottom of the evaporator, and steam and water-vapours are removed through separate outlets.

### 14.3.4 Thin Film Evaporator

In this, food is pumped on to a rotating cylinder and spreads into 9 thin layers. Steam quickly removes water from the thin layers and the concentrated food is then wiped from cylinder wall. The concentrated food and water vapour are continuously removed to an external separator. Here food product is taken out and water vapours are condensed.

### 14.3.5 Vacuum Evaporator

Low temperature vacuum evaporators are used for heating sensitive food. With a vacuum, lower temperature can be used to remove water from food. Often vacuum chambers are in series and food product becomes concentrated as it moves through chambers.

### 14.3.6 Freeze Concentration

All components of food do not freeze at once. First of all water freezes. It forms ice-crystals in a mixture. Before an entire mixture freezes, it is possible to separate initial ice-crystals. To do this, partially frozen mixture is centrifuged, and then frozen slush is put through a fine-mesh screen. Frozen water crystals are held back by screen and discarded. Freeze concentration is commercially used in orange-juice production. It has following advantages.

- It results in higher retention of volatile flavour constituents in the concentrate than any other concentration processes, including freeze-drying. Basic physical principle accounts for this unique feature.
- During this concentration, latent heat is removed from the product and the water in the crystalline form is separated from dissolved solids.
- Comparing with other concentration processes, excepting reverse osmosis, latent heat is added to product in this process. Further, water vapours are removed but volatile flavours driven off by evaporative process are recovered and returned to the product; but the heat required to evaporate water can easily cause change in flavour and result in some loss of vitamins content. Further more, there is an additional cost in recovering volatile materials and in blending them back into the finished concentrate.
- Refrigeration technology has opened gate for developing freeze-concentration technology. By using latest refrigeration developments, new concepts are being created that make freeze concentration competitive with traditional concentration methods. Food-liquid consists of water and dissolved solids. In most cases the water content is 90% or more. Part of this water can be removed by freeze-concentration technique. The benefits of using freeze concentration are that the original characteristics are the product are maintained—low temperature processing prevents heat damage; efficient separation of water in the form of pure ice-crystals prevents loss of aroma or dry matter. The concentrated product has the same basic quality as of the original. Therefore, the success of freeze concentration is based on the quality preservation.

Freeze concentration consists of two steps: crystallization and separation.

*Crystallization.* During crystallization, part of the water is converted into spherical and pure ice-crystals without any inclusions. Traditionally, a separate nucleation and growth principle is used to create these spherical ice-crystals. The separation of ice-crystals is done in a piston-type wash column. The separated pure ice is melted practically without loss.

The positive effect of slurry crystallization is in the design of the equipment and its manufacturing cost can be considerably lowered. A newly developed (Niro's) Ice con process of slurry crystallization reduces capital cost of the process by up to 40%.

*Separation.* In the freeze-concentration system, slurry crystallization combines with an external heat exchanger in a mixing vessel to provide necessary residence time for crystal growth. Recirculation flow controls sub-cooling and keeps crystals suspended. The level of sub-cooling continuously decreases until reaches its lower value just before re-entering heat exchange.

The freeze concentration can be used for every type of liquid with a low-to medium- viscosity. The main advantage of this is that there is no quality loss, and that makes the process ideal for high-quality, heat-sensitive food products—coffee-extract, fruit-juices, wine, beer, vinegar, dairy products and nutraceuticals.

Freeze concentration results in distinct improvement in quality of products over the existing ones, and the slurry crystallization provides a significant cost reduction that will challenge quality-oriented liquid food markets.

### 14.3.7 Membrane Concentration

Fruit-juices have traditionally been concentrated by multistage vacuum evaporation, resulting in loss of fresh-juice flavour, colour degradation and a "cooked" taste due to thermal effects (Zhao and Xie, 2004). The promising alternative to this is reverse osmosis concentration. However, concentration cannot be reached higher than 25-30° Brix with a single stage reverse osmosis (RO) system due to high osmotic pressure limitation, which is quite below the value of 45-65° Brix for the standard products obtained by evaporation. Technological advances related to the development of new membrane distillation, osmotic distillation and integrated membrane processes have been identified and developed for concentrated fruit-juice processing to improve product quality and reduce energy consumption.

With an increase in the quality expectations of the consumers, membrane-based procedures are being seen as safe and environmentally friendly alternatives. Of these processes, osmotic distillation is considered most appropriate for fruit-juices concentration.

The osmotic concentration flow chamber is a continuously changing flow path to provide a region of high turbulence to a semi-permeable membrane. High turbulence at a first semi-permeable membrane interface significantly reduces membrane-fouling during osmotic concentration and allows concentration of products with highly suspended solid contents. The inventive osmotic concentration cell can be used for producing low alcohol wine, concentrating thin wine into premium wine, and concentrating low-quality grape-juice into a higher quality grape-juice for fermenting a premium wine. It can also be used for concentrating various fruits or vegetable juices, and also for concentrating beverages— tea, coffee.

**Membrane separation of major components in liquid foods.** Typical liquid foods are: fruit-juices; green-tea juice; dairy foods. The primary components of fruit-juices are carbohydrates such as food sugars, food acids and low molecular weight flavour compounds, and those of dairy foods are fat, protein and carbohydrates.

The concentration of fruit-juice is done in two operations. In the first, a cellulose acetate membrane is used; the primary objective could be recovery of most (>99%) of the sugars present in the juice; a part of the acids and flavour components are recovered along with sugars.

Fruit and vegetable juices have been one of the most successful applications of membrane technology for juice concentration. UF membrane (PCI BX, 25K MWCO) retained over 80% of the flavour compounds. Sugars and organic acids retention was 10-40%. High pressure (12 bars) and low temperature (20°C) can create dynamic fouling layer that increases retention during processing.

### 14.3.8 Reverse Osmosis (Dewatering Technique)

Generally reverse osmosis process is not cost-effective for straight forward concentration of juice. It has been applied as a pre-concentration stage, prior to heat evaporation, to increase throughput of evaporation equipment. However, concentration has a great scope in manufacturing many heat-desiccated traditional dairy products such as *khoa, peda, burfi, rabri, basundi, kulfi* and *kheer.*

### 14.3.9 Nano Filteration (Dematerializing Process)

It is recommended for decolourization of juice, if required.

### 14.3.10 Ultra Filtration

It is based on the principle of functioning of macro-molecules. It is cost-effective, and presently industry standard for depectinization and clarification of apple-juice is available.

UF has been used in combination with RO microfiltration at many places. Ceramic microfiltration membranes are being developed for juice clarification to replace diatomaceous earth and other filter-aids.

Chapter 15

# Fruits Processing Techniques

## 15.1 Apple Processing

Apple (*Malus pumila*) is a native to Eastern Europe and Western Asia. In India, it is mainly grown in Jammu and Kashmir, Himachal Pradesh and hilly areas of Uttar Pradesh. The crop is harvested during July-September in Uttar Pradesh and during July-November in Himachal Pradesh. India, at present, has a minimal share in the total world apple production. There has been 5-6 fold increase in apple production during the last 50 years, but its productivity level is still low at 5.56 tonnes/ha. Small quantity (5.95% of the total fresh) of apple produced in India is exported, mainly to Bangladesh and Sri Lanka. In the country biggest wholesale market for fruits and vegetables is at Azadpur in Delhi; about 78% of the total trade of apples is through this market. Composition of apple in terms of its nutritive value is given in Table 15.1.

**Table 15.1** Nutritive value of apple in 100 g (Gopalan, 2000)

| | Value |
|---|---|
| Moisture | 84.6 g |
| Protein | 0.2 g |
| Fat | 0.5 g |
| Minerals | 0.3 g |
| Energy | 59 Kcal |
| Calcium | 10 mg |
| Phosphorus | 14 mg |
| Iron | 0.66 mg |
| Fibres | 1.0 g |
| Carbohydrates | 13.4 g |
| Carotenes | 9 mg |
| Vitamin C | 6-15 mg |

The "Delicious" group of cultivars predominates apple market. Lately, improved spur types and standard colour mutants with 20-50% higher yield potential are being favoured.

**Spur types:** Red spur, Stark Rumson, Golden Spur, Red Chief; Deegon spur colour-mutants – Vance Delicious, Top Red, Skyline, Supreme

**Low-chilling cultivars:** Michael, Schlomit

**Early cultivars:** Bononi, Irish Peach, Early Stanberry, Fenny, Alington, Pippn

**Scale-resistant cultivars:** Co-op-12, Florina, Firdous, Shirean

**Juice-making cultivars:** Lord Lamborane, Granny Smith, Fenny

### 15.1.1 Jams and Jellies

They are prepared from the fruits cooked with sugar. Good setting depends upon the proportion of the pectin, sugar and acid quantities.

*Jam.* It is prepared by boiling fruit-pulp with sufficient quantity of sugar to a reasonably thick consistency to hold cooked fruit-pulp in suspension. Some of the important jams are of apple, plum, pineapple, mango and mixed-fruit jam.

*Jelly.* It is prepared by boiling fruits with or without water, straining and mixing clear juice extract with sugar and boiling mixture to a point to be set as a clear gel. Jelly can be prepared from fruits rich in pectin; guava is the most suitable fruit for jelly preparation.

Select slightly under-ripe and some fully ripe apples of good colour, flavour and aroma

↓

Remove leaves, stalks and other undesirable portions

↓

Wash fruits in running water

↓

Peel fruits, and where necessary, stones and cores are removed

↓

Cut peeled fruits into small pieces

↓

If fruis are sour, sugar is added in 1:1 proportion as compared to 1:0.75 when fruits are sweet

↓

Citric acid (1.5-2.5 g/kg of sugar) is added depending on the sweetness of the fruit

↓

Mixed contents of fruits and sugar are cooked to a thick consistency until the end point is reached

↓

Hot jam is poured into a clean, dry glass jar and cooled before being closed with screw-lid

**Apple-jam preparation**

### 15.1.2 Apple Butter

It is practically similar to apple-jam, excepting that it is made from finely sieved apple-pulp; to which small quantities of nutmeg, cinnamon and clove are added. Its pulp: sugar ratio is generally 1: ¾. It is popular among the large number of consumers on account of its milk-spicy taste and flavour.

### 15.1.3 Apple Pickle

Peel, core and slice apples. Put spices in water, and boil vinegar, sugar and spices for 5 min, add slices and let the mass simmer till pieces soften. Take out fruit-slices and pack them in jars. Re-boil vinegar and sugar to syrup consistency, pore it hot on slices and seal the jars. Ingredients for preparation are as follows: Sour apples : 1.8 kg; Spirit or cider vinegar: 0.84 litre; Sugar: 0.9 kg; Cinnamon sticks: 7.5 cm; Spices:1 tsp; Cloves (whole): 20.

### 15.1.4 Apple Juice

Method for juice preparation is as follows.

Apples
↓
Wash with 1.5% HCl
↓
Grading (apple-grates)
↓
Crush for juice extraction (Basket press)
↓
Strain
↓
Clarification by enzyme or gelatin
↓
Filtration
↓
Heat at 82-85°C
↓
Fill hot into cans
↓

Seal
↓
Process at 100°C for 15 min
↓
Cool
↓
Storage

**Juice preparation**

### 15.1.5 Ready-to-serve Beverages

They are prepared by the following process.

Apple fruit (Pulp/Juice)
↓
Mix with strained syrup solution
(sugar + water + acid, heated to dissolve), according to recipe
↓
Homogenization
↓
Bottling
↓
Crown corking
↓
Pasteurization (at about 90°C) for 25 min
↓
Cooling
↓
Storage

**RTS beverages preparation**

### 15.1.6 Canned Apples

Canning of the apples is done in the following way.

Graded apples
↓
Coring and peeling
↓
Dropped in brine solution (1.5%)
↓
Remove seeds and blanch
↓

Cut into sections (six or eight)
↓
Keep in dilute brine for hours
↓
Pass through conveyor-belt for washing
↓
Inspect
↓
Dices filled in cans
↓
Hot-syrup added
↓
Cans are seamed
↓
Pasteurized in boiling water for 10-25 min
↓
Properly cooled

**Canning of apples**

### 15.1.7 Apple Sauce (Puree)

For puree preparation, following steps are followed.

Apple fruit
↓
Peeled
↓
Sliced/chopped into 6-mm thick pieces
↓
Cooked in water or steamed until soft
↓
Pulper with seams of 3-mm or less
↓
Add dry sugar to pulp
↓
Mix and heat
↓
Fill cans

**Apple sauce preparation**

### 15.1.8 Dried Apples

They are prepared by following steps.

Apples
↓
Size grading
↓
Washing
↓
Peeling and coring (slices are dipped in salt water (2% NaCl) to stop browning)
↓
Control
↓
Slicing
↓
Sulphuring (2 g sulphur for each 1 kg of apple, sulphuring time is for 30-40 min)
↓
Drying/Dehydration
↓
Temporary storage
↓
Sulphuring/Treatment
↓
Packaging
↓
Storage

**Dried apple preparation**

### 15.1.9 Apple *Chutney*

Following materials are required for preparation: apple slices: 1 kg; sugar:750 g; salt:45 g; dried dates (chopped) :100 g; raisins:50g; onion (chopped): 250 g; garlic (chopped) :15 g; ginger (chopped) :50 g; red chilly powder:10 g; cardamom powder:10 g; cinnamon powder:10 g; cumin powder:10 g; aniseed powder:10 g; headless clove powder:5; glacial acetic acid :8 ml.

**Method**. Wash apples, peel and remove core, slice and cook slices with all ingredients (excepting sugar and acetic acid) till they soften. Cook gently to the desired consistency. Add sugar and acetic acid and again cook for 5 -10 min. Fill in bottles.

## 15.2 *Aonla* Processing

*Aonla* or Indian gooseberry (*Emblica officinalis* Gareth.) is an indigenous fruit of the Indian subcontinent, grown very well on the marginal and wastelands. The excellent nutritive and therapeutic value of this fruit has great potentiality for processing it into value-added products. It is a richest source of vitamin C. Fruits can be used for preparation of preserve, candy, pickle, jam and also various ayurvedic preparations. Being rich in vitamin C, *aonla* is used for manufacturing medicines to treat leprosy, jaundice, diabetes, skin diseases and for preparing hair oil to stop hair-greying .

Growing popularity for alternate medicine and herbal products has enhanced its demand. Like other herbs, *aonla* has been in use as a medicine for centuries in India (Kalra, 1988). Though trees continue to bear fruits till 60-70 years of age; their fruiting season is short, from October to January. And harvested fruits have a short life and cannot be preserved for long. Raw fruits are highly acidic in content and are astringent in taste. Varieties of *aonla* in the country are: Banarsi (suitable for preparing *aonla* powder); Chakkaya (this has high production, and is suitable for preparing pickle, chutney and syrup); Kanchan and Krishna (suitable for preparing candy and jam); Narendra 7 (suitable for pickle and chutney); and NS 7 (for herbal jam, herbal squash).

Processing techniques available for *aonla* are — solar drier (*aonla* shred and powder); preservation by using sugar; preservation by using salt; fermentation and pickling.

*Aonla* can be converted into the following value-added products (Nath, 1999).

### 15.2.1 *Aonla Murabba*

Select ripe fruits free of wound and bruise. Wash thoroughly and punch with a stainless steel-fork or wooden prick so that fruits do not turn black. The punching should be quite uniform up to the stone. Fruits must not be over-punctured; otherwise they will crack while cooking. Then soak them in alum or lime-water for 3 days; until they are free from astringency and bitterness. It is preferable to change water after every 24 hours. Fruits can also be soaked in 2% brine. Wash fruits thoroughly in water and boil until they are soft. In general, there are two methods of *murabba* preparation.

*Method I.* For one kg of fruits, one kg of sugar and 2 litres of water are required. Prepare syrup with sugar and water, and thin it by heating with addition of little citric or tartaric acid. Remove scum and dirt; strain and boil again. After a few minutes, add fruits to boiling syrup and cook gently for 20-30 min, and let it stand overnight. Again cook until syrup acquires a honey-like consistency. Cool product and fill it in wide-mouthed bottles and cap tightly.

*Method II.* In this, equal quantity of sugar and *aonla* fruits (1 kg sugar and 1 kg fruits) is used. Spread some sugar in the pan and arrange pricked and boiled fruits on this layer of sugar, and cover fruits with the remaining sugar. Pan is then covered for 24 hours. During the period, water present in the fruits will dissolve sugar. Take out fruits, and the solution so obtained by this method is boiled; add 1 kg sugar and some citric acid to hot syrup. Remove scum and dirt, and strain syrup. Cook *aonla* fruits in this syrup until it acquires honey-like consistency.

*Aonla* fruits
↓
Wash
↓
Punch fruits
↓
Soak in either alum or lime water for 3 days
↓
Sugar syrup (1 kg sugar + 2 litres of water) for 1 kg fruits
↓
Boil (citric acid, remove scum)
↓
Add fruits
↓
Cook it for 20-30 min
↓
Cool and keep the product for overnight
↓
Package
↓
Storage

***Aonla murabba* preparation (Method I)**

### 15.2.2 *Aonla* Pickle

The steps involved for preparing pickle are as follows, and the ingredients required are:*aonla*:1 kg; salt: 150 g; turmeric powder: 10 g; nigelle seed: 10 g; red chilly powder: 10 g; fenugreek: 30 g; clove headless: 5; and oil: 350 ml.

*Aonla* fruits
↓
Wash
↓
Boil for 15 min to soften segments
↓
Separate segments and remove seeds
↓
Fry spices in oil
↓
Mix segments with spices in oil
↓
Fry for 5 min
↓
Mix salt
↓
Fill in jar
↓
Keep in sun for a week
↓
Storage

***Aonla* pickle-making**

### 15.2.3 *Aonla* Chutney

Ingredients involved in the preparation of the chutney are: *aonla*: 1.25 kg; sugar: 1 kg; salt: 50 g; onion (chopped): 50 g; ginger (chopped): 50 g; garlic (chopped): 15 g; red chilly powder: 10 g; black pepper: 10 g; cinnamon: 10 g; cardamom (large): 10 g; onion seed: 10 g; cumin (powder): 10 g; and vinegar: 100 ml.

*Aonla* fruits
↓
Wash
↓
Boil for 20 -25 min
↓
Remove seeds
↓
Make pulp
↓
Add one half of its weight, water, sugar and salt, and cook gently

↓

Keep all ingredients (excepting vinegar) in cloth-bag tied loosely. Put mixture on low flame. During cooking, the bag is occasionally pressed

↓

Remove bag after squeezing

↓

Add vinegar

↓

Cook for 2 – 5 min

↓

Fill while hot into hot-and-dry sterilized bottles

↓

Seal (air-tight)

↓

Storage at ambient temperature in cool and dry place

***Aonla chutney* preparation**

### 15.2.4 *Aonla* Sauce

After extraction of pulp, prepare the sauce with following ingredient: *aonla* pulp: 1 kg; sugar: 75 g; salt: 10 g; onion (chopped): 50 g; ginger (chopped): 10 g; garlic (chopped): 5 g; red chilli powder: 10 g; cinnamon: 10 g; cardamom (large): 10 g; aniseeds: 10 g; cumin: 10 g; black pepper powdered; clove (headless): 5; vinegar: 25 ml; sodium benzoate: 0.25 g/kg of product.

Extract pulp

↓

Strain *aonla* pulp

↓

Cook pulp with one-third quantity of sugar

↓

Place spice-bag into pulp and press occasionally

↓

Cook to one-third of original pulp volume

↓

Remove the bag (after squeezing into pulp)

↓

Add sugar and salt

↓

Cook

↓

Judge end-point (by hand refractometer/one-third of original volume)
↓
Add vinegar/aseptic acid and preservative
↓
Fill hot into bottles at 38°C
↓
Crown-corking
↓
Pasteurize for 30 min
↓
Cool
↓
Storage at ambient temperature for 30 min

***Aonla*-sauce process**

### 15.2.5 *Aonla* Nectar

This fruit beverage contains at least 20% fruit-juice/pulp and 15% total soluble solids(TSS) and also about 0.3% acid. It is not diluted before serving. For preparing this beverage, total solids and total acids present in the pulp/juice are determined first and then requisite amount of sugar and citric acid dissolved in water are added for adjustment of TSS and acidity (Mehta and Rathore, 1976).

### 15.2.6 *Aonla* Syrup

Select big-size *aonla* fruits. Dip them in 2% salt solution for a week to remove astringents. After removing from the solution, wash them in clean water. Boil them in water for 20 min to soften them. Prepare *aonla* pulp with ¼ litre of water per kg of fruits. Pulp can also be prepared by using blender. Extract juice with juice-extracting machine. This type of juice is known as water extract of juice. Now boil juice and add slowly required amount of sugar. Heat the juice till it boils, and then remove scum and strain after cooling, and finally fill-in bottles.

### 15.2.7 *Aonla* Pulp

Mature *aonla* fruits
↓
Wash
↓
Heat in boiling water for 10 min
↓
Separate segments and remove seeds
↓

Add water in 1:1 ratio

↓

Pass through pulping machine

↓

Pulp

↓

Squash | Jam | Toffee

Jam

↓

*Aonla* fruit pulp

↓

Mix asparagus root extract and ginger extract

↓

Mix sugar syrup solution (sugar + water + citric acid, according to recipe)

### 15.2.8 Herbal Jam

For preparing herbal jam ingredients are: *aonla* pulp: 50%; asparagus juice: 5%; ashwaganda extract :2%; sugar: 68%; and acidity:1.2%.

*Aonla* fruits' pulp

↓

Mix herbal extract (according to recipe)

↓

Add sugar

↓

Cook

↓

Add citric acid

↓

Judge end point (TSS 68%)

↓

Fill into clean sterilized bottles

↓

Cap

↓

Label

↓

Storage

**Preparation of herbal jam**

### 15.2.9 Herbal Squash

Requirement of different ingredients in percentage for squash preparation are as follows: *aonla* pulp (25%); asparagus juice (5.0%); ginger juice (2.0%); TSS (50%); and acidity (1.2%).

*Aonla* fruit pulp
↓
Mix asparagus root extract and ginger extract
↓
Mix with sugar syrup solution
(Sugar + water + citric acid, according to recipe)
↓
Cook
↓
Judge end product (TSS – 50%)
↓
Fill into clean sterilized bottles
↓
Cap
↓
Label
↓
Storage

**Herbal squash preparation**

### 15.2.10 *Aonla* Candy

Following is the flow chart for *aonla* candy preparation.

*Aonla* mature fruits
↓
Wash with water
↓
Prick
↓
Dip in 2% salt solution (24 hr)
↓
Wash with water
↓
Blanch in boiling water
↓
Steep in 50% sugar syrup (24 hr)
↓

Steep in 60% sugar syrup (24 hr)
↓
Then steep in 70% sugar syrup (3 days)
↓
Drain excess sugar
↓
Coat with pectin or sugar, as per recipe
↓
Shade dry up to 15% moisture
↓
Pack in polyethylene pouch (400 gauge)
↓
Storage

***Aonla* candy preparation**

### 15.2.11 *Aonla* Toffee

Ingredients for *aonla* toffee preparation are:*aonla* pulp: 55%; sugar: 42%; butter: 2.5%; custard powder: 0.5%.

*Aonla* fruit pulp
↓
Concentrate pulp to 1/3 of its original volume
↓
Mix with sugar, custard powder, glucose, skim milk powder and butter (according to recipe)
↓
Cook up to desired consistency
↓
Roll into sheet (0.5-cm thick layers)
↓
Cut into toffee shape
↓
Drying at 55-60°C for 5 hr or up to 9% moisture
↓
Package in tissue-papers
↓
Storage

***Aonla* toffee preparation**

### 15.2.12 *Aonla Churan*

Composition for it is: *aonla* powder: 100 g; salt: 8 g; black salt: 12 g;

sugar: 15 g; citric acid: 3 g; black pepper: 2 g; asafoetida: 1 g; cumin: 1 g; fennel: 1 g; ginger: 1 g; and mint: 2 g.

*Aonla* fruits
↓
Wash
↓
Blanch (6-8 min in boiling water)
↓
Drain water
↓
Separate segments and cut them into 3-4 pieces
↓
Add 1,000 ppm KMS
↓
Dry at 60°C for 6-7 hr
↓
Mill
↓
Package in polyethylene pouches

***Aonla* powder preparation**

## 15.3 Grapes Processing

Grapes are cherished as fresh fruits, are stored as raisins, and are also used in the preparation of wines and medicines. World production of grapes is shared equally for fresh consumption and for processing. Depending on the use, grapes are classified into following groups—table grapes, raisin grapes, wine grapes, juice grapes and canning grapes. India has the distinction of having the highest yield of grapes. The principal types commercially grown are: Anab-e-Shahi, Bangalore Blue, Bhokri, Cheema 7, Cheema 94, Kali-Shahbi, Perlette and Thompson Seedless (Sultana). The export of grapes from the country increased from 14,606 tonnes valued at ₹ 600 million during 2001-02 to over 35,000 tonnes worth about ₹ 1,200 million in 2005-06.

Grapes are rich in reducing sugars, and mature fruits contain glucose and fructose in almost equal proportion and only small amount of sucrose. Pectin content of grapes is usually small. Grapes are poor in protein; however, they contain free amino acids. Nearly 60-90% of the total nitrogen of grape-juice is due to amino acids. Principle acids of grapes are tartaric acid and malic acid; and citric acid is present in small amount. Grapes are poor in vitamins, even vitamin C content is low (1.0 mg/100 g of edible portion).

### 15.3.1 Grape Wine

Wine is alcoholic beverage prepared by the fermentation of grape-juice. Grapes are harvested at the proper time when the sugar and the acid contents are in the right proportion. Immediately after picking grapes (in case of red wine), they are crushed, and juice together with skin, pulp and seeds is transferred to the fermenter. After fermentation, fermented juice is pressed out. In case of white wines, pressing takes place before fermentation. 'Wild' yeast and other microorganisms are present on the skin of the grapes, and they can pass onto juice-pulp (known as must) when fruits are crushed. These organisms are destroyed by adding sulphur dioxide (or potassium meta bisulphite) in the required quantity. If sugar content is low, sucrose is added to the desired strength and *p*H is adjusted at 3.2-3.4 by adding tartaric acid. Later, mixture is inoculated with a pure culture of actively growing yeast (*Saccharomyces ellipsoideus*). Temperature and duration of the fermentation depends upon whether dry or sweet wine is required. Fermentation usually lasts for 4 to 10 days. When it completes, clear wine is siphoned from yeast sediment into barrels (raking), and wine is allowed to age. Wine loses its raw and harsh flavour and mellows down. During maturation, clarification takes place in a natural way. It can also be achieved by fining and filtration. Then wine is bottled and allowed to mature; time of this maturation may extend for number of years to have desired quality.

### 15.3.2 Grape Juice

Select sound grapes, and remove stems carefully. Unripe or decayed grapes are discarded. Wash grapes in water, and afterwards they are heated with a little quantity of water to soften them. Then they are easily crushable and made into pulp. The pulp is then strained through a muslin-cloth. Sugar is added to the juice (approx. 50 g/litre of juice, if juice is sour). The juice is then filled in containers and kept at refrigerated temperatures for 8 to 10 days. During this, precipitation of argols and tartarates occurs. If preservative is added, juice is stored at the ambient temperature; argols precipitation takes 1 to 2 months.

After clarification, it is filtered and heated to 88 °F (31.1°C), filled in bottles, sealed and pasteurized at 85 °F (29.44°C). Besides pasteurization, juice can also be preserved by using sodium benzoate.

### 15.3.3 Grape-Juice Concentrate

It can be prepared by recovering aroma concentrate from the juice in the aqueous form. The juice is enzymatically clarified and then concentrated by conventional means to about 72° Brix in a forced circulation evaporator. Concentrates of aroma and juice can be stored separately and mixed whenever required to prepare a beverage resembling fresh grape-juice.

### 15.3.4 Grape Raisins

About half a million tonnes of dried grapes or raisins are produced all-over the world. Raisins generally contain 10-15% of moisture; if the moisture exceeds 18%, they easily deteriorate. Grapes are dried by various methods, and accordingly raisins are named as per procedure used— Natural, Golden Bleached or Sulphur Bleached. In India, raisins are produced by drying grapes in the sun or by mechanical dehydration with or without preliminary treatment.

Clusters examined to eliminate bruised/contaminated grapes

↓

Grade grapes

↓

Wash them in water

↓

Dip in hot dilute lye-solution (KOH/NaOH)

↓

Wash with cold water to remove excess lye

↓

Sulphuring(2-4hr)

↓

Sun-drying/Mechanical drying

↓

Curing/Sweating

**Grape raisins' preparation**

Treatment of grapes with hot lye-solution leads to cracks' formation on the surface, which facilitate water evaporation and thus hastens drying. Grapes are washed to remove excess alkali to prevent enzymatic discolouration of raisins, and also for enhancing their storage life. Curing/sweating is done after grapes have dried to achieve moisture equilibration. This is important for extended storage. This is practised by keeping raisins in small boxes covered with wide meshed cloth in a well ventilated place for several weeks. Once raisins are cured, they are packed into air-tight containers.

### 15.3.5 Fruit Butter

Butter is made by cooking 1 kg of pulp with 750 g sugar and adding spices like nutmeg, cinnamon, clove etc. On account of its mild spicy taste and flavour of fruit, the product is very popular. The preparation of fruit butter is similar to that of jam except that fine pulp of the fruit is used, and to which small quantity of spices is added.

Select grape fruits (firm and ripe) and wash them
↓
Cut them into thin pieces
↓
Boil with equal quantity of water (to soften pulp)
↓
Sieve (remove seeds and skin)
↓
Mix pulp with sugar
↓
Cook to consistency of jam
↓
Add fine-ground spices and mix
↓
Remove from fire
↓
Fill while hot into clean-and-sterilized bottles
↓
Seal bottles
↓
Store

**Fruit-butter preparation**

## 15.4 Banana Processing

Banana is a dessert fruit; is also known as apple of paradise and poor man's apple. Its botanical name is *Musa paradisica,* cultivar is Cavendishi. Over 10.2 million tonnes of fruits are produced annually in the country, and a major share of the production is consumed in fresh form. Fruits can be preserved for 3 months or more by drying or frying. Banana powder is prepared from pulp or ripe fruits after mashing and drying them in a drum or spray driers. Dried product is pulverized and passed through 20-mesh sieve, and this product is commonly used in hostels, restaurants, bars and houses. Being highly perishable in nature, there is an urgent need to preserve this fruit for preparing products—figs, flour, powder, banana pulp, weaning food for infants, and clarified banana-juice to cater to the needs of different sections of the society.

Banana is the richest source of energy, yields more than 400 k Joules per 100 g of the fruit; it is rich in fibres (2 g /100 g) and is considered good for maintaining cholesterol build-up in arteries, besides containing considerable amount of beneficial mineral potassium(250-500 mg/ 100 g), which can alleviate hypertension. With regular consumption of banana, following disease conditions show improvement— diarrhea, intestinal lesions, and many colic diseases. Reduces symptoms of diabetes, uremia, nephrites, gout, hypertension and cardiac disease, and gives relief against cough, haemorrhoids, constipation and muscle-cramps. Nutrient composition of banana per 100 g of edible portion is: moisture: 70.1; protein: 1.2; fat: 0.3; mineral: 0.8; fibre: 0.4; CHO: 27.2; energy: 116; carotene: 78 (Gopalan, 2000)

### 15.4.1 Banana Figs

Dried ripe bananas are known as 'banana figs'. The fruits are peeled and sliced length-wise. Sulphured and dried in the sun or in a dehydrator. Unripe bananas are peeled after blanching in the boiling water and cut into discs for drying. The dried slices are either cooked or fried. They can also be converted into banana-flour that can be used as such or in combination with cereal flour.

*Method I*

Ripe bananas
↓
Peel
↓
Cut into slices
↓
Sulphuring (15 to 30 min)
↓
Drying (60° to 70°C for 6-19 hr)
↓
Storage

*Method II*

Unripe bananas
↓
Peel
↓

Blanch (in boiling water)
↓
Cut slices
↓
Dry
↓
Dried slices (either cooked or fried)
↓
Flour (used in combination with other cereal flours)
↓
Storage

### 15.4.2 Banana Puree

Full ripened bananas are peeled, and pulp is extracted. The pulp is homogenized, de-aerated and its *p*H is adjusted at 3.5. The puree is then passed through a series of heat exchanges where it is sterlized by steam, partially cooled and brought to a filling temperature. The sterillized puree is then packed aseptically into steam sterilized cans, which are closed in a steam sterilizer.

Fully ripe bananas
↓
Peel
↓
Pulp extraction (screw-type pulper against back pressure)
↓
Pulp
↓
Homogenization
↓
De-aeration (using centrifuge; keeping in vacuum 72.5 cm Hg)
↓
Adjust *p*H (3.5)
↓
HTST processing (using scraped surface heat-exchanger)
↓
Aseptically packed puree
↓
Storage

**Banana puree preparation**

### 15.4.3 Alcohol from Banana-Peel

The peel is macerated, and it undergoes acidification, saccharification and fermentation processes. Then distillation is done to extract commercial-grade ethyl alcohol; 200 ml of ethyl alcohol can be produced from one kg of banana-peel; the waste can be used as an animal-feed.

### 15.4.4 Canned Banana

Fully ripe bananas
↓
Peel
↓
Slice (1.27 cm × 1.89 cm)
↓
Dip in sugar syrup (25-30° Brix, 0.2% citric acid and *p*H 4.5 - 5.3)
↓
Sterilize cans
↓
Filling of cans
↓
Storage

**Canned banana making**

### 15.4.5 Banana Powder

It is very starchy and is used in blends with other cereal powders for various preparations.

Fully ripe banana pulp
↓
Chopper
↓
Colloid mill
↓
Paste
↓
Add 1-2% sodium metabisulphite
↓
Dry (Spray/drum)

### 15.4.6 Banana Flour

Green bananas
↓
Peel
↓
Slice
↓
Expose to sulphur-dioxide
↓
Dry (Counter-current tunnel drier) for 7-8 hr, temp. 75°C
↓
Product (moisture content 8%)

### 15.4.7 Banana Crisps (Chips)

Unripe bananas
↓
Slice
↓
Immerse in potassium metabisulphite
↓
Dry
↓
Fry in hydrogenated oil at 180 – 200°C
↓
Dusting (salt + antioxidant)

### 15.4.8 Banana Beverages

Bananas (ripe)
↓
Cut into pieces
↓
Blanch (2 min)
↓
Pulp
↓
Add pectolytic enzyme (2g enzyme/1kg of pulp)
↓
Heat at 60-65° + 2.7 – 5.5 *p*H (30 min)
↓
Product

### 15.4.9 Cereal Banana-based Ready-to-Eat Extruded Snacks

Blend
(Rice flour + maize flour + banana pulp)
↓
ISS seive No. 100 (sifting)
↓
Dry (in hot air oven)
↓
Condition
↓
Extrusion
↓
Dry

## 15.5 Citrus Processing

There are many distinct species of citrus—lime, lemon, citron, orange, mandarins, mosambis, grapefruit, pumello, tangerenis, shaddocks and kumquots. Many types of citrus fruits found in the world breed freely among themselves in the nature, resulting in new types. Some of them are indigenous to India, and some are from China. Important commercial citrus fruits grown in India are: manadarin orange (*Citrus reticulata*), sweet orange (*C. sinensis*), lime (*C. aurantifolia*) and lemon (*C. limon*). Oranges account for about 65% of citrus production, 15% goes to manadarins, 10% to lemons and limes and 10% to grapefruit. Citrus is grown practically all-over India; Andhra Pradesh and Maharashtra have the largest share, followed by Madhya Pradesh, Asom, Karnataka, Tamil Nadu, Gujarat, Uttar Pradesh and Punjab.

The important citrus species groups are: mandarin, orange group (tight-skin oranges), acid group (lime, lemon), pumelo-grapefruit group and papeda group.

Among fruits, citrus is one of the most nutritious ones (Table 15.2). Vitamin C in citrus-fruits protects human-beings from scurvy; a dreaded disease, causing body sores, bleeding gums, etc. Oranges of reticulate family are good source of β-carotene. Citrus-fruits contain sucrose, glucose and fructose in 2:1:1 ratio; thus they are good energy food too. Acidity in them is mainly owing to citric acid. In sweet varieties, acidity comes down at ripening and sugar level increases. And most citrus-fruits have a trace of bitterness in them, which is due to flavanoid compounds, called narangi and limonoids. The aromatic principle in them is due to limonene and other essential oils — extensively used in the industry, in pharmaceuticals and in food processing (Ting and Rouseff, 1986).

**Table 15.2** Nutritive value of citrus-fruits

| Fruits (100 g) | Energy (Cal) | Cal-cium (mg) | Phos-phorus (mg) | Iron (mg) | Pota-ssium (mg) | Caro-tene (mg) | Vitamin C (mg) |
|---|---|---|---|---|---|---|---|
| *Nimbu* | 59 | 90 | 20 | | | 15 | 63 |
| *Mosambi* | 40 | 40 | 30 | 0.3 | 490 | | 50 |
| Orange | 48 | 26 | 20 | | | 1104 | 30 |
| Sweet lime | 35 | 30 | 20 | 1.0 | 220 | | 54 |
| Lemon | 57 | 70 | 10 | 2.3 | 270 | | 39 |
| Pumelo | 44 | 30 | 30 | 0.3 | | 120 | 20 |
| Grapefruit | 30 | 20 | 20 | | | | 31 |

**Source:** Gopalan, 2000.

### 15.5.1 Freezing Orange Segments

Orange fruits
↓
Peel
↓
Separate segments
↓
Treat with 1.0% hot lye
↓
Wash with water
↓
Dip in 1% citric acid solution
↓
Remove seeds
↓
Pack in polythene bags and cover with 25% sugar containing 100 mg ascorbic acid
↓
Seal
↓
Arrange in cartons
↓
Freeze at –1 to –5 °C
↓
Storage at 18 °C

**Orange segments' freezing**

### 15.5.2 Ready-to-Serve Beverage of Lemon/Lime

Lemon/Lime juice (1.0 litre)
↓
Mix with strained syrup solution (1.3 kg)
(Sugar + water + acid, heat just to dissolve)
↓
Homogenize
↓
Bottle
↓
Crown-corking
↓
Pasteurize at 90 °C for 25 min
↓
Cool
↓
Storage

**Lemon/lime beverage preparation**

### 15.5.3 Squash Orange/ Lime/ Lemon

Ingredients for the preparation are given in Table 15.3.

**Table 15.3** Ingredients required for squash preparation

| Fruit | Ingredients for one litre pulp/juice | | | |
|---|---|---|---|---|
| | Sugar (kg) | Water (litre) | Citric acid (g) | Preservative (g) |
| Orange | 1.75 | 1.0 | 20 | 2.5 KMS |
| Lime/lemon | 2.0 | 1.0 | - | 2.5 KMS |

*Astringency removal from orange-juice*

Oranges
↓
Peel
↓
Dip segments in hot 2% NaOH for 2 – 3 min
↓
Dip in 0.5% citric acid solution
↓
Use for juice extraction

*Preparation of squash*

Juice
↓
Strain
↓
Juice measuring
Preparation of syrup (sugar + acid + water just to dissolve)
↓
Strain
↓
Mix with juice
Add preservative (0.6% of KMS or 1.0 g sodium benzoate)
↓
Bottle and cap
↓
Storage

**Orange squash preparation**

### 15.5.4 Lemon/Orange Syrup

Lemon/orange syrup (with 68% TSS and 1.3% acid) can be commercially prepared by using recipe given in Table 15.4.

**Table 15.4** Recipe for citrus syrup

| Fruit | Juice/pulp (%) | Quantity of water required (litres) |
|---|---|---|
| Lemon | 25 | Quantity of finished product (litres) – |
| Orange | 25 | Quantity of juice (litres) + sugar (kg) + acid (kg) |

*Preparation of syrup*

Fruit juice/pulp/extract
↓
Mix with strained syrup solution (sugar + water + acid) and heat to dissolve
↓
Bottle
↓
Cap
↓
Storage

**Lemon/orange syrup**

Fruit-based syrups do not require preservatives, but for longer shelf-life, 350 ppm of sulphur dioxide or 600 ppm benzoic acid may be added.

### 15.5.5 Orange-Juice Concentrate

In some countries, concentrates of pure fruit-juices, particularly of orange, are highly popular. The methods employed for orange-juice production are: freezing and mechanical evaporation; low temperature vacuum evaporation; and high-speed high-temperature evaporation.

### 15.5.6 Citrus-Juice Powder

Fruit-juice is converted to a free-flowing hygroscopic powder by puff-drying, freeze-drying, vacuum-drying, spray-drying or drum-drying. The powder has the advantage of longer shelf-life and is soluble in cold-water. The flavour lost during drying is compensated by adding to juice natural fruit-flavour in powder form. Reconstituted powder mixture yields full strength to fruit-juice drink.

### 15.5.7 Citrus Marmalade

It is a fruit-jelly in which fruit-slices or peel pieces are suspended, and they are named as jam-marmalade or jelly-marmalade, respectively. The only difference between both is that in jam-marmalade, pectin extract of the fruit is not clarified, whole pulp is used.

Ripe fruits
↓
Wash
↓
Peel outer yellow portion thinly
↓
Cut yellow portion into fine shreds (1.9 – 2.05-cm long and 0.08 – 0.12-cm thick)
↓
Boil (in 2 – 3 times of its weight of water for 40 – 60 min)
↓
Strain extract
↓
Test for pectin content
↓
Add sugar
↓
Cook at 103 °C – 105 °C
↓

Add shreds
↓
Boil till jellying point
↓
Test for end point (sheet/drop/temperature test)
↓
Cool (at 82-88 °C)
↓
Flavour (orange-oil)
↓
Fill in sterilized bottles
↓
Seal
↓
Storage at ambient temperature/Marketing

**Marmalade preparation**

### 15.5.8 Citrus-juice

Mandarin and sweet-orange
↓
Wash
↓
Peel
↓
Separate and clean segments
↓
Juice extraction
↓
Strain
↓
Heat at 80 °C
↓
Boil or can
↓
Cream cork for can-sealing
↓
Pasteurize
↓
Cool
↓
Storage/Market

Sometimes two or more juices are mixed to yield a well-balanced, rightly flavoured, highly palatable and refreshing drink. Some of the commercial blends of juice are:(i) grape fruit (97%) and lime (3%); (ii)grape (50%) and orange (50%); (iii)orange (50 – 75%) and grapefruit (25 – 50%); and (iv)apple (95%) and lime (3%)

### 15.5.9 Lemon/Lime Juice

Fruits
↓
Wash
↓
Cut
↓
Juice extraction
↓
Strain
↓
Juice

### 15.5.10 Lime Pickle

Following ingredients are used for preparing the pickle: lime: 1 kg; salt : 120 g; turmeric: 10 g; cardamom (large): 10 g; red chilly: 10 g; cumin: 10 g; aniseed: 10 g; black pepper (powder): 10 g; and mustard oil: 500 ml.

Lime and green chillies pickle can also be prepared similarly using lime 750 g, green chillies 250 g, salt 200 g, cinnamon, cumin, cardamom (large) and black pepper (powder) 10 g each; and clove (headless) 8.

Recipe for sweet lemon pickle requires: lime: 1 kg; salt: 100 g; ginger (chopped): 50 g; turmeric, black pepper, cardamom (large), aniseed, red-chilli powder each 15 g; clove (headless) 5; and jaggery 700g.

Lime fruits
↓
Wash
↓
Cut into 4 pieces
↓
Squeeze-out juice from ¼ of fruits
↓

Mix all spices and salt with juice
↓
Mix with pieces
↓
Fill in jar
↓
Keep in sunlight for 4 – 6 days
Add oil after heating and cooling it
↓
Store

**Pickle preparation**

### 15.5.11 Cordial Processing

Fruits
↓
Wash
↓
Cut into halves
↓
Extract juice
↓
Strain
↓
Add preservative
(KMS 1 g/litre of juice)
↓
Store in glass-container for 10 – 15 days for clarification
(suspended material settles down)
↓
Syphon off clear juice
↓
Strain and measure
↓
Prepare syrup
↓
Strain
↓
Mix juice with syrup
↓
Add preservatives (KMS 0.6 g/litre of product)

↓

Bottle

↓

Cap

↓

Store in cool and dry place

## 15.6 Figs Processing

Figs (*Ficus carica*) member of mulberry family are unique in that they have an opening called 'ostiole' an 'eye' which is not connected to tree, but helps in development of fruits by communing with environment. Majority of the figs are dried by exposure to sunlight or by artificial processes. And these dried figs are available throughout the year; there is nothing like unique taste and texture of fresh figs. Figs are believed to be indigenous to Western Asia, and were distributed by man throughout the Mediterranean area. The European figs were taken to China, Japan, India, South Africa and Australia.

There are many cultivated varieties of figs. Most popular among them are Celeste and Brown Turkey, followed by Burnswick and Marsulles. Some others are Texas, Amla, Magnolia, Deanna and Kodota. The nutritive value per 100 g of edible portion is given in Table 15.5.

### 15.6.1 Canning of Figs

Figs are usually canned as preserve. They should be allowed to ripen on the tree to give good canned product. Varieties Kadota, Celeste, Mangolia and Symrna are used usually for canning. After grading, figs are wilted by placing in hot-water at 82 °C for 2 to 3 min. They are sometimes lye-peeled and washed with water to remove waxy coating and adhering lye. They then blanched are in boiling water for 10 – 20 min depending upon the size and degree of ripeness and then canned in syrup of 45° to 55° Brix. Addition of 0.5% citric acid to syrup improves blend and keeping-quality.

### 15.6.2 Figs Drying

Smyrna is a large white fig, which is generally used for drying. Fruits are allowed to ripen on to tree and are gathered when drop. They are spread thinly on the drying yard for 3 – 4 days. After drying they are sorted and packed.

Dried culls of the figs are roasted and ground as a coffee substitute. In Mediterranean countries, low-grade figs are converted into alcohol. An alcoholic extract of dried figs is being used for flavouring liquors and tobacco. Generally, sun-drying is preferred, but scientifically

**Table 15.5** Nutritive value of fig per 100 g

| | Fresh | Dried |
|---|---|---|
| Calories | 80 | 274 kcal |
| Moisture | 77.5–86.8 g | 23.0 g |
| Proteins | 1.2–1.3 g | 4.3 g |
| Fats | 0.14–0.30 g | 1.3 g |
| Carbohydrates | 17.1–20.3 g | 69.7 g |
| Fibres | 1.2–2.2 g | 5.6 g |
| Ash | 0.48–0.85 g | 2.3 g |
| Calcium | 80 mg | 126mg |
| Phosphorus | 22–32.9 mg | 77 mg |
| Iron | 6.6–4.09 mg | 3.0 mg |
| Sodium | 2.0 mg | 34 mg |
| Potassium | 194 mg | 640 mg |
| Carotene | 0.013–0.0195 mg | - |
| Vitamin A | 20–270 IU | 70 IU |
| Niacin | 0.32–0.412 mg | 0.7 mg |
| Ascorbic acid | 12.2–17.6 mg | - |
| Citric acid | 0.10–0.44 mg | - |

There are small amount of malic and oxalic acids.
**Source:** Gopalan, 2000.

managed solar-drying is unique option for increasing output and quality of the dried product.

### 15.6.3 Fig Waste Management

*Seed oil.* Dried seeds contain 30% of oil. Oil is edible and can be used as a lubricant.

*Leaves.* Fig-leaves are used for fodder in India. In southern France, they are a source of perfume material, called fig-leaf absolute.

*Latex.* It contains caoutchouc (2.4%), resin, albumin, sugar and malic acid, rumin, proteolytic enzymes such as diastase, esterase, lipase, catalose and peroxides. The latex is used for coagulating milk to make cheese and junket. The protein in it is used for tenderizing meat and rendering fat. It is often used for washing dishes and clarifying beverages.

## 15.7 Guava Processing

Guava (*Psidium gaujava*) is the fourth most important fruit in India after Mango, banana and citrus. Two commercially important varieties of guava are Allahabad Safeda and Lucknow 49. And others are Banarsi, Hafsi, Allahabad Surkhs, Nagpur Seedless, Amsorphi, Banglore, Dharwad, Dholka, Kothrud, Nasik Seedless and Sidh.

Guava flourishes well in areas with a distinct winter than in tropical areas. It is resistant to drought than most other fruits. In India, guava is grown in Bihar, Madhya Pradesh, Karnataka and Uttar Pradesh. In north, only two crops of guava are harvested —one in April-May and the other in August- September The production of guava in India in year 1995-96 was 1.5million tonnes.

Guava-fruits are green, turn yellow on ripening. They are mostly eaten fresh. And are preserved, spiced or made into jam and jelly. Guava-juice is an excellent beverage. The fruits have higher content of vitamin C; which is 4 -10 times more than citrus-fruits. They also contain considerable amount of pectin (Table 15.6).

**Table 15.6** Composition of guava per 100 g

| | Moisture (g) | Protein (g) | Fat (g) | Minerals (mg) | Fibre (g) | CHO (g) | Energy (Kcal) |
|---|---|---|---|---|---|---|---|
| Guava Country | 81.7 | 0.9 | 0.3 | 0.7 | 5.2 | 11.2 | 51 |
| Guava Hill | 85.3 | 0.1 | 0.2 | 0.6 | 4.8 | 9.0 | 38 |

### 15.7.1 Guava Puree

It is used in manufacturing of guava nectar, various juice drinks, and in the preparation of guava jam. Selected fruits are washed and passed through a chopper or a slicer to break up fruits, and then this material is fed into a pulper. Pulper removes seeds and fibrous pieces of tissues, and forces remainder of the product through a perforated stainless steel-mesh (holes between 0.033 and 0.045 inches). The puree passes through a finisher. The finisher is equipped with a S.S. mesh with 0.020 inches holes. The finisher removes stone-cells and provides optimum consistency to product. The material passed through the finisher can be packed and frozen.

Guava fruits
↓
Wash
↓
Chop/slice
↓
Pulper
↓
Pulp
↓
Screening/Seiving
↓
Finisher

↓
Puree
↓
Frozen
↓
Packed
↓
Storage

**Preparation of guava puree**

### 15.7.2 Guava-juice and Concentrate

Guava-juice can be used in manufacturing clear guava jelly and also various drinks. A clear juice is prepared from guava puree by enzymatically depectinization. About 0.1% pectin degrading enzyme is mixed into puree at the room temperature; heating product at approximately 120 °F (48.8 °C) will speed up enzyme action. After 1 hour clear juice is separated from red pulp by centrifuging or by pressing in a hydraulic juice-press. This after centrifuging or after pressing (and subsequent filtration) can be preserved by freezing or by pasteurization in hermetically-sealed cans.

### 15.7.3 Guava Jelly

Ingredients for jelly are: guava pulp: 1 kg; citric acid: 2 g; , water: 1 litre; pectin :1.8% of fresh fruits: and sugar as required.

*Method I*

Guava fruits (firm and ripe)
↓
Wash
↓
Cut
↓
Add water to cover up fruit-slices and
add citric acid 2 g/1 kg of fruits
↓
Cook for 30 min
↓
Crush and press during cooking
↓

Strain extract
↓
Boil residue again by adding 500 ml of water
↓
Strain and mix it with earlier extract
↓
Filter extract
↓
Allow it to stand overnight to be clear
↓
Perform pectin test
↓
Add sugar as required
↓
Cook till end-point reaches
↓
Strain if required
↓
Fill
↓
Cool
↓
Label
↓
Storage

***Method II***

Ripe guavas
↓
Wash
↓
Slice
↓
Cover with water (containing 2g citric acid for every 1 kg of guava)
↓
Heat (30 min)
↓
Drain extract (Ist extraction)
↓
To residue (water equal to ¼ of weight of slices is added)

↓
Second extraction
I and II extracts are combined
↓
Strain
↓
Strained extract (kept overnight)
↓
Cleaned extract siphoned-off

### 15.7.4 Guava Freezing

Guava fruits
↓
Wash
↓
Place in 2% boiling lye till skin becomes black
↓
Remove fruits and wash them in water
↓
Dip in 0.5% acid solution
↓
Cut into 4 pieces
↓
Scoop-out seeds
↓
Pack pieces in polythene bags covered with 100 mg ascorbic acid
↓
Seal
↓
Arrange in cartons
↓
Freeze at –1 to –5 °C
↓
Storage at –18 °C

### 15.7.5 Guava Cheese

It has a long shelf-life and is at its best after 3 – 6 months of storage. It can be prepared by using guava pulp (1 kg), salt (2 g) and appropriate amount of colour. To make it nutritious, fruit cheese can be fortified with protein source either from soya-protein or whey-protein.

Select firm guava-fruits, wash them and cut them into thin slices
↓
Boil in equal quantity of water (to soften)
↓
Sieve
↓
Add sugar, citric acid and butter to pulp and mix thoroughly
↓
Cook till sufficiently thick
↓
Add salt and colour
↓
Remove from fire
↓
Spread hot-cheese in 0.6-cm thick layer on butter smeared tray
↓
Allow to cool and set
↓
Cut to small suitable size pieces
↓
Wrap in butter-paper or polythene sheet
↓
Pack in dry jars, seal and store

**Guava-cheese making**

### 15.7.6 Guava Toffee

It is prepared by using following ingredients:1 kg fruit-pulp, 700 g sugar, 100 g glucose, 150 g skimmed milk-powder and appropriate amount of butter or *ghee*, essence and colour.

Select fruits (firm and ripe)
↓
Wash
↓
Cut into small pieces
↓
Boil with equal quantity of water
↓
Sieve to make fine-pulp
↓
Concentrate pulp to 1/3 volume by heating

↓
Mix pulp with sugar and glucose
↓
Put butter or *ghee* in a pan and place it onto fire
↓
Transfer pulp to pan
↓
Cook till sufficiently thick
↓
Add milk-powder (after dissolving in little water)
↓
Remove pan from fire
↓
Add colour and essence
↓
Spread mass uniformly in 0.5 – 0.75-cm thick layer on a tray smeared with butter
↓
Cool for 4 hr
↓
Cut into pieces of suitable size
↓
Keep in dry jars
↓
Seal jars
↓
Store

**Guava-toffee preparation**

## 15.8 Mango Processing

Mango (*Mangifera indica*) is the most important fruit of India, and has 41 species and 793 cultivars in South-East Asia. Its origin is not exactly known, but it is believed to be a native of Southern and South-east Asian continent, including India, Myanmar, Sri Lanka and Bangladesh. Reference to mangoes as "Food of Gods" is found in Hindu *Vedas*. The name of the fruit has been coined from a Tamil word *Maangai* and a Malayalam word *Maanga,* and has been popularized by the Portuguese; its *Manga* in Portuguese. Mango-crop is grown commercially in 87 countries, and its several hundred varieties exist in India. However, only a few specific cultivars are commercialized. Important mango-producing countries are China, Mexico, Indonesia, Pakistan, Nigeria, Philippines and Chile. To some extent, it is also grown in Egypt, Venezuela, Sri Lanka and Thailand. In India, mango is grown over 1.2 million hectares, producing 11 million tonnes. Mango accounts for 22% of total area (5.57 million ha) and 23% of total production of fruits (47.94 million tonnes) in the country. Though Uttar Pradesh has the largest area (0.27 million hectares) under mango; Andhra Pradesh has the highest productivity of 12 tonnes/hectare. Other mango-growing states are Bihar, Karnataka, Kerala and Tamil Nadu. India ranks first among the mango-producing countries of the world; accounting for 52.63% of the total world's production (Saraswathy *et al.*, 2008).

Mangoes are processed in two stages of maturity. Green fruits are used for making *chutney*, pickle, curries and also for dehydration. And ripe mangoes are processed as canned and frozen slices, puree, juices, nectar and various dried products.

**Mango varieties.** About 30 varieties are grown on a commercial scale in different states of India(Table 15.7).

**Mango composition.** Mango-fruits contain 10-20% sugar and are an important source of vitamin A, besides vitamins B and C. They have rich, luscious aromatic flavour. Young and unripe fruits are acidic, and seed-kernel contains edible fat.

### 15.8.1 Canned Mango Slices

Mangoes are canned as slices. Mango varieties with fine-texture and strong aroma such as Alphonso are preferred.

Select ripe mangoes
↓
Wash them
↓
Peel and slice
↓
Fill cans
↓
Cover with hot-syrup containing citric acid
↓
Exhaust
↓
Seal
↓
Process and cool
↓
Label and pack
↓
Store

**Table 15.7** Important mango varieties of India

| State | Varieties |
|---|---|
| Andhra Pradesh | Banganpalli, Bangalora, Cherukurasam, Himahuddin, Suvarnarekha |
| Bihar | Bombay Green, Langra, Fazli, Himsagar, Kishen-Bhog, Sukul, Balhua |
| Goa | Fernandin, Mankurad, Alphonso |
| Gujarat | Alphonso, Kesar, Rajapuri, Vauraj |
| Haryana | Dushehari, Langra, Bombay Green |
| Karnataka | Alphonso, Bangalora/ Totapuri, Mulgoa, Neelum, Pairi/ Raspuri, Mallika |
| Kerala | Mundappa, Olour, Pairi, Neelum, Mulgoa, Muvandan, Alphonso |
| Madhya Pradesh | Alphonso, Bombay Green, Langra |
| Maharashtra | Alphonso, Kesar, Mankurad, Mulgoa, Paini |
| Odisha | Saneshan, Langra, Neelum, Suvarnarekha |
| Punjab | Dushehari, Langra, Chausa |
| Tamil Nadu | Banganpalli, Bangalora, Neelum, Rumani, Mulgoa |
| Uttar Pradesh | Bombay Green, Dushehari, Fazli, Langra, Safeda, Lucknow, Chausa |
| West Bengal | Bombay Green, Himsagar, Kishen-Bhog, Langra |

### 15.8.2 Canned Mango Pulp

Canned mango pulp finds applications in a variety of products in the food industry — beverages, ice-creams, yoghurts, milk-shakes.

Select firm ripe mangoes
↓
Wash and cut into checks
↓
Extract pulp
↓
Pulp
↓
Adjust *p*H
↓
Heat and fill into cans
↓
Seal
↓
Cool
↓

Label and pack
↓
Canned mango pulp
↓
Store

### 15.8.3 Flavoured Mango-pulp Concentrate

Two-fold concentrate of mango pulp can be obtained by conventional evaporative concentration procedure. Aroma recovery is done during or before concentration, and this enables effective restoration of aroma to mango pulp. Juice concentrate and aroma concentrate can be mixed together to obtain flavoured concentrate.

Select ripe mangoes
↓
Cut into squares
↓
Extract pulp
↓
Pulverize
↓
Aroma recovery
↓
Aroma concentrate | Stripped pulp concentrate
↓
Mix

**Fully flavoured mango-pulp double concentrate**

### 15.8.4 Mango-fruit Juice

Pure juice is extracted from ripe fruits, it contains natural sugars; sweetened juice contains 85% juice and 10% soluble solids.Syrup is prepared by dissolving 200 g of sugar and 1 g of citric acid in 800 ml water (for 1 kg pulp). Commercial juice is adjusted to 15% TSS (15° Brix) and 0.3% acidity.

Mature mango-fruits are collected; avoiding fruits with mould growth. Fruits are to be picked carefully to reduce puncturing, splitting or bruising. Wash them in clean water. Sort them and cut them into slices, and pulp either by hand or mechanically. Pulp finishers are able to separate seeds and skins without cutting, but sieving/filtering is needed, if pulping is done by hand. Filter pulp with coarse filter-cloth. Heat it in a stainless steel boiling pan. Pasteurization is done at 80–90 °C for 10 – 15 min to destroy enzymes and microorganisms. Fill juice in bottles and cap them. Again heating is done. Keep bottles in cool place, and label them and store them.

Select ripe fresh mangoes
↓
Wash them
↓
Peel
↓
Remove stones
↓
Strain pulp
↓
Add water (1 litre pulp: 0.5 litre water)
↓
Make syrup and homogenize it
↓
Heat at 85°C
↓
Fill into bottles and seal them
↓
Sterilize bottles at 100°C in boiling water for 30 min
↓
Cool and store them

**Mango-fruit juice preparation**

### 15.8.5 Mango Pickle

Pickles are classified into salt pickles and oil pickles. Ingredients used for pickle preparation are as follows: mango pieces: 250 g; salt: 60g; turmeric powder: 2-4 g; mustard powder: 30 g; chilli powder: 20 g; fenugreek seeds: 2-4 g; chickpea seeds: 2-4 g; gingelly oil: 20-30 g. All ingredients are mixed together and filled into wide-mouthed bottles of 0.5-kg capacity. Three days later contents are thoroughly mixed again and refilled into bottles. Extra oil is added to form a 1-2 cm layer over pickle.

Green mangoes
↓
Wash
↓

Slice/Cut (removal of seeds)
↓
Mix spices and oil
↓
Fill in jar
↓
Store

**Sweet mango pickle**

Green mangoes
↓
Wash and peel
↓
Slice
↓
Place slices in the jar
↓
Mix sugar
↓
Place in the sun for a week (Shake jar at least twice a day)
↓
Mix spices
↓
Store

### 15.8.6 Mango *Chutney*

This is prepared from peeled, sliced or grated unripe or semi-ripe fruits by cooking shredded fruits with salt over medium heat for 5 to 7 min. Mix this and add sugar, spices and vinegar. And cook this over moderate heat till product resembles a thick puree, then add remaining ingredients and simmer for another 5 min. Let it cool. Preserve *chutney* in sterilized bottles.

Mango fruits (unripe)
↓
Wash and peel
↓
Slice
↓
Cook
↓
Add sugar, salt, spices to cooked slices
↓

Mix and leave for 15 min
↓
Add garlic and ginger
↓
Cook till with thick consistency
↓
Add vinegar and again cook till end-point reaches
↓
Fill into sterilized bottles
↓
Cool
↓
Store

**Mango *chutney* preparation**

### 15.8.7 Mango Powder

Immature fruits are peeled and sliced for sun-drying. The dried mango slices can be powdered to make a product called *amchoor.* Blanching, sulphuring and mechanical dehydration gives a product with better colour, nutrition, storability and with fewer microbiological problems.

Mango fruits (immature)
↓
Wash
↓
Peel
↓
Blanch
↓
Slice
↓
Sun-dry
↓
Grind
↓
Powder
↓
Label and pack
↓
*Amchoor*
↓
Store

**Mango powder preparation**

### 15.8.8 Mango Jam

It can be prepared by mixing mango pulp with sugar and citric acid, and boiling this mass in a steam-jacked kettle. Calculated amount of pectin is added and is boiled again to get required consistency.

Mango pulp
↓
Add sugar
↓
Heat
↓
Add pectin and citric acid
↓
Boil to obtain 68° brix
↓
Add colour and flavour (optional)
↓
Fill into bottles
↓
Cool to set

**Mango Jam preparation**

### 15.8.9 Mango Fruit Bar

It is a confectionery prepared by mixing mango pulp with measured amount of sugar and other ingredients. Spread this on trays and dry in a drier, until moisture is reduced to desired level. The dried sheet is cut into suitable size and is then packed (Ahmed and Singh, 2000).

### 15.8.10 Mango Toffee

For its preparation, mango pulp (puree) is mixed with sucrose, glucose, skim-milk powder and hydrogenated fat. The mixture is boiled in a steam-jacked kettle to reduce final weight. The product is spread on to the trays and allowed to dry in a drier. The dried sheet is cut into desirable sizes and packed.

### 15.8.11 Raw Mango Beverage

Green mango beverage is a traditional product, very popular in India. Its base is prepared with mango slices, sugar, salt, citric acid, and it can be flavoured with spices— black pepper, cumin seeds or cardamom seeds. Gel-formation is the most common feature in preparation of the beverage, which can be overcome by controlled treatment of pulp with pectolytic enzyme. It can be stored for a year at the ambient temperature.

### 15.8.12 Mango Waste Utilization

A number of products can be prepared from the peel. Good quality pectin can be prepared from it to be used for the preparation of jams and jellies. Pectin yield has been shown to be in the range of 10-16%. Peel-waste can also be used for alcohol and vinegar preparation. Mango aroma concentrate can be prepared from mango-peel by steaming it, followed by successive evaporations of condensed mango-peel waste. Aroma concentrate can be used for flavouring beverages and dairy products. The peel has also been shown to be a good source of carotenoid pigment.

Mango-seed or stone content ranges from 9 to 23% and the kernel content of the seed ranges from 46 to73%.The kernel is a good source of fat, which ranges from 9 to 16%.

## 15.9 Papaya Processing

Papaya (*Carica papaya*) is one of the important delicious fruit-crops grown in the tropical and subtropical parts of the world. Although native to Mexico, it has spread to almost all corners of the tropical world. It is a short-duration, easy-to-grow crop. In India, it is mostly consumed as a table-fruit; mostly consumed as a part of breakfast dessert and as a fruit-salad. It is also used in soft drinks, jams, ice-creams, flavourings, crystallized fruits and also sold as canned cubes and as juice in some countries. It is grown all-over India, and is available round the year. However, Karnataka, Odisha, Asom, West Bengal and Gujarat provide ideal climate for its growth. Earlier, India was a leading producer of papaya in the world.

Some of the common papaya varieties in India are: Pusa Delicious, Pusa Majesty, Pusa Grant, Pusa Dwarf, Pusa Nanha. Varieties for Coimbatore are $CO_1$, $CO_2$, $CO_3$, $CO_4$, $CO_5$, $CO_6$; for Bengaluru are Coorg Honey Dew, Pink Flesh; for Pantnagar are: Pant 1 and other varieties are: Ranchi, Washington, H, Honey Dew.

**Composition and nutritive value.** As a source of vitamin A, it is unrivalled by any, excepting perhaps mango. This fruit contains large quantities of carotene. Nearly whole papaya-tree has some medicinal value, owing to a substance called Paparis, which is present in all parts of the tree and the fruit. This protein helps digest proteins in food. And its black seeds contain in trace, a toxic substance called Caprine. This in large quantity is found to lower pulse rate and depresses nervous system. Fortunately fleshy part of the fruit is free from this substance. Nutritive value per 100 g of edible portion of papaya is as follows: energy : 32 kcal; protein: 0.6 g; fat: 0.1 g; carbohydrate: 7.2 g; calcium: 17 mg; iron: 0.5 mg; carotene: 666 mg; and vitamin C: 57 mg(*Source*: Gopalan, 2000).

### 15.9.1 Papaya Pulp

Ripe fruits
↓
Wash
↓
Peel
↓
Cut into halves
↓
Remove seeds
↓
Heat at 80 °C, cool and pass through pulper
↓
Collect pulp
↓
Heat at 85 °C along with 0.5% citric acid
↓
Fill hot into bottles and seal them
↓
Sterilize at 100 °C in boiling water for 30 min
↓
Cool bottles and store them

**Papaya pulp preparation**

### 15.9.2 Papaya *Chutney*

Ingredients required for preparation of the *chutney* are:papaya (shreds): 1 kg; sugar: 750 g; salt: 45 g; onion (chopped): 100 g; garlic (chopped): 50 g; red chilli powder: 15 g; cumin powder : 10 g; cumin powder: 10 g; cardamom powder: 10 g; aniseed powder: 10 g; black pepper powder:10 g; headless clove powder: 5 nos.; and glacial acetic acid: 8 ml

Select mature papayas
↓
Wash
↓
Peel, remove seeds and cut into slices
↓
Grate slices
↓
Cook slices with onion and salt till soft

↓

Add all ingredients (excepting sugar and acetic acid)

↓

Cook gently to desired consistency

↓

Add sugar, acetic acid and cook for 5 – 10 min

↓

Fill hot in bottles

**Papaya *chutney***

### 15.9.3 Papaya Jam

Ripe papayas are peeled along with one or two half-ripe papayas, and cut into pieces. After removing seeds, papaya pulp is cooked with a little amount of water and sugar. A little citric acid is added during cooking.

Firm ripe papayas (1 kg)

↓

Wash

↓

Peel, core

↓

Make pulp after removing seeds

↓

Add sugar (0.70 kg) (add 100 ml water, if necessary)

↓

Boil (with continuous stirring)

↓

Add citric acid (3 g)

↓

Judge end point by further cooking up to 105 °C or at 68 – 70 °C brix

↓

Fill hot into sterilized bottles

↓

Cool and wax

↓

Seal bottles and store

**Papaya jam preparation**

### 15.9.4 Papaya Jelly

Select ripe firm papayas
↓
Wash
↓
Peel and remove seeds
↓
Cut into small pieces
↓
Boil with water for 20 – 30 min
↓
Add citric acid (3 g) during boiling
↓
Strain extract
↓
Add (0.75 kg) sugar to extract
↓
Boil
↓
Cook till end point
↓
Remove scum or foam
↓
Add pectin (2 g) and cook up to 68% TSS
↓
Fill hot in sterilized bottles
↓
Store (at ambient temperature)

**Papaya jelly-making**

### 15.9.5 Papaya Toffee

It can be prepared by the same method as for mango and guava.

### 15.9.6 Papaya Drying

Papaya (mature and free from disease)
↓
Wash
↓
Peel

↓
Cut into 5-mm thick slices
↓
Sulphuring (for 120 min)
↓
Dry/dehydrated (at temperature 55 – 60 °C for 10 – 12 hr)
↓
Sweat
↓
Pack in airtight containers or polythene bags
↓
Store at the ambient temperature in dry place

Papaya slices or cubes are used for canning. About 0.5% citric acid should be added to the syrup to counteract high *p*H of the fruit. Papaya being a quick growing fruit can form the basis for a thriving canning industry.

### 15.9.7 Papaya Waste Utilization

In the processing of ripe papaya fruit, greenish fruits can be lanced on the tree for collection of latex which can be dried to get proteolytic enzyme papain, which finds industrial application in textile and pharmaceutical industries.

## 15.10 Pineapple Processing

Pineapple (*Ananas comosus*) is one of the most popular tropical fruits. It is one of the few important fruiting monocots. It originated in the American continent, probably Brazil and Paraguay, and has spread throughout in tropical and subtropical regions as a commercial fruit-crop. The important pineapple-growing countries of the world are Hawaiian Islands, Philippines, Malaysia, Thailand, Brazil, Ghana, Kenya, Mexico, Taiwan, South Africa, Australia, Puerto Rico and India.

Its commercial cultivation in India started only four decades back. It is grown on a large scale in Asom, Meghalaya, Tripura, Mizoram, West Bengal, Kerala, Karnataka and Goa; and in Gujarat, Maharashtra, Tamil Nadu, Andhra Pradesh, Odisha, Bihar and Uttar Pradesh on a small scale. During 2001-02, India produced 1.26 million tonnes of pineapple from about 80,000 hectares. India produces more than 8% of the total world production of pineapple (Sudheer and Indira, 2007).

**Varieties and composition.** *Giant Kew:* It is the most important cultivar of pineapple. It is ideal for canning industry; *Queen:* It is the second important cultivar, grown in India; *Mauritius:* It is a mid-season variety from Queen group, used exclusively for table-purpose, and is grown in some parts of Kerala; *Jaldhup and Lakhat:* These are two indigenous small-fruited varieties blended with acidity under queen group growers in Asom; and *Charlotte Rothchild:* It is a small-fruited spiny variety of the Spanish group with fruit characteristics and taste similar to Kew.

Pineapple fruit is a good source of vitamin A and B, and is rich in vitamin C, minerals, and calcium, magnesium, potassium and iron. The fruit contains a special enzyme called Bromelin, which digests protein. It is a popular dessert fruit. Its nutritive value per 100 g of edible portion is as follows: moisture: 87.8 g; protein: 0.4 g; fat: 0.1 g; minerals: 0.4 mg; fibres: 0.5 g; carbohydrates : 10.8 g; energy: 46 kcal; calcium: 20mg; vitamin C: 39mg; and iron: 1.2 mg(Gopalan, 2000).

### 15.10.1 Canned Pineapple Slices

Crown and stem portions of the fruits are the first to be removed. Fruits are washed thoroughly in pure water. Slicing is done with mechanical slicer. The core of slices and the eyes are removed. Diameter of the slices is adjusted to can size. For a 2½ cans, slice diameter should be 9.5 cm, and for an $A_1$ tall can, the diameter should be 7 cm. After this, the slices need to be rinsed in water and drained before they are filled in the can. Hot syrup of 35 to 40° Brix is added to the can. Syrup contains 0.2% citric acid. The cans are processed at 100°C for 15-25 min till the centre temperature reaches 85°C. After this, they are cooled and dried.

### 15.10.2 Canned Tit Bits and Chunks

These are prepared and processed in the similar way as for slices. Difference is only in fruit-cutting stage. The slices are further divided to quarters for tit bits, and in the case of chunks into smaller pieces.

Remove crown and stem
↓
Wash
↓

| Pineapple slices | Pineapple tit bits/chunks |
| --- | --- |
| ↓ | ↓ |
| Slices | Core |
| ↓ | ↓ |
| Punch | Punch |

↓
Core
↓
Remove eyes
↓
Rinse
↓
Fill cans, add syrup
↓
Exhausted seal cans
↓
Process
↓
Cool

↓
Slice
↓
Remove eyes
↓
Quartering of slices/ small pieces
↓
Rinse
↓
Exhausted seal cans
↓
Fill cans and add syrup
↓
Process
↓
Cool

**Pineapple slices and tit bits**

### 15.10.3 Canned Pineapple Juice

Juice is the by-product (15-20%) in the preparation of canned slices/ tit bits. It is obtained from the residue of the edible portion of the fruits adhering to peel; trimmings and core are also are used to extract juice.

Acidity and Brix of the juice is estimated, and is adjusted to 16° Brix and 0.5-0.6% acidity by adding appropriate sugar and acid.

After this, juice is heated to 85°C and filtered. Subsequently, it is passed through a heat-exchanger and filled hot (85°C) into cans and sealed, and then processed for 15 min at 100°C. Immediately after processing, cans are cooled in water, dried, checked, and labeled and packaged.

Pineapple fruits
↓
Remove crown
↓
Peel
↓
Slice
↓
Crush
↓

Extract juice
↓
Strain
↓
Heat at 82-85°C
↓
Fill hot in cans
↓
Seal
↓
Process at 100°C for 15 min
↓
Cool
↓
Store

**Pineapple-juice preparation**

### 15.10.4 Pineapple-juice Concentrate

The process is same for this as for juice preparation till the stage when Brix and acidity are adjusted. After this, final juice is heated to 65°C, and subsequently concentrated to desired Brix of 60-65°. If necessary, fresh pasteurized juice can be added to the concentrate to adjust at 45°C Brix. Preservative is added (potassium metabisulphite) to bring $SO_2$ level to 150 ppm. The concentrate is mixed thoroughly, filled, sealed, and kept in a cool storage. If potassium metabisulphite is not added, then concentrate is canned in AR lacquer cans and stored under cold conditions.

### 15.10.5 Frozen Pineapple Slices

Preparation of the fruits proceeds as for canned slices. The slices are placed in polyethylene bags, which are filled with sugar-syrup to cover slices. The bags are then sealed and placed with waxed cartons and frozen at – 40°C. Frozen pineapple slices have a shelf-life of one year.

### 15.10.6 Osmo -Air-Dried Pineapple Slices

Pineapple slices are quartered. These quarters are then dipped into sugar-syrup (70° Brix) until their weight is reduced by 50% as the result of osmosis. They are sulphated and impregnated with sulphur dioxide to a level of 1,000 ppm, and then air-dehydrated in a Ross-flow dehydrator. The product is then packaged. Shelf-life of osmo-air-dried pineapple is approximately 6 months.

### 15.10.7 Pineapple Squash

Pineapple fruits
↓
Wash them
↓
Peel
↓
Cut
↓
Extract juice
↓
Strain
↓
Measure
juice
↓
Prepare syrup
(Sugar + water + acid, heat just to dissolve)
↓
Strain
↓
Mix with juice
↓
Add preservative
(0.6% KMS or 1.08 sodium benzoate/litre of juice)
↓
Bottle
↓
Cap
↓
Store

### 15.10.8 Pineapple Jam

For preparing pineapple jam, following ingredients are required: pineapple pulp (fresh or canned): 75 kg; sugar: 75 kg; citric acid: 375 g; pectin: 563 g; and pineapple essence: 75 ml.

Ripe firm pineapple fruits
↓
Wash them

↓

Peel and cut

↓

Pulp

↓

Add sugar

↓

Boil
(with continuous stirring)

↓

Add citric acid

↓

Judge end point by 68-70° Brix or by sheet test

↓

Fill hot into sterilized bottles

↓

Wax

↓

Cap

↓

Store

**Pineapple-jam making**

### 15.10.9 Pineapple Candy

Pineapple fruits

↓

Wash

↓

Peel

↓

Cut into slices

↓

Prick slices

↓

Dip slices in 2% salt solution for 24 hours

↓

Raise strength of salt solution by 2% every day till it reaches 8%
along with 350 ppm sulphur dioxide

↓

Keep slices in brine solution
↓
Wash and boil them to remove salt and $SO_2$
↓
Dip them in syrup of 30° Brix containing 0.1% citric or tartaric acid and boil for 10 min
↓
Raise strength of syrup by 5° Brix daily until it reaches 50° Brix
↓
Repeat the process of raising the syrup strength till it reaches 80° Brix
↓
Allow fruits in the syrup (70° Brix) for 10 days
↓
Dry fruits
↓
Spread them in a single layer on wire-mesh trays
↓
Allow to dry at room temperature or in a drier at about 49°C

The syrup left over from the candying process can be used in various ways for sweetening *chutneys*, sauces and pickles and in vinegar-making. After suitable dilution, it can be used for candying another batch of fruits.

### 15.10.10 Mixed Fruits Jam

It is prepared by using pulps in equal proportions of apple and pineapple or pineapple, guava and mango.

Fruits
(sound, ripe pineapples, mangoes, apples and guavas)
↓
Wash them
↓
Peel and cut
↓
Boil in water
(Water 250 ml with1 kg of pulp)
↓
Boil (finishing at 70% TSS)
↓

Fill
↓
Cool
↓
Label
↓
Store

## 15.11 Pomegranate Processing

Pomegranate (*Punica granatum*) is an ancient favourite table-fruit of the tropical and sub-tropical regions of the world. The name pomegranate is derived from pomum (apple) and granates (seeded). Pomegranate is native to Iran, and is widely cultivated throughout India. As a commercial crop, pomegranate is grown to a limited extent in selected locations in many states. It is grown on a large scale in Maharashtra, Karnataka, Andhra Pradesh, Uttar Pradesh, Gujarat, Rajasthan and Tamil Nadu. The total pomegranate production in the world is 1million tonnes. India produces 0.5 million tonnes and exports 5,000 tonnes only, whereas USA produces 0.1 million tonnes and exports 75,000 tonnes; and its exports end by December.

In India, preference is usually given to those cultivars which have fleshy, juicy pulp around seeds. Types with relatively soft seeds are classified as seedless. Among the best are Bedana and Kandhari. Bassein seedless is popular in north India. In south India, Paper Shell, Spanish Ruby,Muscat Red and Vellodu are grown. Several new varieties have been developed, and new orchards with well known varieties have come such as Ganesh, Dhoka, Bhagwa, Jodhpur Local, Bedana, Kandhari, Alandi and Kabul

**Composition and nutritive value.** Fruit is 60% edible, and more than 78% of the edible portion contains moisture. Its 100 g has 1.6 g of proteins, 14.5 g of carbohydrates and a little amount of fat (0.1 g), and it yields 65 kcal of energy. Its sugar content increases with age of fruit and of tree. Similarly, vitamin C also increases with maturity and ripening of fruits (Table 15.8).

### 15.11.1 Pomegranate Juice

Fully ripe fruits yield sweet, deep-coloured juice with rich flavour. The juice after filtration is clarified by heating in a flash pasteurizer at 79 – 82 °C. It is then cooled and after settling for 24 hours, it is racked and filtered. It is preserved by pasteurization or by addition of sodium benzoate. The preserved juice has an excellent keeping-quality.

**Table 15.8** Nutritive value per 100 g of pomegranate

| | |
|---|---|
| Proteins | 1.6 g |
| Carbohydrates | 4.5 g |
| Fat | 0.1 g |
| Energy | 65 kcal |
| Thiamine | 0.06 mg |
| Riboflavin | 0.10 mg |
| Niacin | 0.3 mg |
| Iron | 0.3 mg |
| Vitamin C | 16 mg |
| Phosphorus | 70 mg |
| Potassium | 133 mg |
| Zinc | 0.82 mg |
| Magnesium | 0.77 mg |
| Calcium | 10 mg |

**Source:** Gopalan, 2000.

Pomegranate fruits
↓
Wash them
↓
Cut into 4 equal pieces
↓
Separate seeds (basket press)
↓
Strain
↓
Bottle
↓
Crown-cork
↓
Pasteurize
↓
Cool
↓
Store

**Pomegranate-juice preparation**

Pomegranate juice can be converted into an excellent syrup. Anar-rub, it is a product locally prepared from the juice by adding sugar and heating to a thick, viscous consistency. It has a good shelf-life, and is used like sauce or ketchup with different snacks.

### 15.11.2 Pomegranate Syrup

This beverage is prepared with 1 litre of pomegranate juice, 2 kg of sugar, 0.50 litre of water and 5 g of citric acid(350 ppm of sulphur dioxide or 600 ppm of benzoic acid may be added before bottling).

Pomegranate pulp
↓
Mix with strained sugar solution
(sugar + water + acid, heat just to dissolve)
↓
Bottle
↓
Cap
↓
Store

**Pomegranate syrup preparation**

## 15.12 Custard-apple Processing

The original home of custard-apple (sugar-apple) is unknown. It is commonly cultivated in tropical South America; very frequently in southern Mexico, West Indies, Bahamas and Bermuda. In India, its cultivation is not common; but it is found wild extensively in pastures, forests and roadsides. Custard-apple (*Annona reticulata*) is known in English as 'bullocks heart' or 'bull's heart' and in Hindi as 'Sitaphal' or 'Sita's fruit'.

Its tree requires tropical or non-tropical climate and prefers low elevation and warm-humid climate. When ripe, fruits are brown or yellowish with red highlights and have a varying degree of reticulations, depending on the variety. Its flavour is sweet and pleasant.

Custard-apple is a well-balanced food. It is an excellent source of vitamin C(100 g of its flesh provides over 110% recommended daily vitamin C allowance), dietary fibres, vitamin B6,Ca , K and Cu.

The ripe sugar-apple is broken open and its pulp segments are relished. In Malaya, pulp is pressed through a sieve to eliminate seeds and is then added to ice-cream or blended with milk to make a cool beverage. It is never cooked.

Its seeds are acrid and poisonous, and its bark, leaves and seeds contain allaloid and anonaine. Powdered seeds and pounded dried fruits serve as fish poison and as insecticide in India. Seed powder paste is used on the head to kill lice, but precaution must be taken that it is distant from eyes while being used as it is highly irritant and can cause blindness. Heat-extracted oil from seeds is being employed against agricultural pests.

**Medicinal value and food value.** Crushed leaves are sniffed in India to overcome hysteria and fainting. They are also applied on ulcers and wounds. Green fruit is astringent and is used against diarrhoea. Crushed ripe fruit mixed with salt is applied on tumors. Its roots because of strong purgative action are administered as a drastic treatment for dysentery and other ailments (Table 15.9).

**Table 15.9** Food value per 100 g of custard-apple

| | | |
|---|---|---|
| Calories | | 88.9 – 95.7 g |
| Moisture | | 69.8 – 75.18 g |
| Fat | | 0.26 – 1.10 g |
| Carbohydrates | | 19.16 – 25.19 g |
| Crude fibres | | 1.14 – 2.50 g |
| Proteins | | 1.53 - 2.38 g |
| Amino acids | Tryptophan | 9-10mg |
| | Methionine | 7-8mg |
| | Lysine | 54 - 49 mg |
| Minerals | Ash | 0.55 – 1.34 |
| | P | 23.6 – 55.3 mg |
| | Ca | 19.4 – 44.7 mg |
| | Iron | 0.28 – 1.34 mg |
| Vitamins | Carotene | 5-7 IU |
| | Thiamine | 0.100 – 0.13 mg |
| | Riboflavin | 0.113 – 0.167 mg |
| | Niacin | 0.654 – 0.931 mg |
| | Ascorbic acid | 34.7 – 42.2 mg |

**Source:** Gopalan, 2000.

### 15.12.1 Frozen Custard

Select ingredients for base material
↓
Homogenize
↓
Additives of starch slurry and custard pulp (25%) in milk
↓
Gellying (92 °C for 30 min)
↓
Cool (up to 4 °C)
↓
Freeze
↓
Store

### 15.12.2 Ice-cream from Custard-apple

Select fruits
↓
Making of mix (25% of custard-apple pulp)
↓
Pasteurize
↓
Homogenize
↓
Cooling and aging
↓
Freeze
↓
Packaging
↓
Harden and storage

### 15.12.3 Custard-apple Juice/Pulp

Select fruits
↓
Sort and wash
↓
Crush and press
↓
Heat coloured fruits to 80 °C for 1 min to extract better colour prior to pressing
↓
Extract juice/pulp
↓
Strain and filter
↓
Heat at 80-85 °C
↓

| ↓ | ↓ |
| --- | --- |
| Fill hot in sterilized hot bottles by overflow method | Add preservative (0.1% KMS) or sodium benzoate and citric acid (0.5%) |

↓ Crown cork ↓ Keep bottles upside down ↓ Cool at the ambient temperature ↓ Store pulp/juice

↓ Fill in bottles ↓ Seal ↓ Store pulp/juice

### 15.12.4 Custard-apple Jelly

Ingredients for jelly preparation are as follows: fruits extract: 1 kg; sugar: 0.75 – 1 kg; citric acid: 2 g; colour: if needed; and pectin: 2 g.

Wash fruits, remove seeds, stem, duster
↓
Remove core
↓
Boil with water for 20 – 30 min
↓
Strain
↓
Add sugar to extract
↓
Boil
↓
Cook till the end point
↓
Remove scum or foam
↓
Add citric acid and cook up to 68% TSS
↓
Fill hot into sterilized bottles
↓
Seal bottles
↓
Store

**Custard-apple jelly preparation**

## 15.13 *Jamun* Processing

*Jamun* (*Syzygium cumini*) is considered native to India. It grows widely in the Indo-Gangetic plains and Cauvery Delta of Tamil Nadu. Its powdered seeds are being used for treating diabetes.

It is a common roadside tree. There are about 400 to 500 species, and only a few provide edible fruits. Fully ripe fruits are eaten fresh, and can be processed into beverages, jelly, jam, squash, wine, vinegar and pickles.

It is a good source of iron. Quantity of pulp varies depending on the variety — about 88% of the pulp is moisture, 0.7% is protein, 0.1% is fat, 19.7% is carbohydrates and 0.4% is minerals. It is a fairly good source of vitamin C (Table 15.10). Edible portion of the *Jamun*-fruit forms around 70% of the fruit; glucose and fructose are the principle sugars in the ripe fruit; not a trace of sucrose is detected.

*Jamun* is acidic. It is eaten usually after sprinkling salt. Fresh fruits are tasty and they can be preserved in the form of fruit candies and jams. Fruits are used for making preserves, squashes and jellies also. The juice of unripe fruit is used for making vinegar with attractive colour, good flavour, taste and aroma. Ripe fruits, especially in Goa, are used for making good wines.

### 15.13.1 Canning

*Jamuns* are canned to some extent in the USA and in the UK. In India, they are not available for commercial canning in large quantities. Fruits are covered with sugar-syrup of 55° Brix. The can is exhausted at 180 – 212 °F (82.2–100 °C) for 7 – 10 min or till temperature in the centre of the can reaches at least 165 °F/74 °C.

**Table 15.10** Nutritive value of *jamun* per 100 g of fruit

| | |
|---|---|
| Energy | 62 Kcal |
| Iron | 1.2 mg |
| Calcium | 15 mg |
| Phosphorus | 15 mg |
| Vitamin C | 18 mg |
| Folic acid | 3 mg |
| Carotene | 48μg |
| Fibres | 0.9 g |
| Potassium | 55 mg |
| Magnesium | 35 mg |
| Sodium | 26.2 mg |

**Source:** Gopalan, 2000.

### 15.13.2 Juice/Pulp of *Jamun*

Select fully ripe fruits

↓

Wash

↓

Add water
(1 kg fruit: 0.5 litre of water)

↓

Crush fruits

↓

Heat at 80 °C while crushing continuously

↓

Sieve

↓

Strain whole mass through basket press or passing through a pulper

↓

Collect juice/pulp

↓

Heat at 85 °C

↓

Fill hot into bottles and seal them

↓

Sterilize at 100 °C in boiling water for 30 min

↓

Cool bottles and store them

### 15.13.3 Squash/Syrup

This is prepared by using following ingredients: *Jamun* juice : 45.4 kg; sugar : 33 kg; citric acid: 2 kg; water: 11 litres; and sodium benzoate: 85 g.

*Jamuns* are crushed and heated in their own juice gently for 5 – 10 min at 60 °C to extract rich purple colour. The heated material is pressed through cloth in basket press and clear purple coloured juice is prepared, and for making squash 1.80 kg of sugar is made into syrup and citric acid (15 g) is added to it. The clean syrup is blended with appropriate quantity of juice. After proper mixing, a calculated amount of chemical preservative KMS or sodium benzoate is added. The squash may also be preserved by heating at 100 °C for 1 – 2 min.

### 15.13.4 Ready-to-serve Beverages

Pulp (10 – 15%) (with 10 – 15% TSS + 0.3% acidity)
↓
Mixed with sugar syrup (90 g sugar + 825 ml of water)
↓
Heat (90 °C for 1 min)
↓
Fill (5-litre bottles)
↓
Crowning
↓
Cool to ambient temperature

### 15.13.5 Juice Powder/Spray-dried Powder

The juice is sprayed in the form of a fine mist into the evaporating chamber through which hot-air passes. The temperature of the chamber and the blast of the air are so regulated that only dry juice falls on the chamber floor in the form of a fine powder. The powder is collected and packed in dry containers which are then closed air-tight. The powder when dissolved in water makes a pleasant fruit drink similar to original fresh juice.

### 15.13.6 Wines

Different varieties of *jamuns* are utilized for wine preparation. Lately, considerable interest has been shown in making of *jamun*-wine.

Chapter 16

# Vegetables Processing Techniques

## 16.1 Cabbage Processing

Cabbage(*Brassica oleracea* var. *capitata*)is the fourth most widely grown vegetable-crop of India, and is derived from a leafy wild-mustard plant, native to Mediterranean region. The main varieties of cabbage are Pusa Durum Head, Golden Acre, Pride of India, Pusa Mukta and Pusa Synthetic. And there are many other varieties based on the shape and time of maturity. Traditional varieties include Late Flat Dutch, Early Jersey Wakefield, Danish Ballhead and Savoy Cabbage. And Red Cabbage is a small, round head type with dark leaves. Koautman is the most common variety for commercial production of Sauerkrauts (Table 16.1).

**Table 16.1** Top five cabbage producers – 2005

| Country | Production (MT) |
|---|---|
| China | 34,101,000 |
| India | 6,000,000 |
| Russia | 3,985,000 |
| South Korea | 3,300,000 |
| Japan | 2,200,000 |

West Bengal is the largest grower of the Cabbage, followed by Odisha and Bihar. And other major growers are Asom, Karnataka, Maharashtra and Gujarat. Cabbage grown late in autumn and in the beginning of winter is called colewort.

Cabbage is known as an excellent source of vitamin C, besides vitamins A, $B_1$, $B_2$ $B_6$, fibres, proteins, manganese, folate, calcium, magnesium, potassium and omega-3 fatty acid (Table 16.2). Cabbage contains phytochemicals, called indoles and sulforaphane, the breakdown products of glucosinalates. It contains goitrogen, naturally occurring substance, that interferes with thyroid-gland functioning. Cooking inactivates goitrogenic compounds.

**Table 16.2** Nutritional value (per 100g) of cabbage

| Particulars | Amount |
|---|---|
| Carbohydrates | 5.8 g |
| Sugar | 3.2 g |
| Fats | 0.1 g |
| Proteins | 1.28 g |
| Thiamine (Vit. $B_1$) | 0.061 mg |
| Riboflavin (Vit. $B_2$) | 0.040 mg |
| Niacin $B_3$ | 0.234 mg |
| Pantothenic acid | 0.212 mg |
| Vitamin $B_6$ | 0.124 mg |
| Folate | 53 mg |
| Vitamin C | 36.6 mg |
| Calcium | 40 mg |
| Iron | 0.47 mg |
| Magnesium | 12 mg |
| Phosphorus | 26 mg |
| Potassium | 170 mg |
| Zinc | 0.18 mg |

**Source:** Gopalan, 2000.

### 16.1.1 Canned Cabbage

Early season cabbage with tender, yellowish leaves is used for canning. The heads are either cut into 4 - 8 pieces or shredded into pieces of 2.5- cm thickness. Pieces are generally blanched for 5-6 min in boiling citric acid or tartaric acid solution of 1.0% strength, and subsequently cooled in 2.0% to prevent discolouration. Plain cans and 2.0% brine are used for canning.

### 16.1.2 Sauerkraut

It is the cabbage product after its lactic acid bacterial fermentation under conditions favouring production of lactic acid, acetic acid, alcohol and carbon-dioxide.

Mature cabbages are transported by a conveyor to a coring machine. The cored cabbages are passed through an automatic trimmer-and-washer and to a trimming-table, where outer leaves and defective spots are removed. The heads are then passed to slicing machines to be shred. The shreds are conveyed to vats by belt-lines or carts. About 2.25% of salt is mixed with freshly cut vegetable in the vat. Cut-cabbage is covered with a plastic cover that is large enough to cover up to sides of the vat. Water is placed on the cover to serve as a weight to hold shredded cabbage down so that juice rises and covers sauerkraut surface.

Temperature of 15.5 to 23.8°C and acidity of 1.5% or above within 3 or 4 weeks indicate completion of fermentation.

During salting and fermentation, water and nutrients can be withdrawn from the cabbage; unless some liquid is drained, there may be an excess of 20 barrels or more of sauerkraut-juice. Good sauerkraut has acidity of 1.5-2.0% in the vat.

Cabbage (mature, white and with sound head)
↓
Remove core
↓
Trim (remove outer leaves and defective portion)
↓
Wash
↓
Slice (fine shreds)
↓
Place shreds in the jars or vats
↓
Add 2.25% salt
↓
Cover mouth of jar with plastic cover
↓
Allow to ferment for a week at 16-22°C
↓
Remove scum
↓
Drain scum
↓
Drain-out Juice
↓
Pasteurize shreds (Sauerkraut at 75-80°C for 10 min)

**Sauerkraut preparation**

### 16.1.3 Cabbage Juice

Excellent cabbage juice can be produced by milling, followed by pressing in a hydraulic press, but the juice so obtained must then be immediately chilled or frozen to avoid changes in flavour and colour, and to prevent loss of acetic acid.

Raw cabbage
↓
Mill
↓
Press in hydraulic press
↓
Juice
↓
Chilled/frozen juice retains colour and flavour

### 16.1.4 Dehydrated Cabbage

Fresh cabbage, after washing, coring and shredding is blanched, using a hot-air method in a bin-air dryer, to eliminate enzymatic degradation. Initial temperature of 93°C is lowered slowly (15 min) to 55°C. And air-drying at this temperature is continued till moisture reaches to 5%. Before compression, air-dried cabbage is re-moisturized to 13% with a water-mist, and then it is held for one hour for equilibration. Re-moisturized cabbage then is compressed into 9-cm diameter disks using pressures between 7.0 and 14.0 kg/cm$^2$. Discs are dried to less than 5% moisture in a vacuum-oven to ensure stability in storage.

## 16.2 Carrot Processing

Carrot (*Daucus carota*) is one of the most important root vegetables grown in India with a good export potential. It is a nutrient-rich vegetable, comparatively free from pests and diseases. And with the evolution of tropical types, its cultivation has now spread to non-traditional areas also. Commercially cultivated varieties of carrot in the country are: Pusa Kesar, Pusa Meghali, Sel 233, Early Nantes and Pusa Yamdagini.

Carrot root is a rich source of ß-carotene, precursor of vitamin A. Aroma and taste of carrot plays a major role in its acceptance, and this is influenced by its volatile constituents (Table 16.3).

### 16.2.1 Carrot Jam

Ingredients for this are: carrot: 1 kg; sugar: 0.75 kg; citric acid: 2.5 g; and water: 200 ml

Select optimum matured carrots
↓
Wash
↓
Peel
↓

Pulp
↓
Add sugar
↓
Boil
↓
Add citric acid
↓
Judge end point by further cooking up to 105°C or 68-70% TSS or sheet test
↓
Fill while hot in sterilized bottles
↓
Cool
↓
Wax bottles
↓
Store at the ambient temperature

**Jam preparation**

**Table 16.3** Nutritional value of carrot per 100 g

| Particulars | Amount |
|---|---|
| Moisture | 86.0 g |
| Proteins | 0.9 g |
| Fats | 0.2 g |
| Minerals | 1.1g |
| Fibres | 1.2 g |
| Carbohydrates | 10.6 g |
| Energy | 48 Kcal |
| Calcium | 80 mg |
| Phosphorus | 530 mg |
| Iron | 1.03 mg |
| Carotene | 1.890 mg |
| Folic acid (total) | 15.0 mg |
| Vitamin C | 3.0 mg |
| Magnesium | 17 mg |
| Sodium | 59.8 mg |
| Potassium | 43 mg |

**Source:** Gopalan, 2000.

### 16.2.2 Carrot Candy

Select tender carrots with soft pith, scrape-off thin peels and green leafy portion, and prick them and cut them into suitable sized pieces. Blanch the pieces until they are soft.

Carrots (blanched)
↓
Keep carrot pieces and sugar in alternate layers
(1kg carrot: 1 kg sugar)
↓
Remove carrots
↓
Increase TSS consistency of syrup to 60% by boiling
↓
Steep carrot
↓
Repeat the process and raise strength of syrup by 5% TSS
on the alternate days to 70% TSS or 75% TSS
↓

Steeping in 70% TSS for a week
↓
Pressure
↓
Drain
↓
Fill in jars or cans
↓
Cover carrots with freshly prepared sugar syrup or of 68% TSS
↓
Seal
↓
Store

Steeping in 75% TSS for a week
↓
Drain
↓
Shade-dry
↓
Pack
↓
Store

### 16.2.3 Carrot Pickle

Ingredients for pickle-making are: carrot pieces:1 kg; salt : 150 g; ginger (chopped) : 25 g; onion (chopped) : 50 g; garlic (chopped) : 10 g; red chilli powder, turmeric, cinnamon, cardamom, black pepper, cumin, aniseed (powder) : 15 g each; clove (headless): 6; tamarind pulp : 50 g; mustard ground : 50 g; vinegar :150 ml and mustard oil : 400 ml

Carrots
↓
Wash
↓
Cut into 2.25-cm pieces
↓
Place in the sun for 2 hours
↓
Fry all pieces in a little oil
↓
Mix pieces with spices
↓
Fry mixture for 5 min
↓
Cool
↓
Mix paste of vinegar + tamarind pulp
↓
Add the pieces
↓
Fill in jar
↓
Keep in sun for one week
↓
Add oil
↓
Store

**Carrot pickle-making**

### 16.2.4 Glazed Carrot Candy

Cane-sugar and water (2:1 by weight) are boiled in a sauce-pan at 113-114°C, and scum is removed. Thereafter syrup is cooled to 93°C and rubbed with a wooden ladle on the side of the pan when granulated sugar is obtained. Dried candied pieces are processed through this granulated portion of sugar solution one by one by means of a fork, and then placed on the trays in the warm dry room. And when they become crisp, they are packed in air-tight containers.

### 16.2.5 Crystallized Carrot Candy

Candied carrots are placed on a wire-mesh tray, which is placed in a deep vessel. Cooled syrup (70% TSS) is gently poured over carrots to cover them entirely. The whole mass is left undistributed for 12 - 18 hours during that a thin coating of crystallized sugar forms. The tray is then taken out carefully from the vessel and surplus syrup is drained of. The carrots are then placed in a single layer on the wire-mesh trays and dried at room temperature or at 40°C in the dryer.

### 16.2.6 Canned Carrot

Carrots are not needed to be canned to a great extent, as they are available in fresh all the times. If they are to be canned, they are generally sliced in a dicing machine, and are packed quite often in a combination with peas.

The carrots are packed in cans with addition of 2% hot brine, heated to 140°C and sealed at that temperature.

### 16.2.7 Carrot Juice

The vegetable is washed and blanched for 15 minutes in boiling water. It is then pressed in a hydraulic press. And extracted juice is collected.

### 16.2.8 Dried Carrots

For blanching, slices are dipped for 3 minutes in boiling water containing 50 g salt per litre of water, followed by cooling in running water. In some processes, depending on the finished product specifications/customer standards, sulphiting is also carried out (by dipping in solution containing 3 g potassium metabisulphite per litre of water for 3 minutes). The product is evenly spread on the trays of a dryer. Carrots are dried when prepared product's moisture content is about 6%.

Carrots
↓
Clean
↓
Wash
↓
Scrape
↓
Cut
↓

Blanch
↓
(Slices are dipped for 3 min in boiling water that contains 50 g salt/litre of water)
↓
Cool
↓
Sulphuring
↓
Dry to moisture content of 6%
↓
Sort out
↓
Control
↓
Packaging
↓
Store

**Dried carrots preparation**

### 16.2.9 Carrot Preserve

Tender carrots
↓
Peel
↓
Wash
↓
Cut into suitable pieces
↓
Blanch in boiling water till soft and prick
↓
Place carrot and sugar in alternate layers (1:1)
or
Steep carrot in 40% sugar syrup for a day
↓
Remove carrots
↓
Increase consistency of syrup to 60% while boiling along with 0.2 to 0.5% citric acid
↓
Repeat the process and raise strength of syrup by 5% up to 70%

↓

Keep carrot in 70% syrup and fill in the bottles

↓

Seal bottles and store them

### 16.2.10 Carrot *Kanji*

Select dark-crimson coloured carrots (black carrots), wash them, peel them and shred them. Blend these shreds with equal quantity of water in a blender. Filter juice and preserve it. Add salt, mustard powder and preservatives (after dissolving them in small quantity of water) to juice and mix thoroughly. Lactic acid fermentation completes in 7-10 days. Ingredients used for preparation are: Juice: 1 litre; salt: 30 g; mustard powder:10 g; KMS: 0.1 g and sodium benzoate: 0.2 g.

Black carrots

↓

Wash them

↓

Scrape

↓

Make shreds

↓

Take equal quantity of water and blend them in a blender

↓

Filter juice

↓

Add salt, mustard powder and preservative

↓

Mix thoroughly and fill in glass-jars

↓

Keep it in sun for 6-7 days for fermentation

↓

Use as such and/or can be refrigerated for further use

***Kanji* preparation**

## 16.3 Cauliflower Processing

Cauliflower (*Brassica oleracea*) is an annual plant that reproduces through seeds. Typically only the head (the white curd) is eaten and the stalk and surrounding thick, green leaves are discarded. According to the FAO report (2005), China and India are top producers of cauliflower and broccoli. About half of all the cauliflower of the world is raised in

China and one-fourth in India. Cauliflower is cultivated mostly in the north India as it requires a cooler climate to grow, and its annual output ranges around 3 million tonnes from more than 0.2 million hectares. Its traditional varieties include: Snow Ball, Hybrid White, Super Snow Ball, Snow Crown, Mary Flower, Candid Charm etc.

Orange cauliflowers (*B. oleracea* var. *botrytis*) contain 25 times more vitamin A than white varieties. Generally, cultivators include Cheddar and Orange Banquet. Green cauliflower of *B. oleracea* Botrytis group is sometimes called broccoflower. Green curded varieties include Alverda, Green Goddess and Vorda. Purple cauliflower also exists; the purple colour is due to the presence of antioxidant group anthocyanin, which can also be found in red cabbage and red wine.

Cauliflower is low in fat, high in dietary fibres, folate, water and vitamin C(Table 16.4). As the member of the brassica family, cauliflower shares with broccoli and cabbage several phytochemicals, which are beneficial to human health; including sulfurophane which is an anticancerous compound released when cauliflower is chopped or chewed. Cauliflower also contains other glucosinolates besides sulfurophane, which may improve liver ability to detoxify carcinogenic substances. In addition, compound indole-3 carbinol, which seems to work as an anti-estrogen, appears preventive in tumour growth of breast and prostate. High intake of cauliflower has been found to reduce risk of aggressive prostrate cancers.

### 16.3.1 Cauliflower Cooking

Cauliflower can be roasted, boiled, fried, steamed or eaten raw. When cooking, outer leaves and thick stalks are removed, leaving only florets. The leaves are edible, but most often are discarded. The florets should be broken into similar sized pieces so to cook them evenly. After eight minutes of steaming, or five minutes of boiling, florets are softened, but are not mushy. While cooking, stirring can break florets into smaller, uneven pieces.

Low carbohydrate-eaters can use cauliflowers as a reasonable substitute for potatoes; they produce same texture or mouth-feel but lack starchiness of potatoes; cauliflower is actually used to produce a potato substitute known as fauxtato.

### 16.3.2 Baked Cauliflower

For making this, ingredients required are: cauliflower broken into florets: 1 large; butter: 6 tbsp; corn starch: ¼ cup; salt: 1 tbsp; pepper: to taste; milk: 3 cups; soft-bread crumbs: ½ cup and cheese: ¼ cup.

**Table 16.4** Nutritional value (per 100 g) of cauliflower

| Particulars | Amount |
|---|---|
| Energy | 20 kcal |
| Sugar | 2.4 g |
| Dietary fibres | 2.5 g |
| Fats | 0 g |
| Proteins | 2 g |
| Thiamine (vit. $B_1$) | 0.057 mg |
| Riboflavin (vit $B_2$) | 0.063 mg |
| Niacin (vit $B_3$) | 0.53 mg |
| Pantothenic acid (vit $B_5$) | 0.65 mg |
| Vitamin $B_6$ | 0.22 mg |
| Folate (vit. $B_9$) | 57 mg |
| Vitamin C | 46 mg |
| Calcium | 22 mg |
| Iron | 0.44 mg |
| Mg | 15 mg |
| Phosphorus | 44 mg |
| Potassium | 900 mg |
| Zinc | 0.28 mg |

**Source:** Gopalan, 2000.

*Method.* Cook cauliflower in boiling salted water until just crisp-tender for about 6 minutes.

- Drain cauliflower and transfer to a lightly buttered 1½ quart baking dish.
- In small sauce-pan melt 3 tbsp of butter blend in corn flour and salt, until smooth and bubbly.
- Gradually add milk and stir constantly. Continue cooking and stirring until sauce is thickened and smooth for about 3 minutes. Keep heat very low.
- Arrange cauliflower, pour sauce over it in a casserole, and sprinkle cheese.
- Melt remaining butter in a medium size-pan, add bread-crumbs and toss. Cover the cauliflower with this.
- Bake at 375° (until bubbly and browned).

### 16.3.3 Cauliflower Pickle

This is very popular in north India. Following is the method used for its preparation.

Select fully developed and compact heads. Remove outer leaves and central stalk. Cut flowers into pieces of suitable size; wash, drain and place them in sun for 2 to 3 hours to remove surface-moisture. All the spices excepting mustard seeds are ground into fine-powder. Fry them in oil. When they turn brown, add cauliflower pieces and mix well. When the pieces turn slightly soft, cool them. When the mass has cooled down to room temperature, add mustard seeds and mix them thoroughly. Keep the mixture in sun for 5-7 days. Then add 2.2 kg of vinegar, and again keep it in the sun for 3 more days.

***Method I***

| | | |
|---|---|---|
| Prepared cauliflower | - | 18.1 kg |
| Salt | - | 1.12. kg |
| Chilli powder | - | 0.56 kg |
| Cumin | - | 56 g |
| Clove | - | 56 g |
| Cardamom | - | 28 g |
| Cinnamon | - | 56 g |
| Ginger, green | - | 0.56 g |
| Onion chopped | - | 0.56 g |
| Mustard seeds | - | 0.56 kg |
| Rapeseed oil | - | 2.26 kg |

For sweet pickle, add 453 g of sugar or jaggery along with vinegar. The pickle will be ready in about a week.

***Method II***

| | | |
|---|---|---|
| Prepared cauliflower | - | 37.1 kg |
| Salt | - | 2.26 kg |
| Mustard, finely ground | - | 2.72 kg |
| Red chillies (finely ground) | - | 0.90 kg |
| Turmeric (finely ground) | - | 0.22 kg |
| Dry ginger (finely ground) | - | 0.22 kg |
| Onion (finely ground) | - | 0.90 kg |
| Jaggery (gur) | - | 9.07 kg |
| Rapeseed oil | - | sufficient to mix spices |

This recipe requires more of mustard seeds, and gives a good product. Blanch cauliflower pieces for 5-6 minutes in boiling water. Mix all ingredients in the jar and keep it in the sun. The pickle will be ready in 4-5 days. Then add 50 g of glacial acetic acid and mix well.

### 16.3.4 Frozen Cauliflower

Wash cauliflower florets and blanch them for 4-5 minutes in steam; cool them in the water in a flume and then place them on a conveyor with cold-air blowing for rapid evaporative cooling. Cooled, blanched florets are dewatered, sorted and are individually quick frozen or mechanically packed in cartons to be frozen in a plate-freezer or blast-freezer.

For boil-in-bag packaging, florets are usually machine-sliced. Filled cartons are passed on to an inspection station where they are check-weighed, sealed, automatically over-wrapped with a lithographed wrapper, and plate- or air-blast frozen.

## 16.4 Garlic Processing

Garlic (*Allium sativum*) is the second most widely cultivated *Allium* species throughout the world, after onion. It is a well-known valuable spice for food and is a popular remedy to cure some chronic stomach diseases, sore eye and ear-ache. It originated in the Central Asia and Southern Europe, especially in the Mediterranean region. It is being grown in India and China since long.

The global review of area and production of garlic shows that total world area under the crop is 1,091,359 hectares and total production is 11,439,940 tonnes. India, China, Korea, Turkey, Spain and the USA are the major garlic-growing countries. World's largest producer of garlic is the USA. In India, Madhya Pradesh is the leading state with respect to area and production, followed by Gujarat, Rajasthan, Uttar Pradesh, Odisha and Maharashtra.

Uninjured garlic has a colourless, odourless, water-soluble amino acid allicin (Table 16.5). Most of the available garlic cultivars are white; some pink or red types are also found. There are two categories of garlic—hard-necked and soft-necked.

**Uses**. *Medicinal.* In India, under Unani and Ayurvedic systems of medicines, garlic is used as a carminative and a gastric stimulant, and thus aids in digestion and absorption of food; *Bactericidal* . It acts against *Staphylococcus aureus*; *Fungicidal.* Aqueous garlic-bulb extract inhibits growth of about 300 pathogenic fungi; *Insecticidal.* Garlic extract (1%) containing formulations are found to give protection for almost 8 hours against mosquitoes and black-fly.

There is recently increased interest on processing of garlic in the country, mostly for dehydration, pickling, powder and for oil extraction. Such products are nutritionally not good and more over do not have very long shelf-life. Hence there is an urgent need for developing low-cost garlic products with longer shelf-life, which can be integrated with traditional methods of Indian cooking. Jamnagar garlic is the largest and the best, giving highest recovery of dehydrated peeled garlic and garlic powder of good pungency and antibacterial activity.

**Table 16.5** Nutritive value of garlic

| Constituents (%) | Fresh peeled garlic cloves | Dehydrated garlic powder |
|---|---|---|
| Moisture | 60.80 g | 5.20 g |
| Proteins | 6.30 g | 17.50 g |
| Fats | 0.10 g | 0.60 g |
| Mineral matter | 1.00 mg | 3.20 mg |
| Fibres | 0.80 g | 1.90 g |
| Carbohydrates | 29.0 g | 71.40 g |
| Calcium | 0.03 mg | 0.10 mg |
| Phosphorus | 0.31 mg | 0.42 mg |
| Potassium | - | 1.10 mg |
| Iron | 0.001 mg | 0.004 mg |
| Niacin | - | 0.70 mg |
| Sodium | - | 0.01 mg |
| Vitamin A | 0.00 IU | 175.00 IU |
| Nicotinic acid | 0.40 mg | - |
| Vitamin C | 13.00 mg | 12.00 mg |
| Vitamin $B_1$ | - | 0.68 mg |
| Vitamin $B_2$ | - | 0.08 mg |

### 16.4.1 Garlic Powder

There are two methods for producing garlic powder. *Traditional Method*. Remove outer paper layers of the garlic bulbs manually. Cloves are separated and peeled off. And then they are dehydrated and powdered; *CFTRI, Mysore Method.* Cloves are separated from the bulbs, and then papery husk is separated. They are mechanically preconditioned and dried. Dried material is suitably processed to loosen and separate adhering husk-layer from cloves. The dried cloves are finally powdered.

**Uses**. (i)Garlic powder is used both as a condiment and as a medicine; (ii)is used for flavouring several food products; (iii) garlic tablets or capsules can be used as an antibacterial agent; (iv) Garlic can be used as medicinal tablets for gastric stimulation.

### 16.4.2 Garlic Oil

It is used as a flavouring agent for all kinds of meat preparations, soups, canned foods and sauces. Volatile oil is obtained by steam distillation from crushed bulbs or cloves. Garlicin is the main content in garlic oil.

## 16.5 Ginger Processing

Ginger (*Zingiber officinale*) is a slender herbaceous perennial, mainly confined to old world tropics with centre of distribution in Indo-

Malaysia. There are seven different trade types of ginger—Jamaican ginger, Indian ginger, West African or Nigerian ginger, Sierra ginger, Japanese ginger, Rio-de-Janeiro ginger, China ginger. The Indian ginger is further classified as Cochin ginger, Calicut ginger, Assamese ginger and Himachan ginger. Ginger is an important commercial crop cultivated throughout India, and its major producing states are Meghalaya, Kerala, Arunachal Pradesh, Mizoram, Odisha, Sikkim and West Bengal. Cochin and Calicut gingers are graded according to the finger numbers/ rhizome— three fingers, two fingers, for export purpose. Then there are bleached or 'coated' ginger, 'uncoated' peeled decorticated scraped ginger and unscraped ginger. Their prices are fixed depending upon the respective quality as per the Agmark specifications.

The dried rhizome of ginger is used as a spice. And fresh ginger contains water: 80%; proteins: 2.3%; fats: 1.0%; carbohydrates:12.3%; fibres: 2.4%; and ash: 1-2%.Dried ginger contains moisture:10% and volatile oil: 1-3% zingiberine(Table 16.6).

Sesquiterpene called zingiberine ($C_5 H_{12}$) is the chief component of oil. Volatile oil contains about 17% ar-corcumene, 1.1% camphene, 0.1% myrecene, 1.2% limonene and 1.3% linalool (Krishnamurthy *et al.,* 1970). It also contains gernio, nerole, Beta-bisabone and other compounds.

**Table 16.6** Nutritive value of dried ginger on the 100 g weight basis

| Particulars | Amount |
|---|---|
| Moisture | 6.8 (g) |
| Proteins | 8.6 (g) |
| Fats | 6.4 (g) |
| Fibres | 5.9 (g) |
| Phosphorus | 0.15 (g) |
| Iron | 0.001 (g) |
| Energy | 380 (Calories) |
| Sodium | 0.03 (g) |
| Potassium | 0.4 (g) |
| Vitamin A | 17,514 (mg) |
| Vitamin $B_1$ | 0.85 (mg) |
| Vitamin $B_2$ | 0.13 (mg) |
| Niacin | 1.9 (mg) |
| Vitamin C | 12.0 (mg) |

**Source:** Gopalan, 2000.

Many products manufactured from ginger are dehydrated ginger, ginger paste, ginger candy, ginger oil and oleoresins.

**Food items.** As a condiment, ginger is used for flavouring many products like tomato sauce or ketchup. It is also used in preparation of ginger preserve, sweet meat, curry powder and pickles. Soft drinks like cordials, cocktails and carbonated drinks are important products of ginger. As a spice, ginger is used invariably in a number of kitchen-items. Its oil is used to impart flavour to a range of food products.

**Alcoholic beverages.** Ginger is used in the preparation of beer, candy, wine and gingerale.

**Medicine.** In Ayurvedic system, ginger has been considered carminative and stimulant of gastro-intestinal tract, and hence is being used in dyspepsia and flatulent colic. It is also used in tincture. Ginger oleoresin is used in pharmaceuticals in the preparation of throat lozenges and similar other preparations.

**Cosmetics.** A very small amount of ginger is used in perfumery and cosmetics.

### 16.5.1 Ginger Candy

The best ginger for candying is canton variety. It is rich in flavour, is juicy and is succulent. Ingredients used for this are:juice: 1 litre; salt: 30 g; mustard powder: 10 g; KMS: 0.1 g; and sodium benzoate: 0.2 g.

Ginger rhizomes
(Tender, fibreless and large-sized rhizomes)
↓
Wash them
↓
Peel
↓
Cut
↓
Boil or Cook
(With 0.5% citric acid solution for 6 hours in copper-pan)
↓
Prick
↓
Wash
↓
Boil
(30% sugar syrup for 15 min and leave it overnight)
↓
Increase conc. of syrup by about 5° Brix by adding sugar
↓

Again boil

↓

Repeat this process daily till syrup is of 60° Brix

↓

Add corn syrup

(25% by wt, boil and leave for 24 hours)

Raise conc. to 75°C Brix

↓

Allow it to stand for 2 to 3 weeks (ginger in syrup)

↓

Boil it for about 5 min

↓

Dry syrup

↓

Roll ginger pieces in fine ground sugar

↓

Place pieces on wooden tray and keep in shade till they are no longer sticky

↓

Ginger candy ready

↓

Package

↓

Store

**Ginger-candy preparation**

The syrup left over after candying can be used again after dilution, for candying another batch of fresh gingers. It can also be used as ginger-syrup for flavouring aerated water.

### 16.5.2 Dry Ginger

The crop is harvested between 245 and 260 days, and the produce is kept soaked well in water to be cleaned. After cleaning rhizomes are taken out. Then peeled rhizomes are washed and dried in sun for a week to 10% moisture. For good appearance, peeled rhizomes are soaked in 2% lime-water for six hours and then dried. This is known as bleached ginger. Dry ginger yield is 20-25% of the fresh ginger; depending on the variety and the location.

### 16.5.3 Ginger Powder

Ginger is washed, peeled and cut into pieces and dried. It is then pulverized into powder. And then is sieved through a mesh size of 50-60.

### 16.5.4 Ginger Oil

It is obtained by steam distillation of fresh ginger. About 70-75% oil recovery has been noted from dried ginger powder.

### 16.5.5 Oleoresin

It is obtained by solvent extraction of ginger powder / dried rhizomes, fresh rhizomes, using acetone or ethylene dichloride as a solvent. The ginger-oleoresin is commercially known as gingerin and contains gingerol, zingerone, ohogoal, volatile oil and resin-phenol.

### 16.5.6 Ginger Preserve

It is obtained by imparting fresh ginger pieces in heavy sugar syrup.

### 16.5.7 Gingerade

It is prepared from dry ginger-syrup by fermenting and/or adding sugar.

### 16.5.8 Ginger Beer

To prepare its syrup, dry ginger is cooled and fermented with yeast. Then citric acid is added to it, and it is kept for a few days. Supernant is taken out and sealed in bottles.

### 16.5.9 Ginger Wine

It is prepared by combination of ginger, sugar, chillies and water; allow it to ferment, and then add charred sugar and citric acid to it.

### 16.5.10 Ginger Squash

It is prepared from fresh-ginger juice after mixing it with sugar-syrup, citric acid and potassium metabisulphite.

### 16.5.11 Salted Ginger

It is prepared from fresh ginger harvested after 4-5 months, as it has less fibre content. Rhizomes are soaked in citric acid and common salt for 14 days; maintaining *p*H 2.5 and 2.8. After that skin is removed, and they are packed. It is available in good flavour and attractive baby-pink colour.

## 16.6 Onion Processing

Onion(*Allium cepa*) is an important vegetable crop of India. India has the largest area under this crop in the world, while output-wise, it is second in the world, after China. Onions are mainly cultivated in Maharashtra, Bihar, Karnataka, Gujarat, Andhra Pradesh, Uttar Pradesh, Odisha and Madhya Pradesh.

Area under onion is 7.41% of the total area under vegetables, while output is 5.70% of the total of vegetables. The Nasik region (in Maharashtra) accounts for 30% of the total crop production, followed by Gujarat (11-13%), Karnataka (10%), Uttar Pradesh (8-10%) and Tamil Nadu(6%).

Onions have medicinal value as well (Table16.7). Onion oil is used for treatment of stomach-ulcer, eye-disorder, gastro-intestinal disturbances, high-blood pressure, fever and intestinal worms. Composition of onions vary according to variety, agronomic practices and environmental growth conditions. In general, varieties with high (up to 20%) dry matter are selected for processing. Onions are rich source of amino acids and γ-glutamyl peptides, anthocyanins, flavonols and phenolics. Non-structural carbohydrates consisting of free sugars, trisaccharides and fructans contribute for major portion of the dry weight of onions. Onions are rich in sulphur-containing compounds also.

**Table 16.7** Nutritional and medicinal values of onion per 100 g

| Nutrients | Value |
|---|---|
| Moisture | 86.8% |
| Carbohydrates | 11.6 g |
| Proteins | 1.2 g |
| Fats | 0.1 g |
| Calcium | 0.2-0.5 mg |
| Phosphorus | 0.05 mg |
| Fe, Al, Cu, Zn, Mn, Carotene, thiamine, riboflavin, nicotinic acid and ascorbic acid | traces |
| Energy | 160 (KJ) |

**Source:** Gopalan, 2000.

The main varieties grown in India are Pusa Red, Pusa Ratnar, Nasik Red, Patna Red, N 404, N 207-1, White Patna, N 53, N 2-4-1, Bellary Red, Bellary Bag Onion, B 780, Udaipur 101and Udaipur 103.

Onions are generally dehydrated and pickled; the ones with high solid content (dry matter) are preferred for dehydration. Varieties with 15-20% TSS are most desirable. Onions used for processing should have good pungency, since dehydrated product is used primarily as a flavouring agent; some of the pungency is lost during dehydration process also. White bulbs are preferred to yellow or red varieties.

### 16.6.1 Dehydrated Products—Flakes and Powder

***Onion Powder***

Onions
↓
Clean them
↓
Peel
↓
Slice or chop them
↓
Dehydrate (at 70 –60 °C)
↓
Grind
↓
Onion powder with final moisture content of 4%
↓
Store

### 16.6.2 Onion Pickle

For preparing the pickle, following ingredients are required:onion: 1 kg; vinegar : 1 litre; salt: 250 g; red chilli powder: 10 g; cardamom (large): 10 g; black pepper: 10 g; cumin: 10 g and clove (headless): 5 nos.

Onions (small)
↓
Peel
↓
Blanch for 5 min
↓
Fill blanched onions in jar
↓
Add salt
↓
Let this remain for 24-48 hours
↓
Drain water

↓

Add vinegar and spices

↓

Store

**Onion-pickle preparation**

### 16.6.3 Onion Oil

It is obtained by distillation of minced onions. Oil yield ranges from 0.002 to 0.03%, depending upon the raw material and processing conditions. It has flavour strength of 500 times more than that of dehydrated product.

### 16.6.4 Juice

Juice obtained from the hydraulic pressing is viscous and dark-brown. It can be mixed with a support such as propylene glycol, leultin or glucose to produce oleoresin with a flavour intensity 10 times of the dehydrated onion powder.

### 16.6.5 Other Products

Canned and bottled onions are also used for catering industries in North America. Onion-rings are common products in the fast food industries.

## 16.7 Potato Processing

Potato (*Solanum tuberosum*) with an annual production of nearly 300 million metric tonnes is one of the major food crops grown in a wide variety of soils and climatic conditions. It ranks as the fourth major food group of the world, after wheat, rice and maize. Per capita availability of potato is highest in Europe, especially in Eastern Europe, where larger share of the total production is fed to livestock. Countries of the western Europe, United States and Japan have the highest potato yields in the world.

Following commercial varieties are grown in the United States: Katdhdri, Red Pontiac, Russet Burbakor, Netted Gem, Cobbler, White Rose, Bhis Trumpil, Kennebec, Cherokee and Chippewa.

Old local potato varieties such as Phulwa, Darjeeling Red Round, Craigs Defrance, Great Scot and Salka as well as the improved varieties such as Hybrid 9, 45, 208, 209, 2236, Kufri Red, Kufri Safed, Kufri Kuber, Kufri Kusan, Kufri Kundan, Kufri Kuman, Kufri Jeewan, Kufri Chandramukhi have mainly been developed at the Central Potato Research Institute, Shimla.

Although potatoes are rich in carbohydrates, they also provide significant quantities of proteins, minerals (iron) and vitamins (vitamin B-complex and vitamin C) (Table16.8). Nutritional and chemical composition of potato-tubers varies with variety, storage, growing season, soil type, pre-harvest nutrition and method of analysis used. The average composition of potato is: water 80%, carbohydrates 18%, proteins 2%, lipids 0.1%,and minerals and vitamins 0.1%.

**Table 16.8** Nutritional value of potato (per 100 g)

| Particulars | Amount |
|---|---|
| Carbohydrates | 60-80 g |
| Proteins | 2.1g |
| Energy | 0.31 MJ |
| Vitamin C | 25 mg |
| Thiamine | 0.1 mg |
| Iron | 1 mg |
| Calcium | 9 mg |
| Phosphorus | 50 mg |
| Ascorbic acid | 20 mg |

**Source:** Gopalan, 2000.

Potatoes are processed into many types of products: (i) fried products—wafers/chips etc., (ii) dehydrated products such as dice etc., (iii) frozen products such as French-fries, patties, puffs, dices etc.and (iv) canned products. Potatoes are mainly used for chips (42%), frozen French-fries (36%), dehydrated products (4%), miscellaneous use (4%) and are canned (new potatoes) (2%). For such diversified forms of products, raw material requirements vary (Table 16.9).

**Table 16.9** Raw potatoes' requirement for processing

| Characteristics | Potato products | | | |
|---|---|---|---|---|
| | ***Dehydrated*** | ***French-fries*** | ***Chips*** | ***Canned*** |
| Tuber shape | | Long shape | Round to round-oval shape | - |
| Tuber size, mm | 30 | 50 | 40-60 | 35 |
| Eyes | Shallow | Shallow | Shallow | Shallow |
| Specific gravity | 1.080 | 1.080 | 1.080 | 1.080 |
| Texture | Fairly firm to mealy | Fairly firm | Fairly firm to mealy | Firm (waxy) |
| Dry matter (%) | 22 - 25 | 20 - 24 | 22 - 25 | 18 - 20 |
| Starch (%) | 15 - 19 | 14 - 16 | 15 - 18 | 12 - 24 |

### 16.7.1 Pre-peeled Potatoes

Potatoes are washed to remove dirt and are peeled by various methods including abrasion-peeling, lye-peeling, steam-peeling or a combination of lye and steam washing to remove any peel left, and are trimmed, trained to remove eyes, residual peel and damaged, diseased or green areas. Pre-peeled potatoes are immersed in sulphite solution. They are then drained, packaged, refrigerated and used for preparing processed products.

### 16.7.2 Frozen Products

*Potato-chips/Wafers*

Pre-processing operations

↓

Slice

(1/15 to 1/25 inch thick slices by rotary slicer)

↓

Dry

(Optional process, may be done by drum dryers)

↓

Fry

(In continuous batch fryers using refined oil)

↓

Salting and additional flavouring

↓

Cool and inspect

↓

Packaging

↓

Storage

*French-fries (Frozen Potato-chips)*

These are prepared for serving by finish-frying in deep-fat. For potato-chips, reducing sugar content should be low to avoid dark fried pieces. French-fries are prepared from good quality potatoes. Process includes washing and peeling, trimming, sorting, cutting, blanching, frying, defatting, cooling, freezing and packaging. Sodium acid tryphosphate calcium lactose can be used during blanching to improve texture. The blanched product is fried in oil at 177 – 187 °C. Excess fat is removed from fried product and it is then air-cooled.

Pre-processing operations
↓
Cutting(into strips by strip-cutter)
↓
Sorting of strips
(Remove broken, discoloured and defective pieces)
↓
Blanch
↓
Remove excess moisture
↓
Fry
↓
Defatting
↓
Cool and inspect
↓
Packaging
↓
Freeze
↓
Storage (for 2-4 months)

**French-fries making**

***Fabricated French-fries and Chips***

They are prepared from dried potatoes; gelatinized, glutened and oiled and finally shaped into discs and dried to 12% moisture and deep-fried.

### 16.7.3 Dehydrated Products

***Potato Granules***

They are one of the important products prepared from dehydrated meshed potatoes, containing 6-7% moisture.

Pre-processing operations
↓
Slice and wash
↓
Blanch
↓
Cool

↓
Steam-cooking
↓
Condition
↓
Air-lift drying
↓
Sieving
↓
Meshing, mixing, sulphiting + other additives
↓
Fluidized bed-drying
↓
Final product (Potato Dehydrated Product)

***Potato Flakes***

Dehydrated flakes are prepared by applying cooked meshed potatoes to the surface of a drum-drier fitted with applicator rolls, drying deposited layer of potato solids rapidly to the desired final moisture and breaking sheet of the dehydrated potato solids into suitable sizes for packing. Many additives are employed in making potato flakes to improve their texture and extend product shelf-life.

Pre-processing operations
↓
Slice
↓
Wash
↓
Blanch
↓
Cool
↓
Steam-cooking
↓
Mixing, sulphiting + other additives
↓
Drum-drying

***Diced Potatoes***

These are prepared from whole potatoes by slicing, followed by blanching and dehydration.

Processing operations
↓
Cut and wash
↓
Blanch in water
↓
Sulphiting
↓
Drying (tunnel) + Belt

***Potato Flour***

It is commonly used in the baking industry. It is prepared by dehydration of peeled, cooked potatoes on a single drum-drier equipped with applicator rolls. Thin, dried sheet of potato solids is ground to desired fineness. Potato flour is used in bread to the extent of 6%. It is also used in doughnuts, cakes and cake-mixes and snack foods,and as ingredient in many dehydrated soup-mixes.

Pre-processing operations
↓

| | |
|---|---|
| ↓ | ↓ |
| Slice | Cook |
| ↓ | ↓ |
| Wash | Blanching and sulphiting |
| ↓ | ↓ |
| Dry | Drum-drying |
| ↓ | ↓ |
| Grind | Grind |

### 16.7.4 Miscellaneous Products

***Canned Potatoes***

Potatoes
↓
Pre-processing operations
↓
Cutting
↓
Blanching for 3 min
↓
Cool

↓
Fill cans
↓
Brining
(Add 3% brine)
↓
Seal
↓
Sterilize
↓
Cool
↓
Store

Potatoes serve as raw material for several other food and industrial products. Industrial wastes and industrial products can be utilized for cattle-feed and for isolation of chemicals. Potatoes have been used for production of canned potato seeds, canned French-fries, pancakes, soups, chip bars, chip confections, potato nuts, potato puffs, sponge dehydrated potatoes and potato snacks.

### 16.7.5 Traditional/Domestic Processing

Potatoes are generally cooked to be consumed. Cooking of potatoes include baking them with or without peels, frying and microwave-cooking.

## 16.8 Tamarind Processing

Tamarind tree (*Tamarindus indica)* is native to India. It is mainly grown in Maharashtra, Karnataka, Andhra Pradesh, Kerala and Uttar Pradesh. It is used as a food flavouring agent. In medicine, it was prescribed for its anti-inflammatory action, as a laxative and for various other disorders. And it is widely used as an ingredient for making *sambhar*; a curry prepared from *tur dal*. Powder obtained by pulverizing de-shelled tamarind-seed is used as an ingredient for sizing material in textile processing industry and in jute processing. It is also used for manufacturing industrial gums and adhesives. Tamarind seed oil (obtained seed powder) can be used in soap-making and also for edible purposes after refining. Ripe-fruit on an average comprises 55% tamarind pulp, 33% seed and 12% fibres, and reducing sugars consists of 70% glucose and 30% fruit sugar (i.e. fructose). Only a trace of sucrose or cane sugar is present. The pectin present in the pulp is of good quality; of 180-200 jelly grade (Table 16.10).

**Table 16.10** Nutritive value of tamarind per 100 g

| | |
|---|---|
| Moisture | 18.2 g |
| Free acid (Tartaric) | 9.8 mg |
| Combined acids | 6.7 g |
| Total sugars as invert | 38.2 g |
| Proteins | 2.8 g |
| Pectins | 2.8 g |
| Fibres | 19.4 g |
| Mineral matter | 2.8 mg |
| Niacin | 0.2 mg |
| Calcium | 0.17 mg |
| Phosphorus | 0.11 mg |
| Iron | 0.011 mg |
| Energy | 283 calories |
| Vitamin A | 100 IU |

**Source:** Gopalan, 2000.

### 16.8.1 Tamarind Fruit-Juice Concentrate

Indigenous tamarind fruit, an important acidulant in Indian cookery, requires preliminary soaking, squeezing, draining etc., which is a tedious job. The tamarind juice concentrate developed at the CFTRI is convenient to use and is finding an internal as well as export market.

Spray-dried fruit-juice powder is hygroscopic and loses much of its original fresh flavour in drying. It is free from fibres, seeds and foreign matter, and is hygienic. It is almost of jam consistency, and is easily dispensable in the hot water at the time of use.

Tamarind-fruits
↓
Remove seeds
↓
Soak pulp in water
↓
Boil pulp in stainless steel steam-jacketed kettle
↓
Filter
↓
Further filtration to obtain fine pulp
↓
Hydraulic pressing

↓

Mixing with extract

↓

Filtration

↓

Vacuum evaporation

↓

Concentrate

**Tamarind-juice concentrate preparation**

**Pulp**. Under the traditional practice of pulp extraction, pods are sun-dried for one or two days. Pod-shell is then removed and pulp along with seed is sun-dried for 2-3 days. And the pulp obtained is sun-dried and preserved. In another process, the shell is separated manually, followed by agitation of seeds in the water to disperse pulp and separate it from seeds.

**Juice**. Clarified tamarind juice is obtained by treating juice with 0.12–0.15% gelatin. After agitation of fruit-pulp with gelatin, the mass is left standing for 10-15 days at 6-10°C. As the result, colloidal particles precipitate, which are removed by decantation and filtering in the vacuum using asbestos sheet. It is pasteurized for five minutes at 80-85°C. The juice so obtained is transparent and has a distinctive colour.

**Powder.** It is obtained manually by cleaning, de-seeding and removing fibres from the pulp.

Clean tamarind pulp

↓

Mix

↓

Dry

↓

Pulverize

↓

Granulating and conditioning

↓

Packaging

↓

Final product

↓

Powder-making

## 16.9. Tomato Processing

Tomato (*Lycopersicon esculentum*) is considered "King of vegetables", and is grown worldwide on a wide variety of soils and climates. United States, Turkey, Italy and Spain are the leading tomato countries, and India ranks second, accounting for about 7.427 million tonnes. Important tomato-producing countries are China, Italy, Turkey, Egypt, Romania and Spain. In India, tomato is grown in abundance in summer and in winter but winter-grown tomatoes are of superior quality as they contain more total solids. The most important qualities of tomato required for processing are: dark red colour, contributed by lycopene; high solid content; low *p*H; and low fruit crack. Major tomato-producing states are Karnataka (27%), Uttar Pradesh and Bihar (33%), Andhra Pradesh (15%), Maharashtra (15%); together accounting for 80% of total production. Ripe tomatoes are a good source of carotene and ascorbic acid (vitamin A and vitamin C). Tomatoes are rich in carbohydrates and some minerals. Fresh-ripe fruits are refreshing and appetizing and are consumed raw in salads, and are used in vegetarian and non-vegetarian curried dishes.

Tomatoes are commercialized for manufacturing juices, puree, paste, ketchup, sauces, soups and powder. Based on the end-use tomatoes can be grouped into: (i) tomatoes to be supplied fresh to the consumer and(ii) tomatoes for commercial processing —manufacturing various products.

High solid content is an important economic factor for making puree and paste. And the most prevailing organic component of the tomatoes is reducing sugars— fructose and glucose. Alcoholic insoluble solids(AIS) also are important, as the consistency of the products made from tomatoes is closely related to the concentration of celluloid and pectin compounds. High AIS results in thicker ketchup, sauce and good consistency in paste. In addition, organic acids are the major determinant of *p*H. Since tomatoes are processed as an acid-fruit, *p*H of less than 4.5 is desirable for safe processing. Major nutrient components of tomatoes are vitamin A and C; vitamin C content is related to fruit size, shape as well as to locular content, and is dependent on the exposure of the fruit surface to light.

**Fruit composition**. *Moisture*.It increases from about 91 to 93% as the fruit matures (Salunkhe, 1974); good quality ripe-fruits average moisture content ranges from 94 to 94.5% and dry matter varies from 5 to 7.5%. *Sugar.* Dry matter of tomatoes constitutes 50% sugars—sugar concentration increases from 3.25% at the mature green to 4.25% at the red ripe stage. *Starch* (It is only a minor constituent of ripe fruits).Immature green tomatoes contain considerable amount of starch; it decreases progressively with age; from just over 1% of fresh weight in the immature fruit to 0.10 and 0.15% in the red ripe fruit. *Ascorbic Acid.* It is 25 mg per 100 g of fresh weight. Some hybrids have between 16 and 25 mg/100 g of fresh weight. *Organic Acids.* Predominant organic acids of ripe-tomato fruits are citric and malic acids (Table 16.11). Other acids are formic, acetic and transaconitic acids, with traces of lauric and fumaric acids.

**Table 16.11** Malic and citric acids (mg /100 g of fresh fruits)

| Organic acids | Mature green | Green yellow | Yellow orange | Orange red | Red ripe |
|---|---|---|---|---|---|
| Malic acid | 246 | 212 | 168 | 141 | 111 |
| Citric acid | 187 | 231 | 215 | 195 | 197 |
| M/C ratio | 1.29 | 0.90 | 0.78 | 0.69 | 0.56 |

**Commercial Processing.** The quality and the flavour of the processed products depend on the chemical composition; and their physical characteristics vary with varieties of tomatoes. High-quality tomato products can be obtained by enhancing consistency (tomato pulp) by using ultra-centrifugation and addition of $CaCl_2$ to improve texture. Inclusion of natural red colour tomatoes is most important for manufacturing quality-tomato products. Green pigment chlorophyll of unripe tomatoes, when comes in contact with iron, copper, salts, and is heated for a long period causes browning of lycopene, and thus affects acceptance of the product in the market.

**Equipment for Tomato Products' Preparation.** *Open Cooker.* Open kettles made of stainless steel, fitted with a stainless steel coil (flash coil) that allows rapid uniform heating are used for concentration of tomato-pulp.

*Vacuum Pan.* Principle advantage of this is in retaining colour and flavour of tomatoes to a remarkable degree by reducing boiling point of the tomato-pulp to 70°C or less.

*Reverse Osmosis Concentration Plant.* Concentrating tomato-juice is difficult as it has high pulp content (25% fibres) and high viscosity. Thus, reverse osmosis concentration of juice is limited by osmotic pressure and viscosity. Natural tomato-juice concentration from 4.5° to 8-12° Brix to form tomato-puree and further at 28-29° to form tomato-paste is possible by using DC1 AFC-99 tubular membrane. In this, retention of organic acids (citric acid and malic), sugars (glucose, fructose), mineral ions (K, Mg, Na, phosphates, chlorides) and free amino acids is excellent. Some losses of low molecular volatile (methanol, ethanol) compounds were observed. Colour is retained and shows no browning; which is normally associated with evaporation. Colour quality is retained when evaporated at 28-29°Brix paste because of reduced time in the evaporator. The operation cost of the plant is very low as it consumes low energy.

**Tomato Products' Packaging**. Bulk packaging is well established for aseptic filling of fruits and tomato products. The container used for this purpose may be metal-drum supported by multilayered aseptic bags. Puree or paste is filled in the aseptic-bag in a sterile environment.

Use of standard ingredients and additives like sugar, salt, spices, colours, preservatives would ensure quality standard of the product. Standardized techniques in the flow process of manufacturing at blending, pasteurization, filling temperature, weighing, sealing, retorting should be maintained. TSS, acidity, sensory evaluation for taste, colour and consistency are essential in quality control. Shelf-life of the product depends on the storage conditions and packaging. Faulty seam in can or faulty filling of crown-cork can spoil the product.

**Tomato Waste Management and Byproduct Utilization**. Efluents from tomato-processing industry contain 652-2,305 mg of chemical oxygen demand (COD)/litre, 454-1,575 mg of biological oxygen demand (BOD)/litre, and their *p*H ranges from 5.6 to 10.8. Waste water is treated traditionally either in the form of oxidation ponds or lagoons or by activated sludge process, utilizing microbial capacbilities for degradation of waste and reducing pollution load of BOD/COD. Adoption of treatment processes based on the anaerobic degestion and biological reactor like up-flow, anaerobic sludge-blanket process (UASB - FBAR) will control effluents.. Common immobilized bioreactor used in the anaerobic treatment of food industry is Fluidized Bed Reactor (FDR) for waste. The waste of the USSB is retained within the unit with the development of highly settable bacterial flocks of 1.5-cm diameter granules.

Addition of 5-15% whole or defaulted tomato seed-meal in Egyptian Balady bread improved gas production, moisture content, loaf diameter and organoleptic characteristics. Incorporation of tomato processing waste (pomace) in food may provide two-fold benefits—disposing of tomato processing waste and enhancement of dietary fibres content of other food products.

Incorporation of tomato seed-meal in wheat-flour improves acceptability of bread with high-loaf volume and lysine content without affecting staling rate. The fat-free seeds contain 39.5% proteins and can be utilized for food or feed. They contain 13% more lysine than soya protein.

### 16.9.1 Tomato-Juice

In preparing tomato-juice, tomatoes are washed and sorted. They are chopped to 1- to 1.2- cm size for crushing prior to juice extraction. Immediately after chopping, they may be subjected to hot-break or cold-break procedures. In hot-break method, chopped or crushed tomatoes are rapidly heated to at least 82°C for 15 seconds to inactivate pectin enzymes. Heat treatment is usually given in the rotating coil tanks, followed by heat exchanger, and holding tube to active 104°C to retain at least 90% of potential serum viscosity of the original fresh tomato. This produces better quality juice with respect to flavour and body to cooked tomatoes. In the cold-break procedure, tomatoes are scalded to loosen skin before chopping. The fruits are chopped or crushed at the temperature lower than 66°C and then are placed in a holding tank, where they remain static for a few seconds to minutes. During this period, the pectin enzymes liberated during crushing can catalyze pectin breakdown. This is claimed to give better coloured, flavoured juice with a better retention of vitamin C. Following the treatment, tomatoes are conveyed to a cyclone for juice extraction; 70-80% juice is extracted commercially. And juice is de-aerated immediately after extraction to stop vitamin C losses, and is acidified with citric acid to enhance flavour, is salted if necessary, and is filled in cans or bottles. The cans are closed at about 82-88°C, followed by water cooling, and the juice is pasteurized at 121°C for about 0.7 minutes, and the hot juice is poured into cans to ensure sterilization of containers.

According to EEC regulation No. 1599/84, tomato-juice is the food prepared by squeezing fresh, round, mature tomatoes from suitable varieties of bright-red colour, free from skin and seeds, duly chopped, pulped and refined. It must have the following general features.

- Dry matter should not be less than 5% and not exceeding 7% (values net from added salt) after 3 to 4 hours in oven. If tomato-juice is obtained by diluting tomato-paste, ingredients must be declared on the label, i.e. water and tomato-paste, and any added salt and aromas; however in general "tomato-juice" is only juice obtained directly from fresh tomatoes and not from concentrate; drinkable tomato-juice obtained by dilution of tomato-paste with water is allowed in other European countries at the condition that the label shows a fantasy name together with "tomato-juice" to diversify natural juice having higher quality from blended juice. And its *p*H value shall not exceed 4.5.
- Mould count shall not exceed 60% of positive fields with reference to a sample at 7° Brix. For England and North America such limit is reduced to 40% of positive fields.

- The value of total sugars, as invert sugar, must be at least equal to 42% by weight of the dry matter net from added salt.
- Volatile acidity, as acetic acid, shall not exceed 0.4% by weight of the dry matter net from added salt.
- The tenor of mineral impurities shall not exceed 0.1% by weight of the dry matter net from added salt.
- Colour shall be a typical bright red.
- Product must be free from odours and have a pleasant smell, typical of a properly processed product.
- Taste shall be free from off flavours, particularly from caramelized or burnt taste.
- Texture shall be homogeneous and free from serum separation (liquid separation from pulp), free from skins, seeds, black spots and/or any other large fruit particles.
- Following ingredients are allowed to be added to tomato-juice: natural salt, natural spices, aromatic herbs and/or their extracts, natural aroma, citric acid (for *p*H correction); lemon-juice and ascorbic acid can be added too but only in tomato-juice having dry matter lower than 7% and in any case in a volume not exceeding 0.03% of the weight of the finished product.

*Production Norms.* The entire production cycle shall be accomplished in compliance with the highest sanitary standards, shall be accomplished with the most advanced technology, and shall be under management control and supervision.

**Drinkable tomato-juice from fresh tomatoes.** This is normally produced during tomato season, when they have reached their prime; and shall be produced from selected varieties with a solid content not less than 5° Brix. Production technology is basically the same as is used for production of tomato-paste and/or "passata" (obviously with exclusion of concentration phase). Special attention has to be paid to screen meshes of juice extractor (standard size is 0.4 mm, while in the UK, it can be even 0.3 mm). Tomato-juice is normally packed directly into the final container; however, it could also be stored into 20/50 $m^3$ aseptic tanks or in 1,000-litre aseptic bags and re-processed later according to the market demand. Tomato-juice can also be made from aseptic tomato-paste (particularly for the northern European countries); in both the cases preparation processes before filling into final containers shall be as follows.

- Preparation of the final recipe in a suitable tank by adding all the necessary ingredients: salt, spices, aroma and other ingredients in line with the final market demand; the tanks shall be provided with suitable stirrers to assure adequate blending of ingredients.

- When production starts from the tomato-paste, filtered/ dematerialized water shall also be added to reach desired quantity of dry matter, homogenization at 150/200 bar shall also be done but only for juice obtained from tomato-paste to prevent serum separation. Juice obtained directly from fresh tomatoes requeris no homogenization.

Tomatoes (Fully ripened red ones)
↓
Wash them
↓
Sort and trim (Remove green portion of the stem)
↓
Cut and chop (4-6 pieces)
↓
Pre-heat at 70-90°C for 3-5 min (soften)
↓
Juice extraction
↓
Refining
↓
Concentrate at 10-12° Brix
↓
Fill in sterilized can
↓
Seal
↓
Pasteurize
↓
Cool
↓
Label
↓
Storage/Marketing

**Tomato-juice preparation**

### 16.9.2 Tomato-Puree and Tomato-Paste

They are prepared from one or any of the combinations of the liquids obtained from ripe-tomatoes of red or reddish varieties, from the residue consisting of peels and cores after preparing tomatoes for canning, and also from the residues obtained after partial extraction of juice. For the preparation of puree, the liquid is separated from seeds, skin and cores and concentrated in the tanks with rotating steam-coils or in vacuum pan. The liquid is then evaporated to less than or equal to one-half of its volume to obtain a puree of specific gravity of 1.035-1.05. It is then filled into cans at 88°C, sealed and carefully cooled to stop loss of flavour, colour and stack-burning.

Tomato-paste is prepared in a similar way with the addition of salt, spices, flavouring agents and sometimes baking-soda. Both puree and paste may be light, medium or heavy, depending on the degree of the concentration. Accordingly, as determined by refractometer of the minimum percentage of solids (without considering salt), the following description may be used (Table 16.12).

The quantity of tomatoes used for paste production should have high content of total solids, should be intensively red coloured with high sugar content and low acidity.

Prior to manufacturing, incoming batches of tomatoes are carefully checked for: uniformity in colour; over-ripeness or under-ripeness; infestation by insects or moulds; presence of excessive dirt, mud and other foreign matter, and appropriateness of the variety for the preparation.

First of all wash tomatoes thoroughly. Different types of washing procedures are—single static tanks to high pressure water jets and agitation by compressed air. Then tomatoes are taken for sorting and trimming. And then they are crushed or broken to form pulp. After removal of skin and seeds, the pulp is refined to reduce particle size and then pulp is used for concentration; it is heated at a temperature ranging from 65 to 90°C depending upon the type of the product desired. This process is referred to as 'hot-break' if prior to crushing the fruit, it is heated briefly. The 'cold break' consists of crushing tomatoes at a room temperature and then holding them from a few seconds to minutes.

**Table 16.12** Variations of tomato puree with refractometer solids

| Minimum% of refractometer solids | Description |
|---|---|
| 11 | Light tomato-puree |
| 15 | Medium tomato-puree |
| 22 | Heavy tomato-puree |
| 28 | Light tomato-paste |
| 36 | Medium tomato-paste |
| 45 | Heavy tomato-paste |

During the holding period, enzymes released during the crushing catalyze pectinolysis, and to avoid this, the pulp is transported quickly to a heat exchanger. In 'hot-break' method, rapid heating for a few seconds prior to crushing, destroys pectinolytic enzymes and liberates gummy material along with pectin, thus helps in giving 'body' to the paste. The difference between the two products of two processes lies in apparent viscosity, measured in Bostwick centimetres. The hot-break (HB) product is more viscous, and therefore denser and has an average Bostwick viscosity ranging between 3.5 and 6 centimetres, while cold-break (CB) product is less viscous, therefore, less dense, and measures normally between 9 and 16 Bostwick centimetres in viscosity. The HB product is used mostly for ketchup and different sauces, requiring 28-30° Brix, while CB is mainly used for triple concentrate paste at 36-38° Brix, packaged in 500 or 1,000- gram cans for domestic use.

This procedure, which increases viscosity in tomato-paste by using heat, is technically identified as the enzymatic inactivation procedure. This not only increases consistency of the finished product, but also decreases consistently serum separation (the separation of the liquid from the fibrous parts), a phenomenon which is not at all appreciated by end-users. It has been demonstrated that if pectolytic enzymes, naturally present in the tomatoes and fruits, are exposed to oxygen during chopping process, they are revitalized and begin to destroy pectin. Pectin is the substance which gives consistency to tomato-paste. It has also been observed that pectolytic enzymes can be de-activated at temperatures exceeding 85°C. Therefore, all enzyme deactivation systems, known as Hot-Break Units, raise product's temperature up to 85° C and over, so as to deactivate enzymes as quickly as possible, and therefore, preserve product's natural viscosity.

Definition-wise, tomato-puree is a product of concentrating tomato-juice, obtained from fresh-round tomatoes of red sharp colour, from suitable varieties, freed from skin and seeds, duly chopped, pulped and refined. The general features of the product are as follows.

- Final product shall be homogeneous, free from added salt , from pesticide traces, and also from any kind of additives, chemicals, preservatives and colouring matter.
- Raw material shall be free from diseases, insects and parasites and deterioration owing to sand, foreign matters of any nature.
- Typical preservation guaranteed life shall be of two years.

*Production Norms.* The entire production cycle shall be carried out under the highest degree of sanitary environment and be carried out according to the state-of-the-art technology under proper management control and supervision.

Hopper
↓
Crusher (Crushing of tomatoes by rotation blades/boxes)
↓
Pre-heating
↓
Cyclone screen (Removal of seeds)
↓
Heat exchanger
↓
Cyclones (Removal of skin, seeds, break-down of fibres and cells)
↓
Refined homogenous smooth pulp
↓
Concentrate
(Vacuum or continuous evaporators— Final solids content 28-30%)
↓
Raise temperature to 90 °C (destroys surviving organisms)
↓
Fill into cans
↓
Seal
↓
Sterilize
↓
Cool
↓
Packaging

**Tomato puree and paste processing**

### 16.9.3 Tomato Concentrate: Industrial Approach

As there are many varieties of tomatoes, it is essential to know when tomato concentrate should be produced, and when the product will be a cold-break or a hot-break type to carefully organize farmers' work and also choose variety well in advance. It is advisable to use hybrid seeds and not seeds from the harvested tomatoes to obtain a higher disease resistance and increased yield. A concentrate-plant requires a precise-and-constant supply of hundreds of tonnes of fresh tomatoes everyday as a raw material, and this can be obtained: (i) by organizing tomatoes harvesting and delivery of the exact amount at the factory at the right time (not too early and not too late); and (ii) by installing pools in the plant; these tanks, usually 5m × 30m each, can hold about 150 tonnes of tomatoes and 150 tonnes of water and act as stockpiles, providing processing line with a constant supply. It is important that tomato-processing line operates constantly at the maximum capacity, not at a reduced capacity or intermittently. In fact, everytime tomato-processing line is shut down, all machinery needs to be cleaned, resulting in loss of several working hours subsequently along with the wastage of large amount of water and a large amount of product contained in the evaporator. Furthermore, fresh and ripe tomatoes cannot be kept for long in the store-yard at the ambient temperatures of over 30°C for more than 24-48 hours to be processed; this will lead to inferior quality of finished product with lower Brix.

### 16.9.4 Tomato Ketchup

It can be made directly from fresh juice or from concentrated pulp or bulk-stored tomato-paste. The other constituents of ketchup are sugar, salt, vinegar, onions and spices; all are cooked for 30-35 minutes in a steam-kettle or a tank with steam-coils. Thickness of the ketchup is an important part of its quality. Part of the thickness is owing to pectin present in tomatoes. Some manufacturers prefer a hot-break before tomatoes are cycloned to retain largest possible amount of pectin. The hot-break method dissolves some of the mucilagenous material from seeds, contributing to final consistency. The ketchup is bottled, de-aerated and sealed at 82-88°C and then cooled to prevent loss of flavour and stack-burning. The total soluble solid contents should be 25-29 for grade C, 29-33 for grade B and over 33 for grade A.

Tomato ketchup can be defined as sweet-and-sour sauce containing tomato-paste, vinegar, sugar, salt, various blended aromas and spices and a variable amount of water, depending on the quality and the cost of finished product. Ketchup can also be produced by blending natural or modified corn/rice starch, carrot and apple puree, isoglucose (corn-sugar), corn-flour, saccharine, citric acid, glutamate, and if permitted, various colouring matters. Practically, we can say that each ketchup label has a different recipe, based on the preference of final destination market, with special attention to production cost.

Tomatoes

↓

Sort them

↓

Wholesome red tomatoes

↓

Soak and wash
↓
Coring and slicing
↓
Heat and crush
↓
Pulping
↓
Tomato-pulp
↓
(Spices, sugar, salt, onion, garlic, vinegar, thickener)
↓
Cool and concentrate
↓
Finisher
↓
Add preservatives
↓
Fill in sterilized cans
↓
Low pasteurization
↓
Cool
↓
Label
↓
Storage and marketing

**Tomato ketchup processing**

A bottle of tomato ketchup, thick and saucy, is perfect accompaniment for sandwiches, burgers and more. The main reason for consumption of condiment-ketchup is that it adds flavour to food. The Bureau of Indian Standards (BIS) grades ketchups according to their colour, consistency, flavour and absence of defects. These are known as organoleptic requirements, and accordingly, ketchups are of two grades—Grade 1 and 2. These are essentially sensory tests and are subjective in nature.

*Tomato Ketchup Processing*. The process described herein is a "batch type" i.e. non-continuous. Normally tomato ketchup is being produced from the tomato-paste during off-season; is rarely produced on-line from fresh tomatoes. Tomato-paste at 30/32°Brix of hot-break type is pumped from aseptic storage tanks or from 200 litres aseptic bags in drums into the first mix tank. Drinkable/softened water is added in a volume to reduce solids content down at 15 –16 ° Brix. Soon after vinegar, and one or two types of liquid sugar (glucose or fructose) shall be added into the first mix tank according to specified volume of the recipe.

Cool the mix now at about 25-35°C for 5 minutes and add spices and essential oils according to the recipe and mix again for 5 minutes. Make a second batch while discharging from the first mix tank. The process can be made a continuous blending process but it requires complicated controls, and in consideration of costs involved, it might be convenient only for large processing capacities.

The final mixture (ketchup) can now be pumped through a tube-in-tube heat exchanger to be heated up to 77-87°C; temperature control and diversion line shall be provided in case this temperature is not obtained; only when set temperature is reached ketchup will go through homogenizer or high shear mill performing at least 180 – 200 bar working pressure.

After homogenization, ketchup shall be pasteurized at 99-104°C into a tube-in-tube heat exchanger or by steam injection device, in both cases temperature control and diversion line shall be provided to make sure that set temperature has been obtained.

Pasteurized ketchup is de-aerated into an under vacuum de-aerator from which product will come out at about 87-93°C, ready for hot-fill into final containers (glass bottles, plastic-bottles, aluminum-bags, etc.).

If the chosen container for final product cannot be hot-filled at 87-93°C, cold-filling process shall then be used. In this, ketchup from de-aerator shall be cooled down at 32-37°C by an aseptic tube-in-tube heat exchanger then pumped to "clean room" for filling into appropriate containers. It is recommended that all heat exchangers are made of special stainless steel of titanium alloy or high molybdenum content as ketchup can cause corrosion.

**Plastic containers filling provided with dispenser.** Two kinds of plastic containers are normally available for tomato ketchup— monolayer polyester containers— cheaper, but cannot accept filling temperatures higher than 75°C; and multilayer polyester/polypropylene containers— more expensive, but perform better at filling temperature up to 95°C besides providing better oxygen barrier, particularly if moulded with an intermediate layer of EVAL.

In the former type, it is not possible to pasteurize container thus chemical preservatives shall be added to the product to have reasonably longer shelf-life. In any case, being permeable to oxygen, the product gets a colour degradation rapidly thus at the end, product's shelf life is reduced to 5-6 months only.

In the latter, it is possible to hot fill the product at 90°C, and better oxygen barrier is provided allowing shelf-life up to 18 months without preservatives. It is recommended that full bottles are held at about 80 – 85°C for 7-8 minutes into a tunnel then cooled at 45°C and dried; thus they are ready for labeling and/or final packaging. Furthermore, whenever production volume exceeds 5 million pieces, it will be convenient to manufacture such plastic bottles at the plant itself directly from polypropylene granulate.

**Tomato content.** High tomato content is touted as the unique selling point of ketchups. However, no brand reveals on its label exactly how much tomato content the product has. Tomato content can be detected by analyzing "lycopene content" of the ketchup. Lycopene is a photochemical, naturally found in tomatoes that give red colour to tomatoes. It has been identified as a powerful antioxidant that is said to reduce risk of prostate cancer. This has led processed tomato-product producers to advertise their processed foods as packed with healthful benefits. The more the lycopene, the higher is the content of ripened tomatoes in the ketchup.

**Shelf-life.** Ketchup has a shelf-life of 12 months, because of the presence of preservatives in the processed food products. A bottle of ketchup has emulsifying and stabilizing agents also. In most of the ketchups, synthetic acetic acid is used as acidulant. Acetic acid keeps yeast and mould away and extends shelf-life of ketchup. The BIS requirements prescribe a minimum of 1.2% of acetic acid, and PFA and FPO prescribe 1%. Benzoic acid is another preservative added to ketchups to prevent deterioration of nutritional value and taste. The BIS, PFA Act and FPO have set a limit of 750 parts per million (ppm) of it for ketchups.

Sugar acts as a sweetening agent and preservative for ketchup as well as adds to flavour. There are no limits for sugar content in ketchups under the Indian standards. Sugar content should neither be high, nor low. According to this criterion, ideal sugar-content should be 9.26%.

*Toxic metals: Within safe limits and meeting eco-mark requirements.* There may be presence of toxic metals like arsenic, lead and mercury. While PFA Act, FPO does not specify limits for toxic metals, the BIS standards set 1.1 ppm maximum limit of arsenic, and 2.5 ppm for lead. It is advisable to keep ketchups in a cool place once opened to maintain its quality. All ketchups are packed in glass bottles with a crown and a cap.

**Ketchup variety.** Till some years ago in India, local ketchup brands survived owing to the price difference between them and of expensive MNC brands. That distinction, however, is fast disappearing. Unlike

West, where ketchup has a strong flavour identity, Indian consumers are not aware to experiment with flavour and taste. They can choose if they want it garlicky, sweet and sourly, spicy, extra spicy, a little tangy with a dash of tamarind, and the list goes on. This probably has to do with the myriad varieties of chutneys that dot Indian cuisine platter, and with which Indian food enthusiasts have had been accustomed.

*Tomato or pumpkin?* There is a common consumer anxiety that a bottle of branded ketchup may have vegetables rather than actual tomatoes. This may be true of a product labeled as "sauce", but law prohibits ketchup from having anything else other than tomatoes. Normally, we interchange sauce for ketchup. When we talk about sauce, what we are referring to is ketchup.

A test programme is based on the relevant Indian Standards IS: 5403-1969, IS 5887-P5-1976 and IS 3500. This is also referred to the PFA Act rules and the Standard Weight and Measures Act 1977 and FPO ACT-1955. Parameters like lycopene content are additionally included in the programme to ascertain quality of the tomato ketchup.

*Ketchups: High on salt ?* What gives ketchups that irresistible taste is the presence of sugar, salt and other ingredients like garlic? No ketchup notifies the amount of salt it contains. The UK Food Standards Agency has been running a salt campaign to make consumers aware of foods that have high salt content, and the agency advises consumers to go easy on ketchups, soy sauces, mustards, pickles and mayonnaise, as these can be high in salt.

*Viscosity.* Ideally, ketchups should remain in a homogenous form, and not separate into fluid. This property is commonly perceived as thickness of ketchup. On visual analysis, one should verify that water should not be separated in the ketchup brand.

### 16.9.5 Tomato Powder

It is produced by almost complete dehydration of tomato-juice, usually after concentrating tomato-paste to approximate density. The powder should be readily reconstituted in water and the resultant gain should resemble as closely as possible to the natural product in flavour, colour, physical structure and chemical composition. The powder may be prepared by spray or roller drying. The roller-dried powder tends to be flaky, and is difficult to reconstitute, as compared to spray-dried one. The dried powder is extremely hygroscopic and should be packaged into sealed containers, preferably using gas or vacuum packing. Solar dryer can also be used for drying tomatoes; for this, first of all tomatoes are sliced and kept in the dryer for one or two days depending upon the solar radiations for conversion into the final dried product.

Selected tomatoes
↓
Wash
↓
Trim
↓
Sort
↓
Drain
↓
Slice
↓

Tomato pigments are stable as they are rich in carotene, so, pre-processing—blanching and sulphuring—is not necessary. Alternatively slices may be dipped for 3 min in 0.7% potassium metabisulphite solution ($K_2S_2O_5$ + 10% salt)

↓
Dry
↓
Packaging
↓
Label
↓
Store

**Dried tomatoes-making**

### 16.9.6 Whole Peeled Tomatoes

They are whole (entire, not broken or rotten) tomatoes from which skin has been removed; the final product is to be freed from skin, seeds and topped with natural or semi-concentrated tomato juice. The general features of these tomatoes are as follows.

- They are similar to red coloured mature and sound tomatoes.
- Have taste and smell of fresh tomatoes, free from off-flavours.
- They are to be free from parasites and damages of any type.
- Their drained weight is not less than 60% of the net weight (net weight = whole peeled tomatoes + topping juice, without container).
- Containers not exceeding 400 g of net weight (tomatoes + juice) shall contain perfect entire fruits for at least 70% of the drained weight; for larger containers, this value is 65%.
- Dry residue net from added salt should not be less than 4%.
- Skin remains: an average value shall be determined over at least 5

containers and shall not exceed 3 $cm^2$ per each 100 g of drained product; in any case each container shall not exceed four times of the value calculated as above.

- Topping juice shall represent not more than 40% of the net weight, and can be concentrated up to 7° Brix.
- Howard mould count should not exceed 40% of the positive fields.
- Superior quality features may be claimed by the producer and declared on the label when in addition to the above, following are met: (i) drained weight is not less than 70% of the net weight (net weight = whole peeled tomatoes + topping juice, without the container); (ii) dry net residue from added salt should not be less than 4.5%; skin remains: an average value shall be determined over at least 5 containers and shall not exceed 1.5 $cm^2$ per each 100 g of the drained product. In any case, each container shall not exceed four times of the value calculated as above; (iii) Topping juice shall represent not more than 30% of the net weight and shall have a concentration degree of not less than 8° Brix; (iv) Howard mould count should not exceed 30% of the positive fields.

An additional rule is that topping whole peeled tomatoes with semi-concentrated tomato juice is allowed when final dry residue, net from added salt, carried out on shake product is not less than 6°Brix (for shake product mean the whole content of a can i.e. whole tomatoes and juice, milled and homogenized).

Following ingredients can also be added: NaCl (salt) in a volume such that the percentage of chlorides in the finished product as sodium chloride should not exceed 20% of the dry residue; some basil leafs; citric acid of correct acidity and calcium chloride

*Whole Peeled and Diced Tomatoes' Processing.* When producing peeled and/or diced tomatoes, it is advisable to use varieties which have been specifically assesrsed for this use, and processing should be only of fully ripened tomatoes. Another important consideration is that peeled and/or diced tomatoes processing must always be taken along with tomato-paste production. It is not economical to produce only peeled tomatoes as there will be enormous wastage; waste products of grading and sizing operations, which may be as high as 30% and wastes from peeling process can be about 10%. How fresh tomatoes are delivered to factory is important, as fruits for processing must be perfectly preserved to have a good yield from the peeling line. Tomatoes should be transported in plastic boxes of 350 – 470 kg; rather than loosely in truck.

***Peeled tomato.*** Fresh tomatoes are unloaded into a *flume* (a *hydraulic duct*), which transports fruits to a grading station, where staff remove cracked, immature or excessively small tomatoes. This process eliminates about 5% of the incoming raw material. Suitable tomatoes shall be divided according to the size so that peeling machine can be fed with almost homogenous fruits; this eliminates 15% of the incoming raw material. The sized fruits are placed into a "scalder" (or boiling-water rotating tank) to facilitate skin removal in the subsequent peeling stage. The peeling phase can be carried out by using: (a) caustic soda, (b) mechanically and (c) with steam (known as thermo-physical peeling). It is generally recommended that only mechanical and thermo-physical methods should be used; as caustic soda process produces inferior quality finished product (loss of colour and flavour) and causes pollution.

Mechanical peeling, also known as Savi from the name of the company which invented this procedure, is most suitable for small productions (up to 10-15 tonnes of raw material /hr). It is economical due to reduced machinery cost, total recovery of waste product and due to finished product with extremely high quality features (colour, flavour, etc.). The disadvantages lie that fruits must be carefully sized and that mechanical parts must be constantly serviced; even if this, then also maintenance procedure is not particularly expensive as these devices are quite simple. During mechanical peeling, the scalded fruits (rapid skin heating) must be channelled and then rotating blades incise on the skin surface. Mechanical "hands", manufactured in special rubber, literally take hold of tomatoes and by exerting a light pressure, retain skin while letting whole tomato slip out. Strips of skin remaining on the peeled tomatoes are then removed by separators, positioned immediately after mechanical peeling machine.

Thermo-physical steam-peeling method is recommended for large quantities (i.e. over 15 tonnes/hr) to amortize higher machinery cost. There are basically two main advantages associated with this method: large quantities of the product can be processed using only a machine (even up to 50 tonnes/hr); the machine can also be used for peeling tuber vegetables such as potatoes, carrots, etc.

In the steam-peeling, pre-heated fruits are brought up to about 115°C temperature rapidly in a high pressure chamber, and then cooled rapidly under vacuum to produce a sort of skin explosion, whereby skin comes out. The skin is not entirely detached from the fruit inside the peeling machine, but it is done by skin-removal units, positioned after peeling unit. Furthermore, thermal stress at 115°C under high pressure causes wastage of pulp lying immediately under skin, which is the best part of the fruit; this does not happen while using mechanical peeling machine. Inspection is carried out manually by specialized personnel or by an electronic device, called Optical Selector that recognizes unsuitable fruits and removes them. Obviously these electronic devices can be justified only for larger workloads and in countries where manual labour costs are high. The peeled and selected tomatoes can be sent for packaging in metal-cans with a capacity ranging from 0.5 kg to10 kg. Through telescopic fillers, this process is carried out automatically. The empty space inside the can, which represents about 35– 40% of its total weight, must be filled with natural tomato- juice or semi-concentrated juice of 7° Brix. This is carried out automatically using a juicer. Filled cans can be sealed. Containers and contents are sterilized to provide a stable bacteriological level and to ensure long product preservation. The filled cans are placed inside the large pasteurizing machines, equipped with a can-rotating device at atmospheric pressure. These machines heat product up to 98°C for a pre-set time which varies according to can's dimension. The can's core must reach at least 95°C to ensure perfect product-pasteurization. It is essential to use can-rotating pasteurizing machines in this process as heating time would otherwise be excessively long, thereby reducing finished product quality. This machine also cools and dries filled cans at a temperature of 35 – 40°C, to be ready to be packaged automatically in the cardboard boxes. It is extremely difficult to draw conclusions about the output when dealing with peeled tomatoes, as many technological process variables must be taken into account, although it is clear that the quality of the raw material is a decisive factor as regards to the end-product yield.

However, statistics from Italy (the largest peeled tomato producer in the world) show that every 100 kg of fresh tomatoes on the processing line produce 60 kg of peeled tomatoes for canning and 40 kg of total processing waste (grading rejects, calibration, peeling). About 30 kg of these rejects are used to produce concentrate or additional juice for peeled tomatoes. Therefore, unusable waste is only 10 kg(this is average value).

**Diced tomato.** For this, tomatoes undergo same technological process as for peeled tomatoes up to peeling stage, after which product is cut into cubes using a dicer, and dejuiced by using a vibrating screen, graded manually or electronically (like peeled tomatoes) and pre-heated at 50°C. It is then sent for final juice-filling at 90°C and packaging, which is same as for the peeled tomatoes. Yields are almost the same as for peeled tomatoes or slightly higher.

Unlike peeled tomatoes, diced tomatoes can be aseptically filled in 200–1,000-litre containers. In this case, the technological process is as follows: after chopping, cubes are sent to cylindrical mixing tanks. Usually three tanks are required to ensure continuous processing (one is always on the loading phase, one is full for product stabilization, and one is on the discharge phase for aseptic sterilization. Firstly entire diced product must be mixed with tomato-juice in a ratio of 50/50 inside a special upright tank to allow maximum heat exchange as well as minimal mechanical damage to cubes. The tank agitators are designed for optimal mixing without damaging cubes. The juice/diced mixture must be left to stabilize (with the agitator on) at the maximum possible temperature, always over 90°C, for at least 5 minutes (or even longer depending on the product's *p*H value). Some countries require and/or allow 900 ppm of calcium chlorine ($CaCl_2$) to be added to the mixture, though this must always be indicated on the label. Adding this substance causes diced product to harden, thereby making it firmer and consequently easier to pump. This long settling time is essential for optimal dice/juice osmosis (to make it denser) and to prepare it properly for the subsequent sterilization stage.

At the preparation stage inside the tank, dices are sent to aseptic sterilizing-cooling system via large diameter tubes, special valves and pumps, which do not damage dices. Inside the tubular sterilizer, the product is gradually sterilized up to a temperature of 115°C (depending on the product's *p*H value), kept at this temperature for at least 5 minutes, and then quickly cooling at 30 – 35°C in a tubular exchanger, using cold and/or refrigerated water. The aseptic diced product can be filled inside special 200 or 1,000- litre bags via a 2-inches opening instead of 1-inch used for tomato concentrate. Thus, aseptic filler must be equipped with a 2-inch opening.

## 16.10. Bittergourd Processing

Bittergourd (syn. Bitter cucumber, balsam pear) *Momordica charantia* is an important cucurbit vegetable, grown in Maharashtra, Kerala, Karnataka and Tamil Nadu. There are three types of bittergourd varieties:(i) small, 10 -12-cm long of 100 – 300 g, usually dark-green e.g. Akra Haut; (ii) long, 30 – 60-cm long of 200 – 600 g, light in colour with medium size protuberances, e.g. Priyanka; (iii) triangular fruit type, cone-shaped, 15 – 30-cm long of 300 – 600 g, light to dark green with prominent tubercles.

**Composition and nutritive value.** *Composition*. Bittergourds are rich in iron (1.8 mg/100 g), vitamin A (210 IU/100 g) and vitamin C (88 mg/ 100 g), and form an ideal diet for diabetics. The nutritive value of bittergourd is as follows: moisture: 92.4%; protein: 1.6 g; fat: 0.2 g; minerals: 0.8 g; fibres: 0.8 g; carbohydrates : 4.2 g; energy: 25 g; calcium: 20 mg; phosphorus: 55 mg and iron: 1.8 mg(Source: Gopalan, 2000).

### 16.10.1 Bittergourd Pickle

Ingredients used for pickle-making of 1 kg of bittergourd are: salt: 150 g; tamarind pulp or *amchur*: 250 g; red chilli powder : 10 g; turmeric, cardamom, cumin, aniseed (powder): 10 g each; mustard (grind):10 g and mustard oil: 500 ml.

Bittergourd (mature, green)
↓
Wash
↓
Incise them
↓
Remove pulp and seeds
↓
Mix a little salt
↓
Keep in sunlight for 3 hours
↓
Drain of water
↓
Shade-dry (for 2 hours)
↓
Fry spices in oil
↓
Cool
↓
Mix with salt and lime-juice
↓
Fill this into bittergourds
↓
Pack in jar
↓
Add oil after heating and cooling it
↓
Store

**Bittergourd pickle-making**

### 16.10.2 Dehydrated Bittergourd

Wash, remove both ends and cut into 10-mm thick slices. Blanch for 7–8 minutes and dry at 65–70 °C or sun-dry.

Bittergourd
↓
Wash
↓
Peel
↓
Cut
↓
Blanch
↓
Spread on flat wooden trays
↓
Sulphuring (Usually at 1.8 – 3.6 kg per tonne of fruit)
↓
Drying/Dehydration
↓
Occasional turning
↓
Sweating
↓
Packing (in air-tight containers or polythene bags)
↓
Storage (at ambient temperature in dry place)

### 16.10.3 Canned Bittergourd

Bittergourd
↓
Trim both ends
↓
Deep slit longitudinally
↓
Cut into circular discs
↓
Soak in 10% brine solution (overnight)
↓
Drain
↓
Wash
↓
Blanch for 4 to 5 min (hot water and steam)

↓
Cool
↓
Canned
(Covering material : salt–2%; citric acid 0.1%)
Cans are filled with hot brine

## 16.11 Coriander Processing

Coriander (*Coriandrum sativum*) derives its name *Coriandrum* from the Greek word 'Konis' meaning bed-bug. The unpleasant bug-like and fetid odour of its green foliage and fruits is responsible for this name. Such a disagreeable 'buggy' odour gradually gets replaced into a fragrant spicy aroma as fruits ripen to dry. Coriander is believed to have originated from Mediterranean basin and the Caucasus Mountains. It is chiefly produced in Russia, India, Central Europe, Hungary, Poland, Romania, Guatemala, Mexico, Asia Minor, Morocco, Yugoslavia, Argentina and in the United States. In India, it is grown on a commercial scale in Andhra Pradesh, Tamil Nadu, Rajasthan, Gujarat, Madhya Pradesh, Tamil Nadu, Rajasthan, Gujarat, Madhya Pradesh, Uttar Pradesh and Bihar, and to a limited extent in Karnataka and Odisha. Rajasthan is the most leading state in area and production, followed by Andhra Pradesh.

Coriander seeds contain two types of oil— essential oil and fatty oil. The fragrant odour and pleasant aromatic taste of coriander are mainly owing to the presence of the volatile oil in the dry seeds.

**Composition and nutritional value.** The dried ripe fruits of coriander contain volatile oil, fixed oil, tannins, cellulose, proteins, pigments, calcium oxalate, minerals and sugar. The major constituents of coriander seeds are fibres, about 23-36%, carbohydrates 20%, fixed oil 16-28% and proteins 11-17% (Table 16.13).

### 16.11.1 Drying

This process completes in two steps. In the first, plants after harvesting are piled into small stacks and left in the field for 2-3 days to wither. In the second, after threshing, seeds are dried in a partial shade. In advanced countries, drying is practised by artificial means. Coriander fruits are fairly stable to heat, thus may be dried artificially under controlled conditions without any significant loss of volatile oil. An air temperature of 80-90°C has been found optimum for drying without any excessive deterioration of the quality.

For extra longevity and safe storage of seeds, their moisture should

**Table 16.13** Nutrient content per 100 g of coriander on fresh weight basis

| | Leaves | Seeds |
|---|---|---|
| Moisture (g) | 87.90 | 6.30 |
| Carbohydrates (g) | 6.50 | 24.0 |
| Proteins (g) | 3.30 | 1.30 |
| Fat (g) | 0.60 | 19.60 |
| Total ash(g) | 1.70 | 5.30 |
| Calcium (mg) | 0.14 | 0.80 |
| Phosphorus (mg) | 0.06 | 0.44 |
| Iron (mg) | 0.01 | 6.00 |
| Vitamin A | 10,460 IU | 175 |
| Niacin (mg) | 0.8 | 3.20 |
| Thiamin (mg) | 60.0 | 0.23 |
| Vitamin C (mg) | 135.0 | 12.00 |

**Source:** Gopalan, 2000.

be below 6%. The seeds are dried in sun to lower down moisture to a safer level. After drying produce is passed through sieves of different sizes to remove dirt and plant refuse. After proper cleaning and sizing, produce is packed usually in gunny bags lined with polyethylene film.

### 16.11.2 Coriander *Chutney*

Coriander *chutney* is eternal favourite. It goes very well when served with many Indian snacks like *samosas* and *pakoras*. Its ingredients are finely chopped fresh coriander leaves: 1 cup; freshly grated coconut or dried unsweetened coconut: ¾ cup; hot green chillies: 3 g; cumin seeds: 2 tsp; sugar: 2 tsp; juice (lime): ¾ lime and salt : as per taste.

Blend all ingredients at the high speed in a blender adding just enough water to make a thick pouring consistency. Store it in refrigeration. Serve chilled or at a room temperature.

## 16.12 Fenugreek Processing

Fenugreek (*Trigonella foenum – graecum),* used for seeds as well as leaves, is an important condiment, occupying third place area-wise and fourth production-wise among all minor spices grown in the country. Fenugreek is native to South Eastern Europe and West Asia. It is found growing wild in the north-western parts of India. Rajasthan, Madhya Pradesh, Gujarat, Uttar Pradesh, Maharashtra and Punjab are the leading states in fenugreek production. In Rajasthan, Nagaur, Sikar, Jaipur, Chittoor, Bhilwara, Banswara, Baran and Jhalawar are major fenugreek-producing districts. It is being grown in India, Argentina, Egypt, France, Morocco and Lebanon.

**Composition.** Fenugreek is a rich source of proteins, minerals, vitamins A and C. Excepting for vitamins A and C, fenugreek seeds are richer in nutrient content compared to leaves (Table 16.14).

**Table 16.14** Nutrient value (100 g) of leaves and seeds of fenugreek

| Component | Leaves | Seeds |
|---|---|---|
| Moisture | 86.16 g | 6.3 g |
| Proteins | 4.49 g | 9.5 g |
| Fat | 0.99 g | 10.0 g |
| Carbohydrates | 6.09 g | 42.3 g |
| Fibres | 1.19 g | 18.5 g |
| Minerals (total ash) | 1.59 mg | 13.4 mg |
| Phosphorus | 51 mg | 0.48 mg |
| Sodium | 46.1 mg | 0.09 mg |
| Calcium | 360 mg | - |
| Vitamin A | 6450 IU | 1040 IU |
| Vitamin $B_1$ | 0.05 mg | 0.41 mg |
| Vitamin C | 54 mg | 12 mg |
| Iron | 17.2 mg | - |

**Source:** Gopalan, 2000.

### 16.12.1Processed Products

The harvested crop is stacked on the threshing flour under sun till drying. After drying, seeds are separated by hitting pods using stick. The collected seeds are sieved or winnowed to clean them. The cleaned seeds are packed in gunny bags and stored.

For leaves, tender green leaves are nipped off; fresh leaves are sorted, trimmed off, washed and stalks are removed. Leaves are subjected to blanching treatments for two minutes in boiling water. They are then dried in sun or at 60 – 65 °C under controlled conditions. The dried leaves are packed in a suitable polythene packing.

# Bibliography

Achanta, S. and Okos, M.R. 1996. Predicting the quality of dehydrated foods and biopolymers – research need and opportunities. *Drying Technology* **14**: 1329–32.

Ahmed, M.S. and Singh, S. 1999. Effect of various post -harvest treatments on shelf life of Amrapali Mango. *Orissa Journal of Horticulture* **27**: 29–39.

Ahmed, M.S. and Singh, S. 2000. Studies on extension of storage life of Amrapali Mango. *Orissa Journal of Horticulture* **28**: 73–76.

Alkawdi, O.M. 1990. Effect of gamma radiations and temperature on potatoes during storage. *Acta Agron Hungarica* **39**: 331–40.

Annual Report. 2003-04.Ministry of Food Processing Industries.

Ansari, M.D. 2004. Light pulse technology for preservation. *Indian Food Industry* **23** (4): 12–15.

APEDA. 2008. Agriculture Processed Food Export Development Authority, **www.apeda.com**.

Barmore, C.R. 1987. Packaging technology of fresh and minimally processed fruits and vegetables. *Journal of Food Quality* **10**: 207–15.

Baviskar, M.R. 1995. Effects of various post harvest treatments on shelf life and quality of *ber* fruit. *Indian Journal of Horticulture* **52**: 37–45.

Bhowmik, S.R. and Pan, J.C. 1992. Shelf life of mature green tomatoes stored in controlled atmosphere and high humidity. *Journal of Food Science* **57**: 948–53.

Beraha, L. 1961. Gamma-radiation in the control of decay in strawberries, grape and apples. *Food Technology* **15**: 94–98.

Bhupinder, K. 1992. Perlette grape juice: Effect of extraction method; $SO_2$ – Concentration and storage on the physico-chemical composition. *Indian Food Packer* **46** (6): 5–13.

Brody, A.L. 2006. Nano and food packing technologies converge. *Food Technology* **60** (3): 92–94.

Brosnan, T. and Sun, D. 2001. Precooling techniques and application for horticultural products – a review. *International Journal of Refrigeration* **24**: 154–70.

Dash, S.K. and Chandra, P. 2001. Evaporative cooling system for storage of fruits and vegetables. *Indian Food Packer* **55** (1): 79–87.

Dharkar, S.D. and Sreenivasan, A. 1972. Irradiation as a method for improved storage and transporation of mangoes. *Acta Hort.* **24**: 259.

Dhillon, B.S. 1988. Packaging, storage of kinnow oranges. A souvenier on *Packaging of Fruits and Vegetables in India. Agri – Horticultural Society*, Hyderabad, pp. 57–59.

Dunn, J. 1995. Pulsed – light treatment of food and packaging. *Food Technology* **49**(9): 95–98.

Ertekin, F.K. and Cakaloz, T. 1996. Osmotic dehydration of peas. II. Influences of osmosis on drying behaviour and product quality. *J Food Proc Preserv*. **20**: 105–19.

FAO. 2002. Statistical database. Food and Agriculture Organization, Rome, **http://www.fao.org.**

FAO. 2003. Compendium on post harvest operations chapter XX Mango: Post harvest operations. Food and Agriculture Organization, **http://www.fao.org./inpho/content.**

FAO 2005. Current situation and medium term outlook for tropical fruits. Food and Agriculture Organization, **http//www.fao.org/es/esc/commom/ecg/108849.**

Farr, D. 1990. High pressure technology in the food industry. *Trends Food Sci. Technol.* **1**: 14–16.

Fernandes, FAN. *et al.* 2006. Optimization of osmotic dehydration of bananas, followed by air drying. *Journal of Food Engineering* 77: 188–93.

Gopalan, C. 2000. *Nutritive Value of Indian Foods*. National Institute of Nutrition, Indian Council of Medical Research, Hyderabad. pp. 47–77.

Gustavo, V.B.C. 1997. Application of light pulses in the sterilization of foods and packaging materials. In: *Nonthermal Preservation of Foods*. Marcel Dekker Inc., New York.

Holley, C. 2005. Nanotechnology and packaging, secure protection for the future. *Verpackungs – Rundschau* **56**: 53–56.

IARI. 1985. Zero energy cool chamber. Indian Agricultural Research Institute. New Delhi. *Research Bulletin* No. **43**, pp. 24.

Jain, S.K. 2003. Thermal processing of *aonla*. *Indian Food Packer* **57**(1): 46–49.

Jayaraman, K.S. and Dasgupta, D.K. 1992. Dehydration of fruits and vegetables – Recent development in principles and techniques. *Drying Technol.* **10**: 10–50.

Joshi, V.K. and Thakur, S. 2000. Lactic acid fermented beverages, pp. 1102. In: *Post-harvest Technology of Fruits and Vegetables*. Verma, L.R. and Joshi, V.K. (eds). Vol. II. Indus publ. Co. New Delhi.

Kader, A.A. 1980. Prevention of ripening in fruits by use of controlled atmosphere. *Food Technol.* **34** (3): 50–54.

Kader, A.A. 2004. Controlled atmosphere storage. In: *Commercial Storage of Fruits, Vegetables and Florist and Nursery Stocks.* Agriculture Handbook No. **66**. USDA, ARS. **http://usna.usda .gov./hb66/013ca pdf.**

Kalra, C.L. 1988. The chemistry and technology of *aonla* – A resume. *Indian Food Packer* **42** (4): 67–83.

Khetarpaul, N. 2005. *Food Processing and Preservation*. Daya Publishing House, Delhi.

Lakshmi, B. and Vimla, B. 2000. Nutritive value of dehydrated green leafy vegetable powders. *J. Food Sci. Technol.* **37**: 465–71.

Lam, C.D. and Wang, K.M. 1988. Fungicides for the control of post-harvest diseases. *Progr Hort* **5**: 73–76.

Maini, S.B. and Anand, J.C. 1992. Evaporative cooling system for post harvest management of horticultural crops. *Agric Market* **35** (3): 34–39.

Marwala, R.S. 1997. Processing of potatoes: Current status, need, future potential and suitability of Indian varieties – a critical appraisal. *J. Food. Sci. Technol.* **34**: 457-71.

Mehta, U. and Bajaj, S. 1983. Effects of storage and methods of preservation on the physico –chemical characteristics of citrus juices. *Indian Food Packer* **37**: 42-51.

Mehta, U. and Rathore, S. 1976. Storage study on preserved juice from *amla*. *Indian Food Packer* **30** (1): 9-11.

Mishra, N.K. and Agarwal, A.K. 2005. Effect of various predrying treatments on dehydration characteristics of cauliflower and peas. *Bev Food world* **32**(2): 59–60.

Mitra, S. 2001. Post-harvest physiology and storage of tropical and subtropical fruits. *CAB International*, UK. pp. 167-89.

Moris, J.R. 1986. Effect of fruit maturity, juice storage and juice extraction temperature on quality of concord grape juice. *J. Am Soc. Hort. Sci.* **111**: 742–45.

Nath, V. 1999. Delicacies of *aonla. Indian Horticulture* **44**: 15–18.

Neeraj. 2004. Effect of HDPE, LDPP and PVC plastic packaging on the ascorbic acid content and decay loss during storage of *aonla* fruits cv. Chakaiya. *Haryana J. Hort Sci.* **33**: 231-15.

NHB. 2006. Commodity bulletin on fruits. National Horticultural Board, India. **www. Hortibizindia.org.**

Palou, E. 2002. Innovative fruit preservation methods using high pressure in engineering and food for 21st century, CRC Press, Bocaa Raton, FL, 715-725.

PFA. 2003. *Prevention of Food Adulteration Act 1954 Rules, 1955* , pp. 140– 141. 19th edn. International Law Book Co., Delhi.

Pinaga, F. 1984. Experimental simulation of solar drying of garlic using an adsorbent energy storage bed. *J. Food Eng.* **31**: 187-203.

Pokharkar, S.M. and Prasad, S. 1998. Mass transfer during osmotic dehydration of banana slices. *J. Food Sci. Technol.* **35**: 336-38.

Puttraju, T.B. and Reddy, T.V. 1997. Effect of precooling on the quality of mango. *J. Food Sci. Technol* **34**: 24-27.

Rameshwar, A. 1988. Packaging of guava. A souvenier on *Packaging of Fruits and Vegetables in India*, *Agric – Horticultural Society*, Hyderabad, pp. 81.

Rashmi, H.B. 2005. Studies on osmo – air-dehydration of pineapple fruits. *J. Food Sci. Technol.* **42**: 64–67.

Ray, B. and Daeschel, M.A. 1992. Food biopreservatives of microbial origin. CRC Press, Boca Raton, FL.

Rice, J. 1994. Sterilizing with light and electrical impulses. *Food Processing* **7**: 66.

Rosa, M.D. and Giroux, F. 2001. Osmotic treatments (OT) and problems related to the solution management. *J. Food Eng.* **49**: 223–36.

Ryall, A.L. and Lipton, W.J. 1973. *Handling ,Transportation and Storage of Fruits and Vegetables.* Vol. **2**, AVI pub. Co., West Port, Connecticus.

Sagar, V.R. and Maini, S.B. 1997. Studies on packaging and storage of dehydrated onion slices. *Indian Food Packer* **51**(1): 5–10.

Saraswathy, S. Preethi, T.L., Balasubramanyan, S. Suresh, T. Reveathy, N. and Natrajan, S. 2008. *Post-harvest Management of Horticultural Crops*. AGROBIOS (India).

Satin, M. 1996. The prevention of food losses after harvesting, pp. 81–94. In :*Food Irradiation*. 2nd edn. Technomics, Pa Lancaster.

Smit, O. 1987. Transport and storage of potatoes, pp. 203–86. In: *Potato Processing*. Talburt WF, Smith O (eds), Van Nostrand Reinhold, New York.

Salunkhe, D.K. 1974. Development in technology of storage and handling of fresh fruits and vegetables. *CRC crit Rev Food Technol* **4**: 15–43.

Soomoro, A. 2002. Role of lactic acid bacteria (LAB) in food preservation and human health. A review. *Pakistan J Nutr.* **1** (i): 20-24.

Stanley, J.K. 1991. *Post-harvest Physiology of Perishable Plant Products*, pp. 278–79 Van Nostrand Reinhold, New York.

Sudheer, K.P. and Indira, V. 2007. Post-harvest technology of horticultural crops. In: *Horticulture Science Series*-7. Peter, K.V. (ed.)

Swientek, R. J. 1992. High hydrostatic pressure for food preservation. *Food Process* **53**: 90–91.

Tauscher, B.K. 1999. Effect of high pressure treatment to nutritive substances and natural pigments. *Emerging Food Science and Technology. Tempere, Finland* **58**: 22–24.

Thakur, N.S. and Lal, B.B. 1989. Evaluation of plastic carton and corrugated fibre board carton vis-à-vis conventional wooden box for packaging and transportation of apple. *J. Food Sci. Technol.* **26**: 10–14.

Ting, S.V. and Rouseff, R.L. 1986. *Citrus Fruits and their Products – Analysis and Technology*, pp. 293. Marcel Dekker Inc., New Delhi.

Von, P. and Loesecke, H.W. 1998. *Drying and Dehydration of Foods*,pp. 88–89. Allied publ, Bikaner, India.

Zagory, D. and Kader, A.A. 1988. Modified atmosphere packaging of fresh produce. *Food Technol.* 7(2): 70–77.

Zhao, Y. and Xie, J. 2004. Practical applications of vacuum impregnation in fruits and vegetables processing trend. *Food Sci. Technol.* **15**: 434–51.

# Subject Index

## About the Book

India is one of the most important fruits and vegetables producing countries of the world. Diverse agroclimatic zones make the country amply suitable for cultivation of almost all varieties of fruits and vegetables— over 40 types of vegetables and 30 types of fruits. It is reported that more than 30-35% of the total fruits and around 20-25% of the total vegetables produced are lost due to poor post-harvest practices. Herein, post-harvest management technology offers promising option for increasing production of vegetables and fruits quantity-wise and also in maintaining quality of the products. Post-harvest management involves all the activities that occur after production or harvesting of commodities, including procurement, removal of field heat, sorting, grading, packaging, storage, transportation, primary and secondary processing and marketing of agricultural products from farm-gate to distributors.

This book is an effort to document vast available knowledge on the various aspects of post-harvest management and processing, and it will prove worthy for teachers, students and extension workers for understanding post-harvest management and processing of fruits and vegetables. It has 16 chapters covering storage, packaging, advanced preservation technology and value-addition of fruits and vegetables.

भाकृअनुप
ICAR

**Indian Council of Agricultural Research**
**New Delhi**

9 788171 641154